

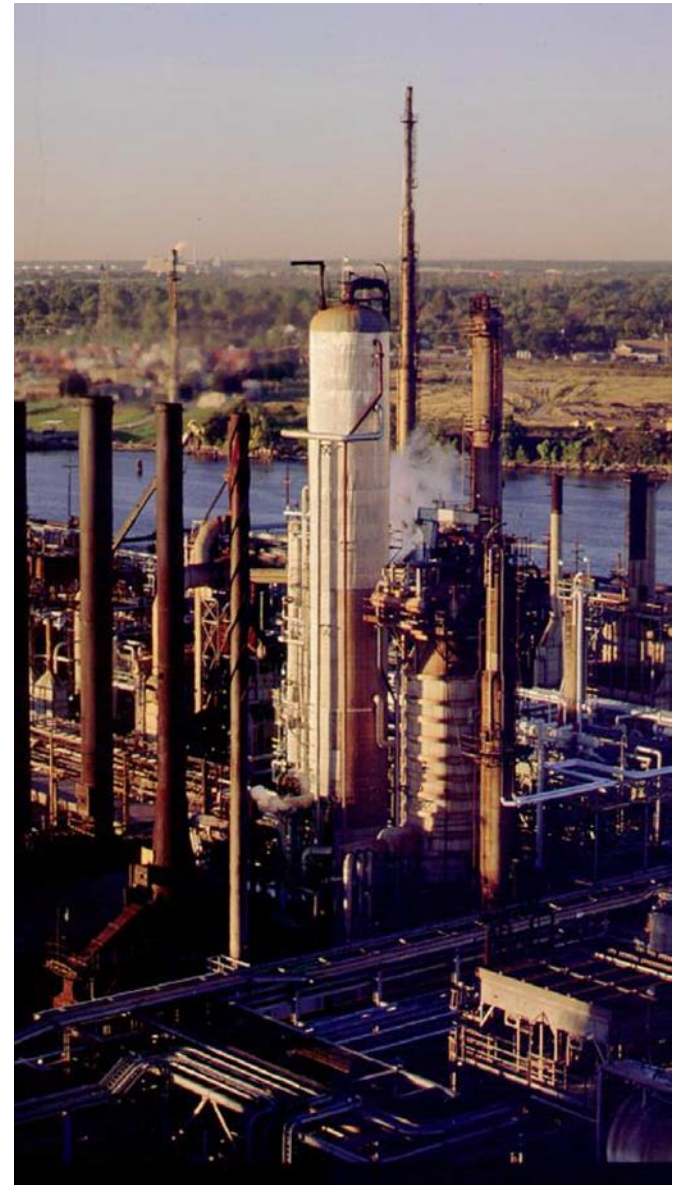


Refinery Overview

CCN

Doug Kriebel, PE

January 13, 2016



What do refineries do?

Raw Material

Crude Oil

- TX, OK, CA, LA
- Alaska
- Canada
- Mexico
- OPEC
- Tight Oil
 - Bakken



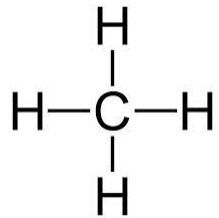
Separate Products
Increase Value
Raise Octane
Reduce Sulfur

Products

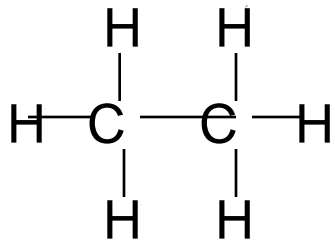
- Gasoline
- Diesel
- Heating Oil
- Jet Fuel
- Kerosene
- Petro Chem Intermediates
- Asphalt/Coke
- Based on Market and Crude Feed Stock

Crude Oil-Mixture of Hydrocarbons

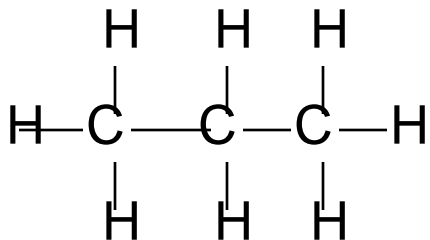
Hydrogen Carbon



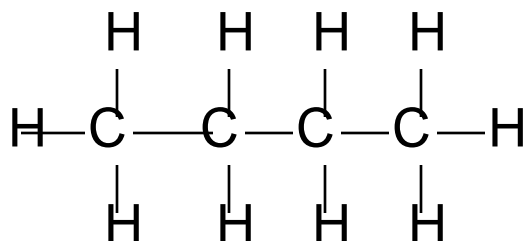
CH_4 Methane



C_2H_6 Ethane



C_3H_8 Propane



C_4H_{10} Butane

C5 C_5H_{12} Pentane

C6 C_6H_{14} Hexane

C7 C_7H_{16} Heptane

C8 C_8H_{18} Octane

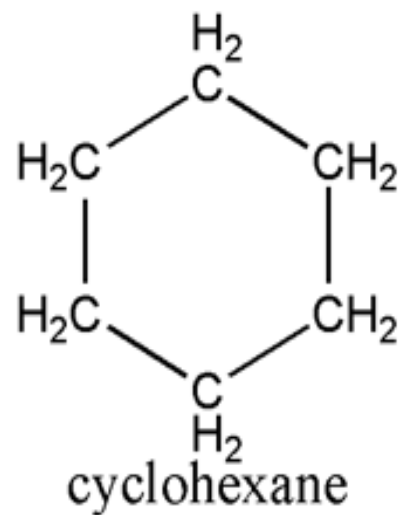
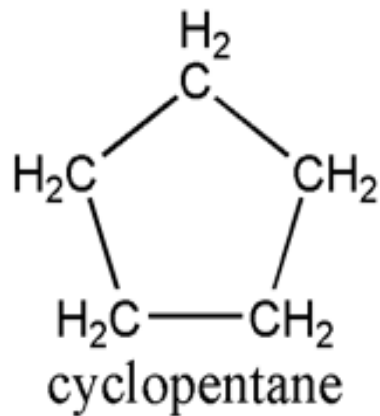
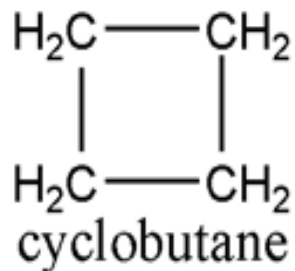
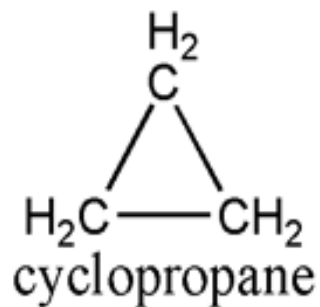
C9 C_9H_{20} Nonane

C10 $\text{C}_{10}\text{H}_{22}$ Decane

>C70



Cycloalkanes (Naphthenes)



Other Stuff

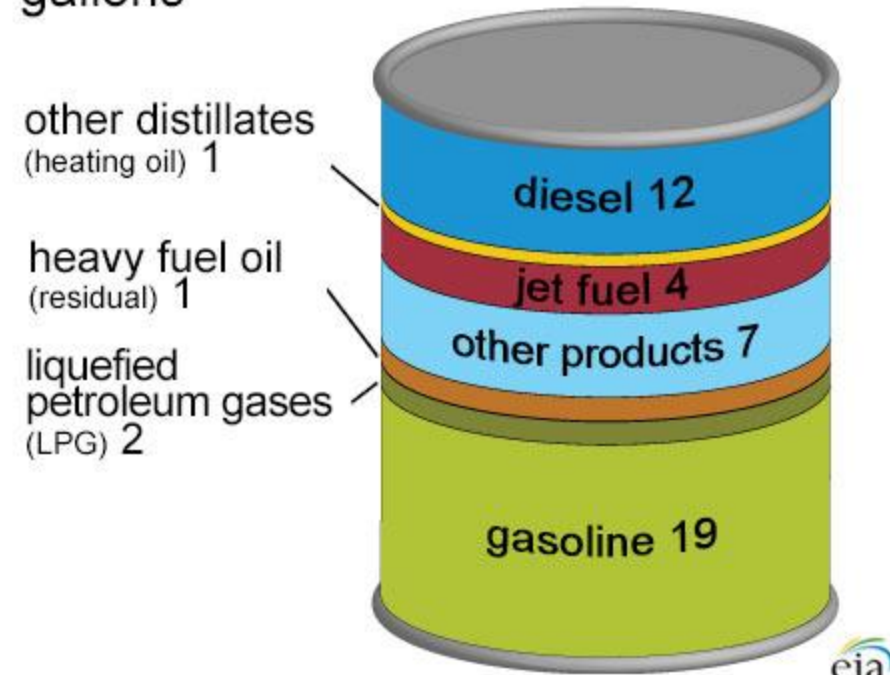
- Sulfur Sour (0.7%)
- Nitrogen
- Salt
- Metals
 - Iron
 - Copper
 - Nickel
 - Vanadium



What we want

- Meet Product Specs
 - High Octane
- Meet EPA
 - Low Sulfur gasoline 10 ppm
 - ULSD 15 ppm
- Meet Market Yields
 - Diesel
 - C3=

Products made from a barrel of crude oil, 2014 gallons

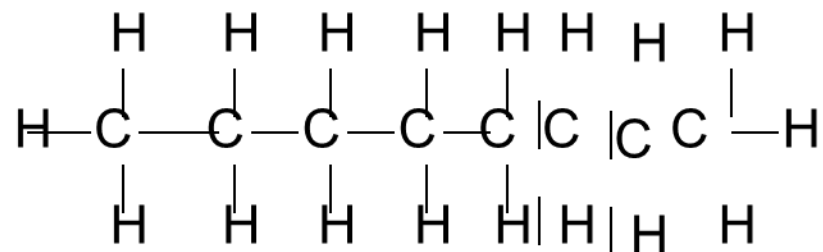
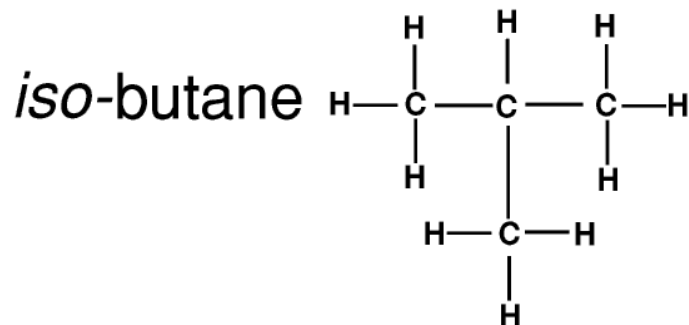
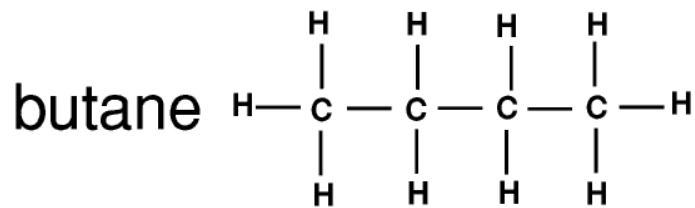


Source: U.S. Energy Information Administration, *Petroleum Supply Monthly* (April 2015)

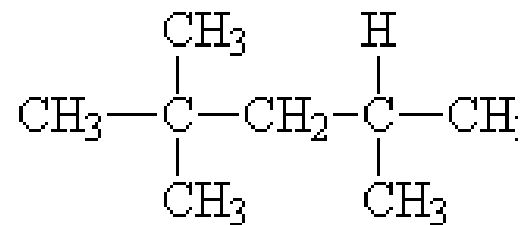
eia



Isomers



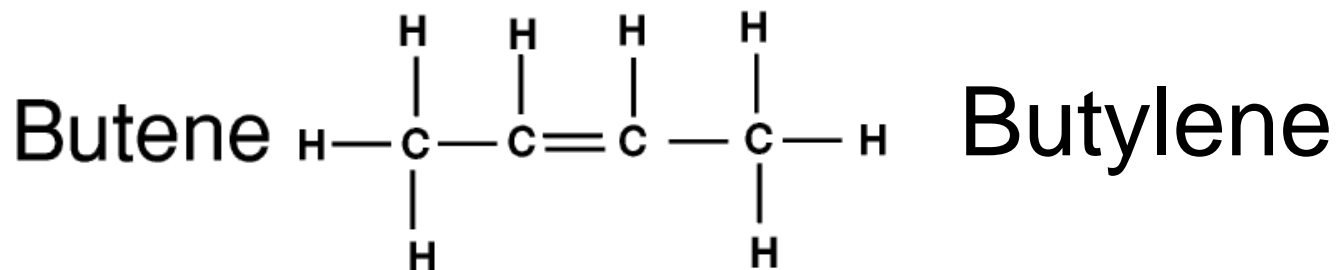
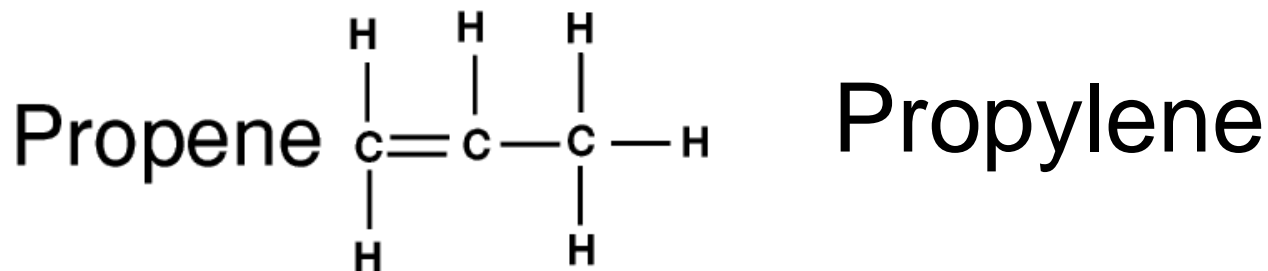
octane



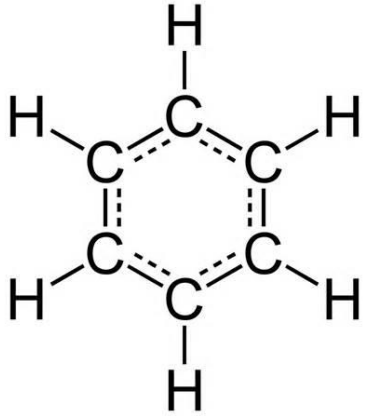
Iso-Octane



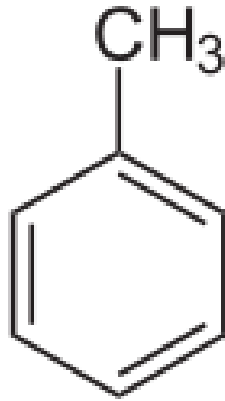
Alkenes (Olefins)



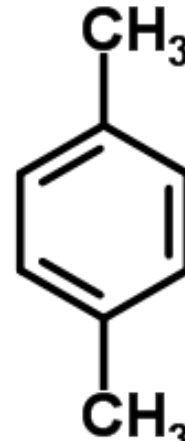
Aromatic Hydrocarbons



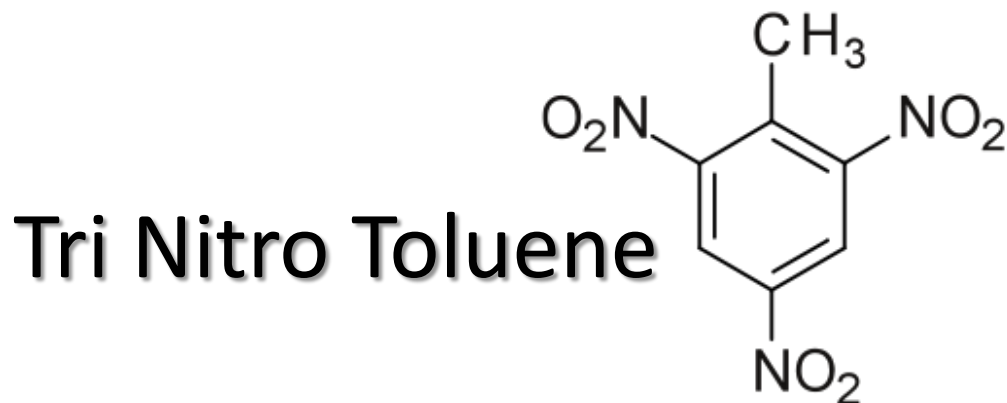
Benzene



Toluene



Xylene

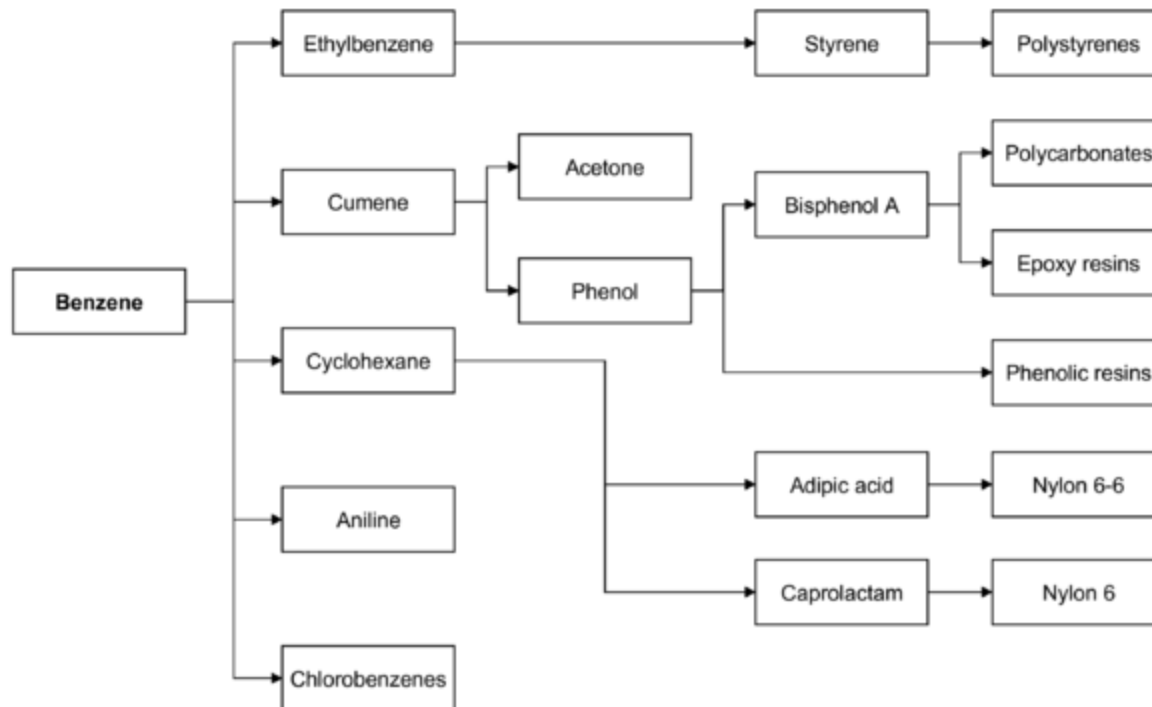


Tri Nitro Toluene

Polyethylene terephthalate



Benzene



Tank Farm

Tanks

Solid Roof

Floating Roof

Pressure Vessels

Pipes

Pumps

Transfer

Fire Pumps

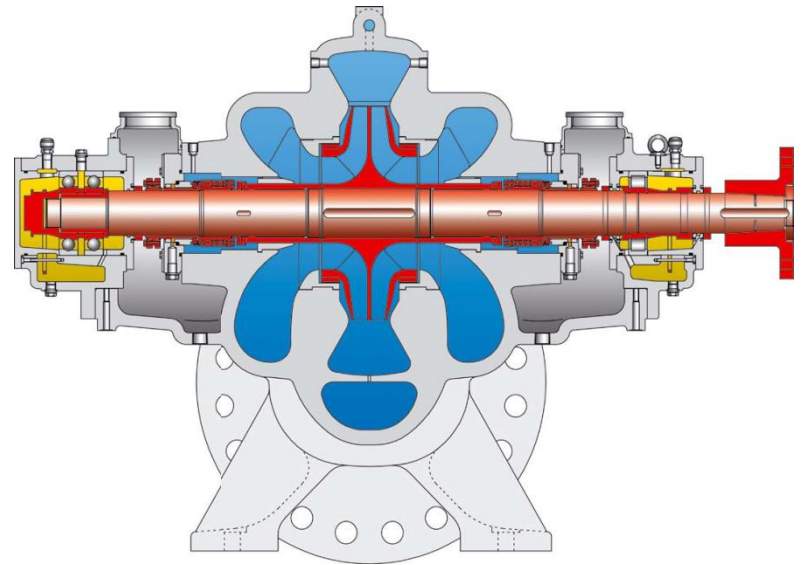
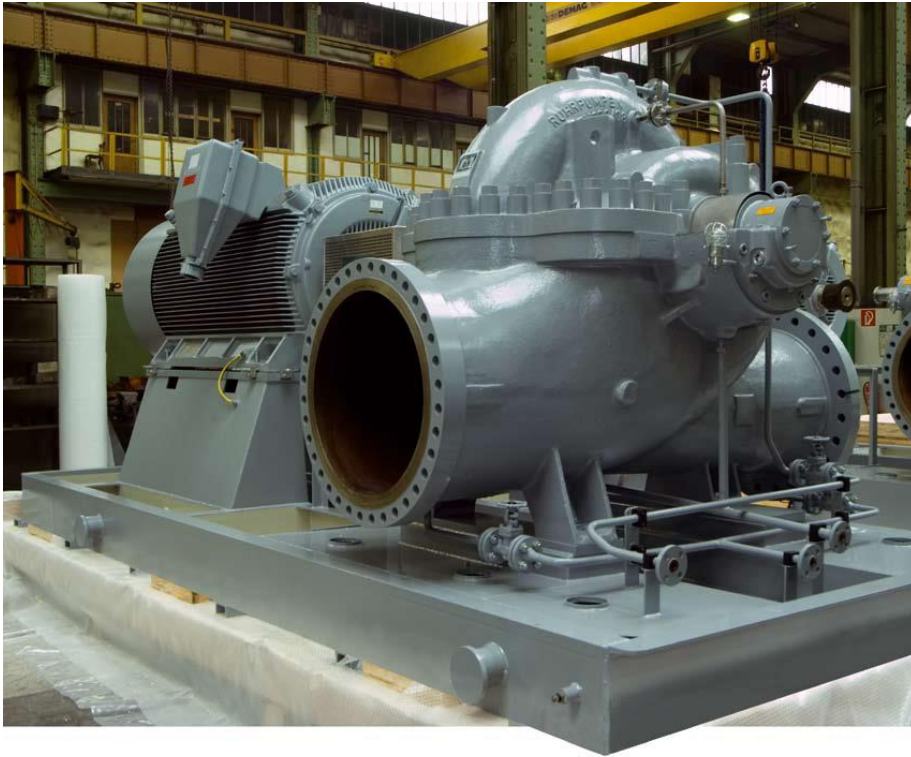
Sumps



293JLA00564 [RF] © www.visualphotos.com



BB-1 for OBL

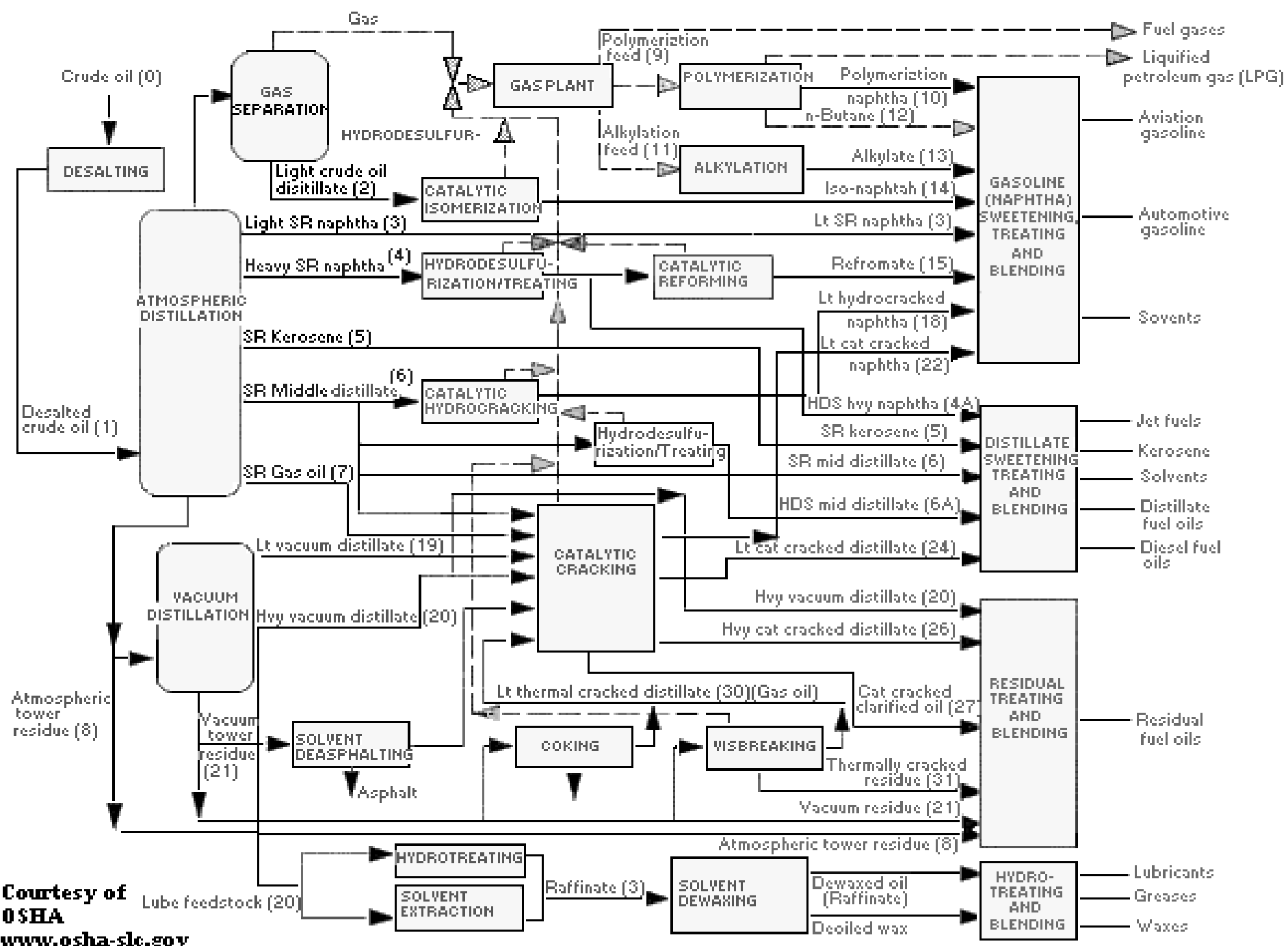


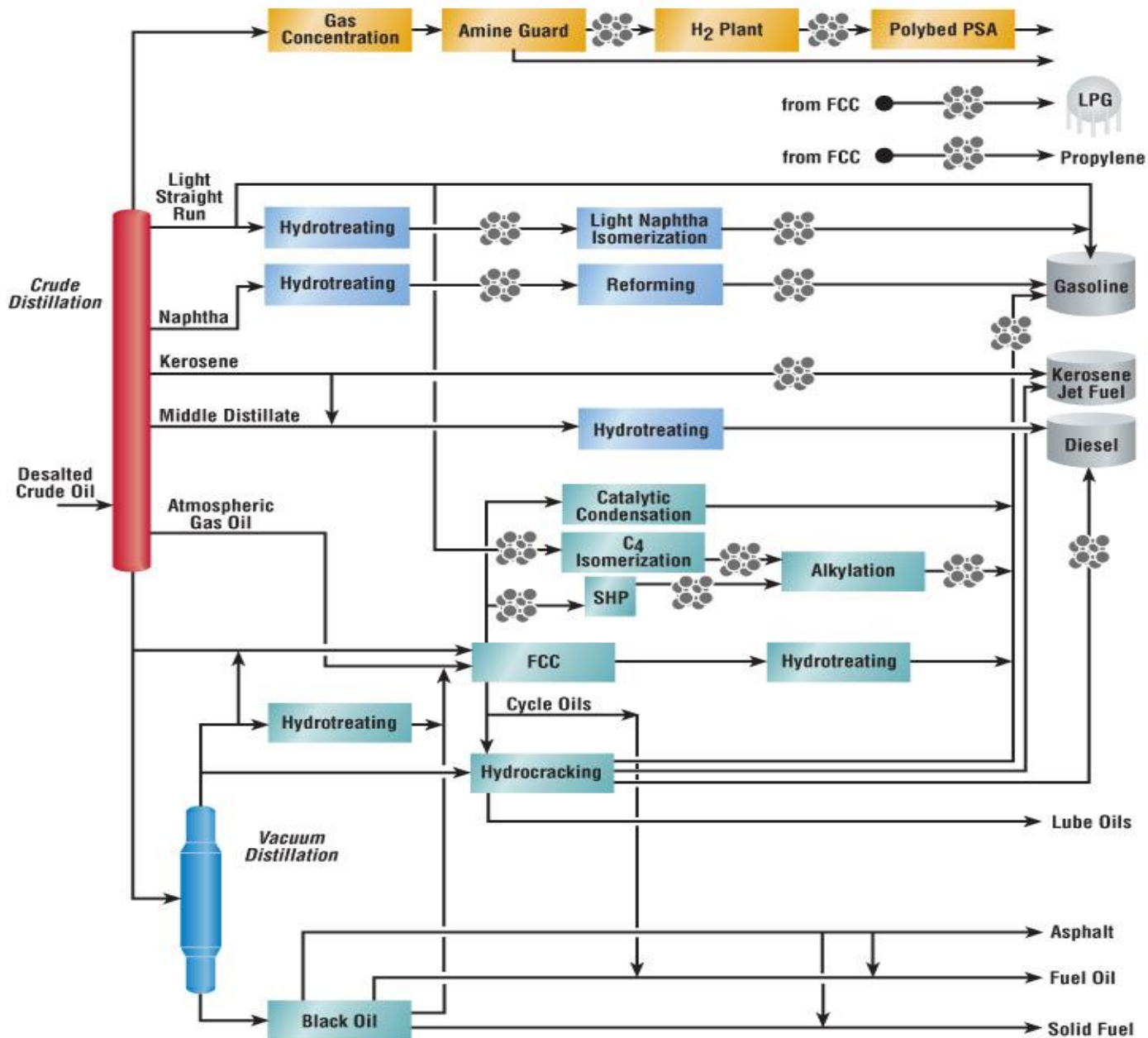
VS6 Vertical Can Pump



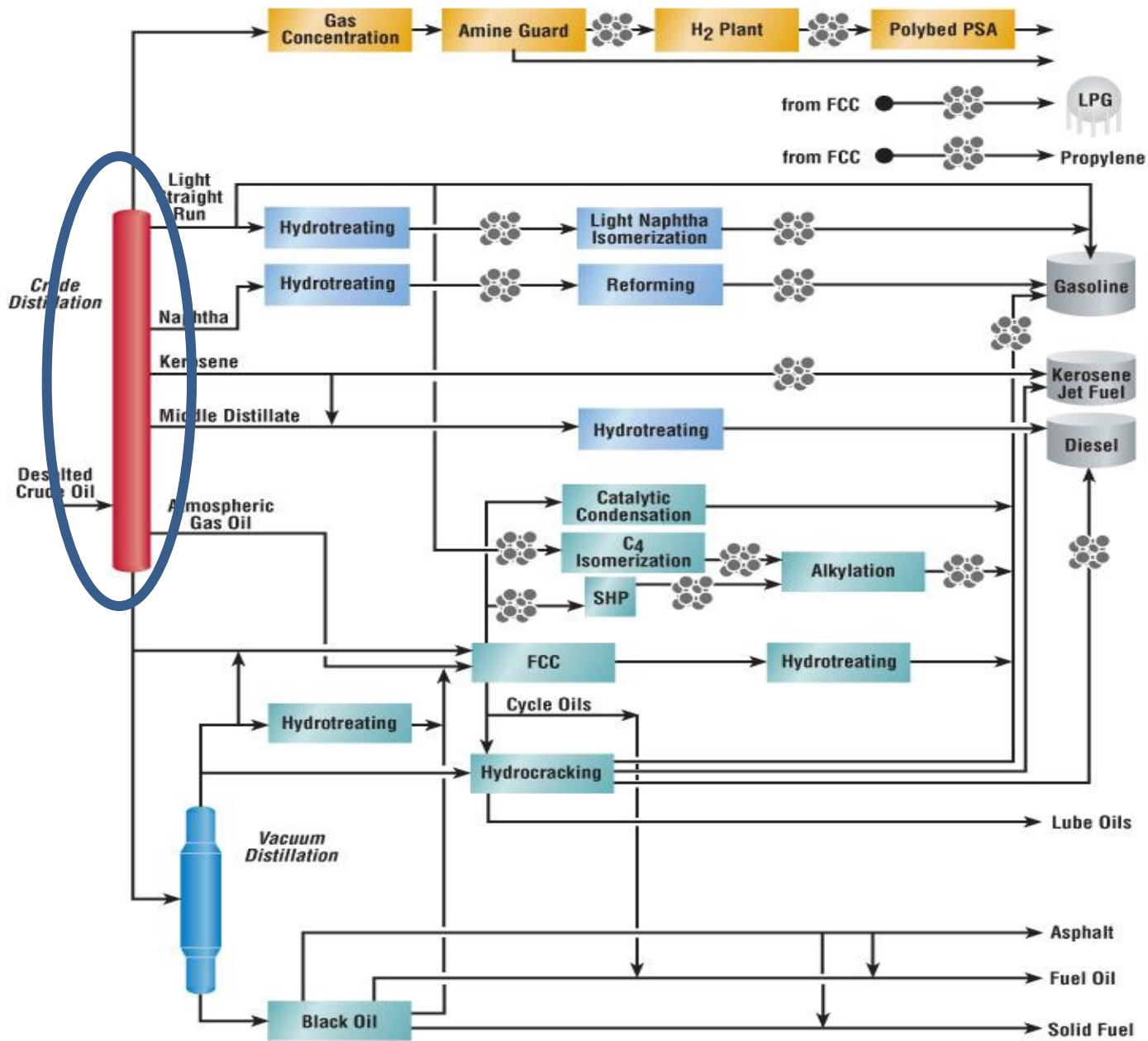
Ethane
Propane
Butane







Refinery Adsorbent Locations for Contaminant Removal

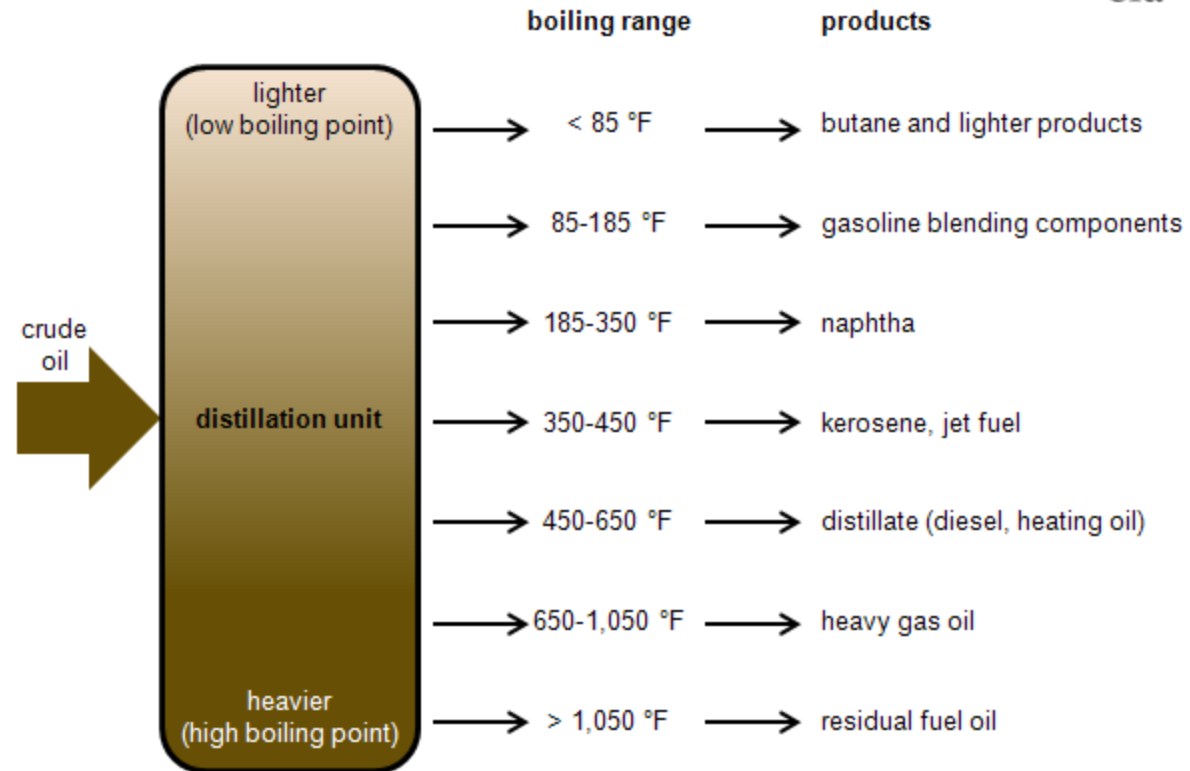


Refinery Adsorbent Locations for Contaminant Removal

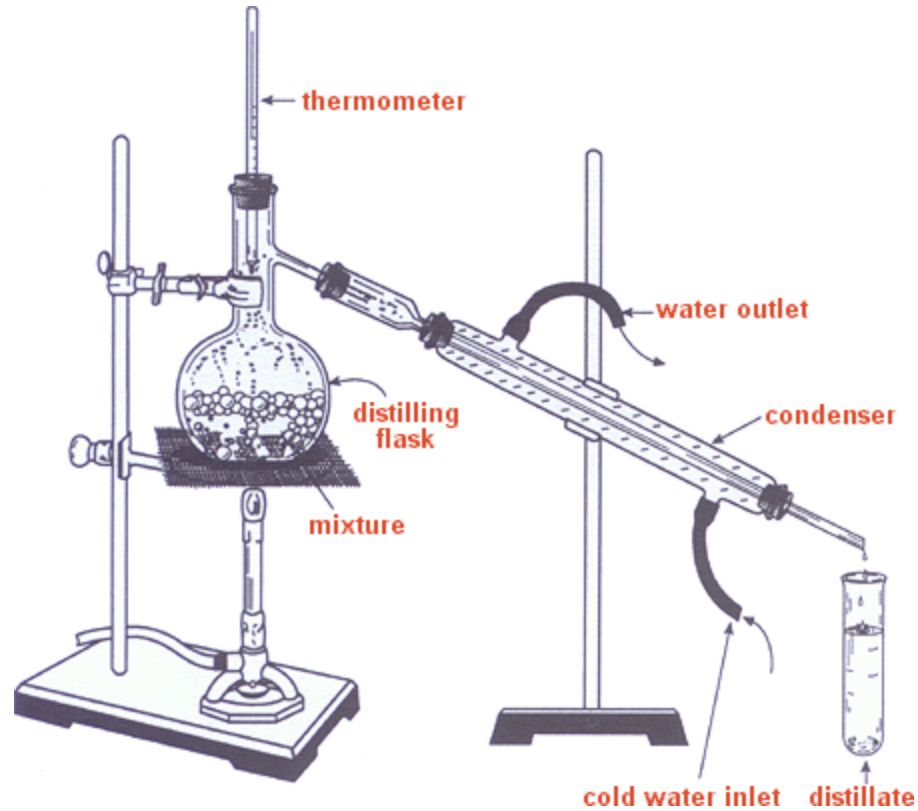
Crude Distillation Unit (CDU)

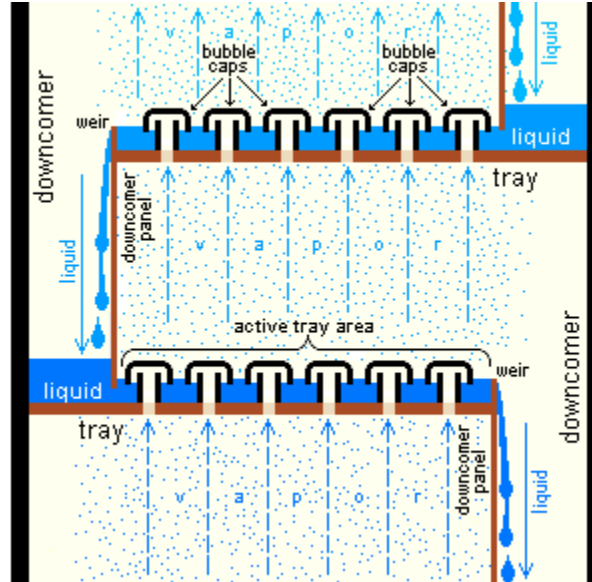
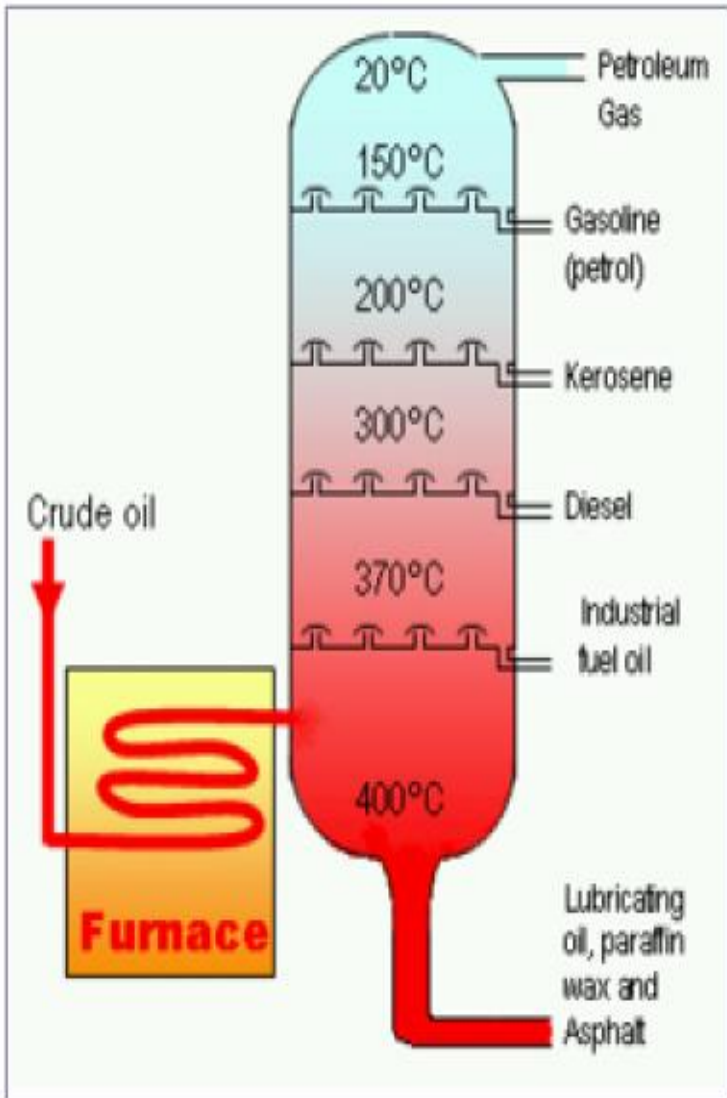
- The CDU is the first separation unit to take the crude into separate components

Crude oil distillation unit and products

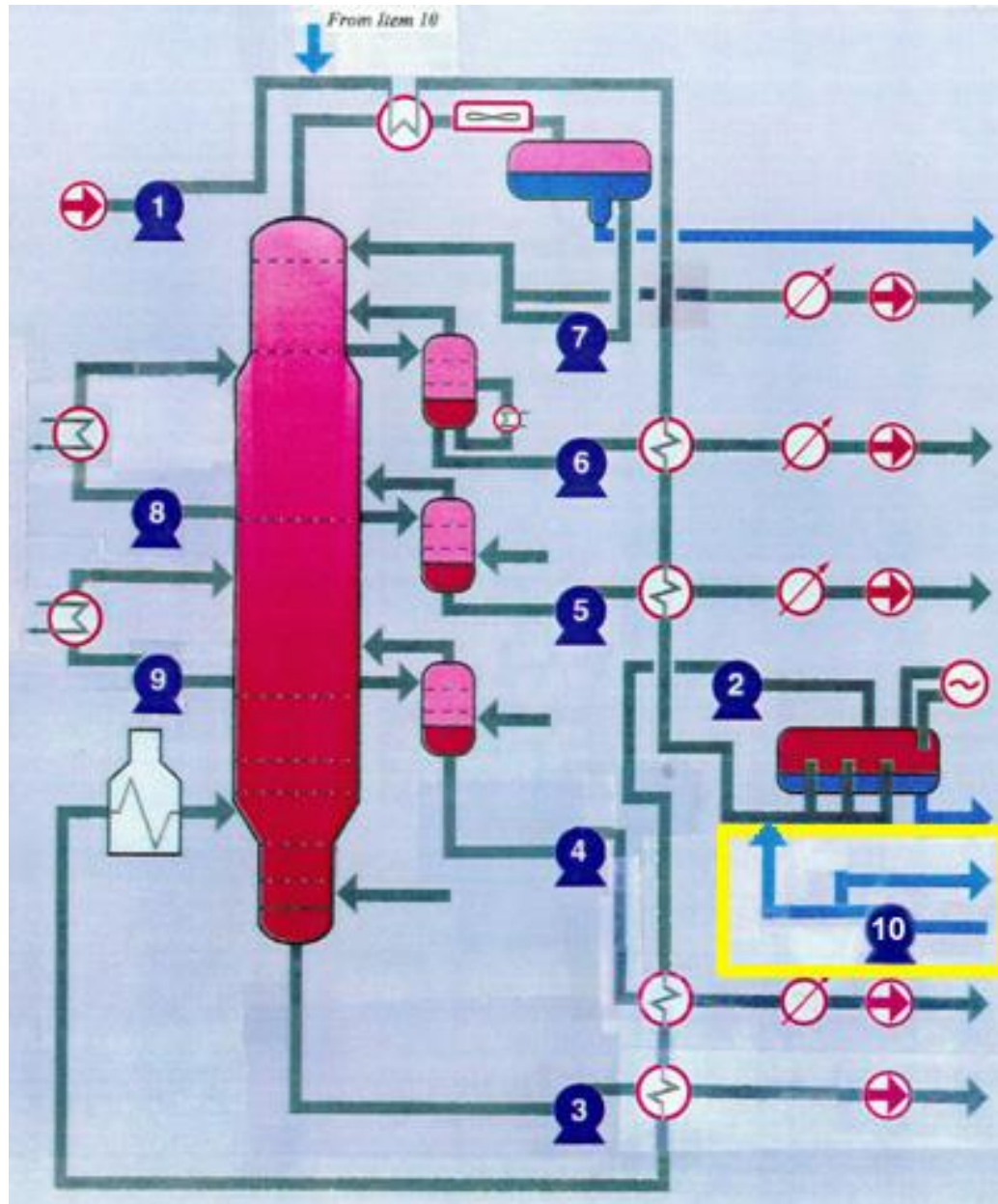


Distillation

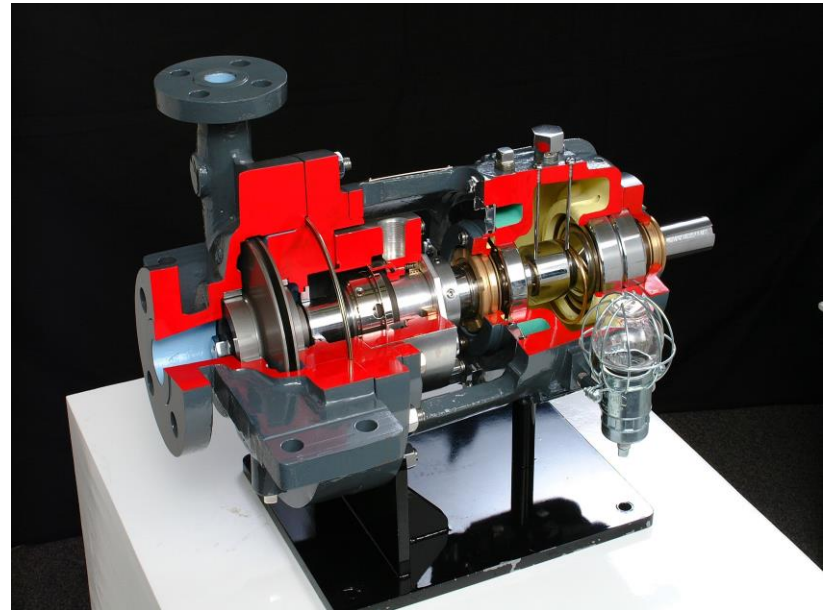




Crude Unit



OH-2 API 610



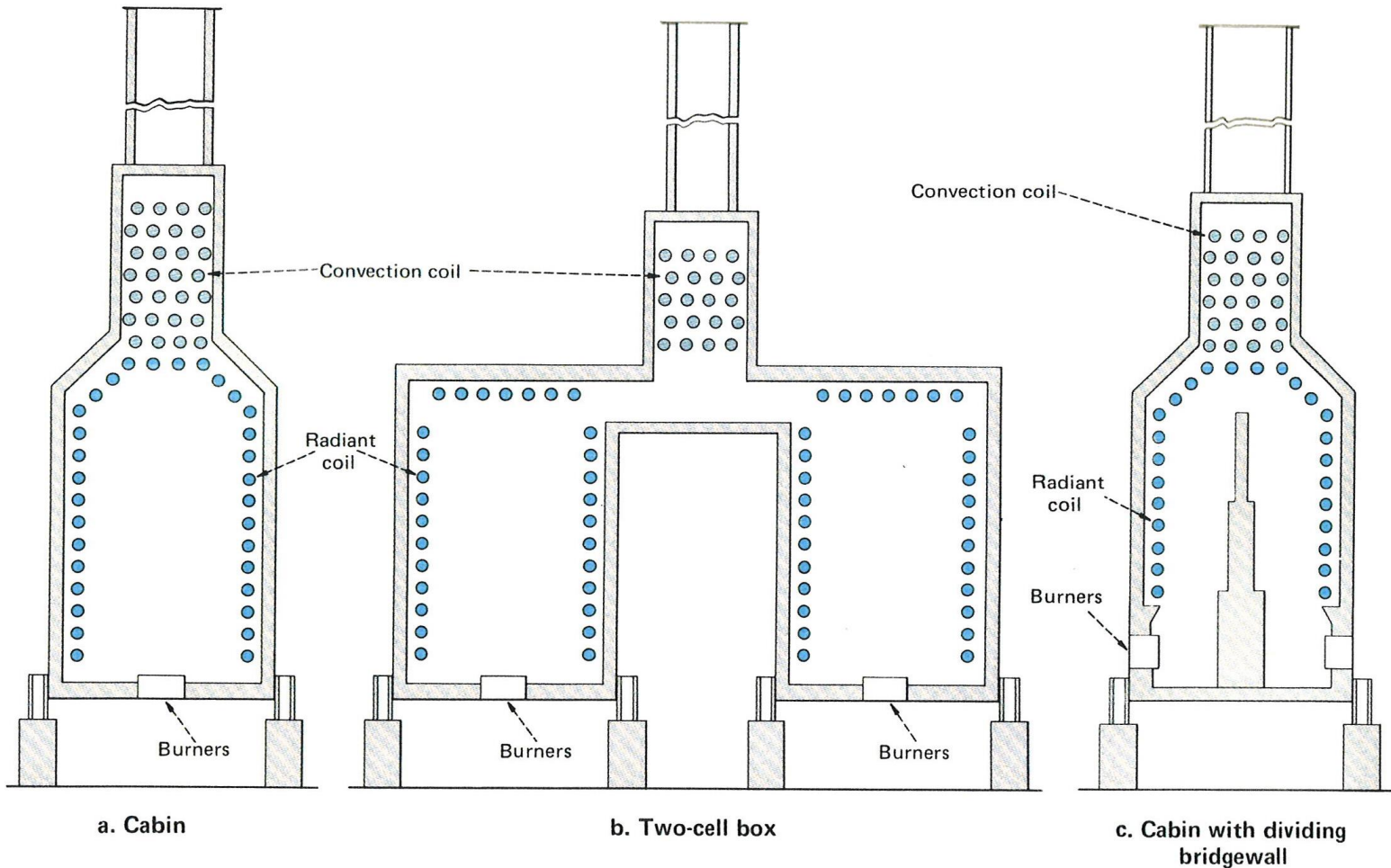
OH 2



Direct Fired Heater API 560



Additional Layouts



Six basic designs used in horizontal-tube fired heaters. Radiant-section coil is horizontal

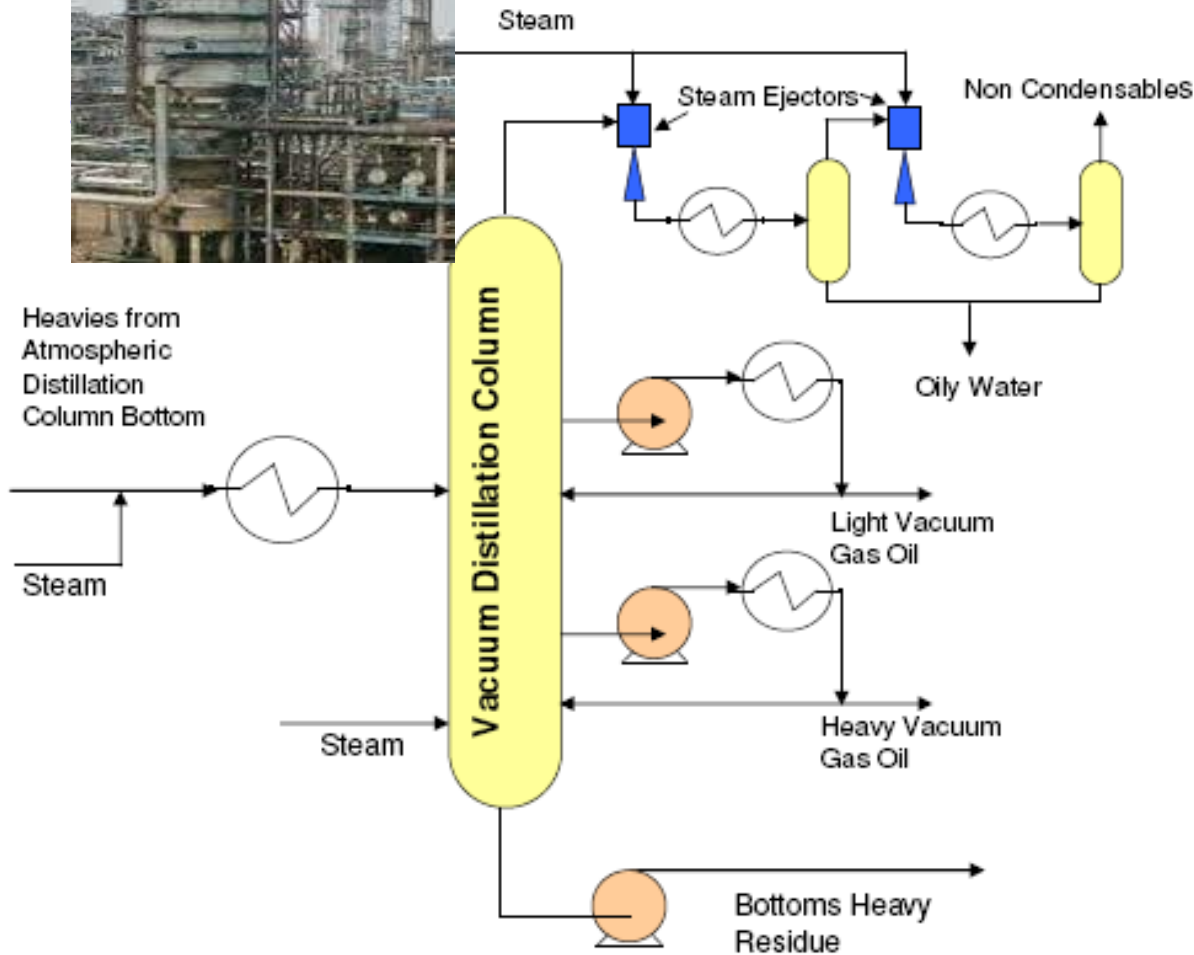
Fig. 2



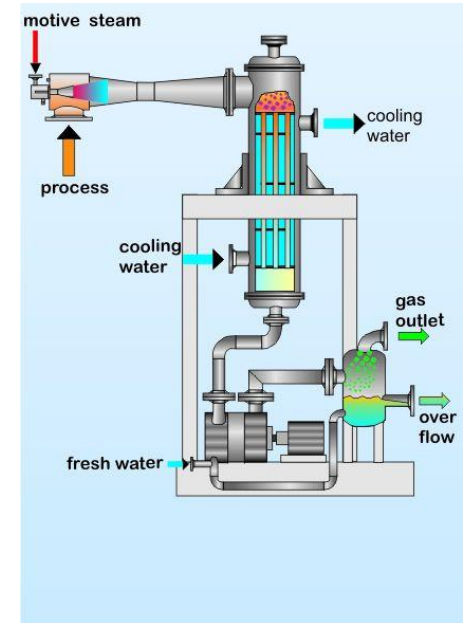
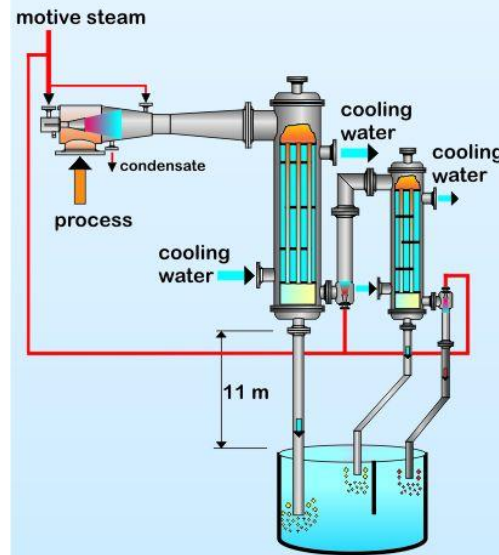
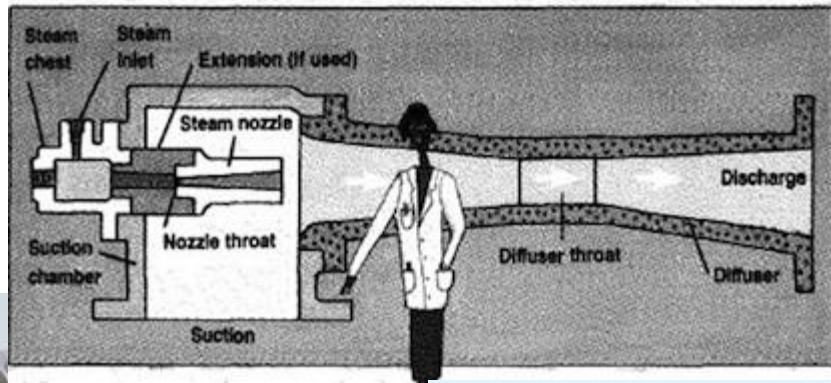
Vacuum Distillation

- Takes the residual from CDU and, under vacuum separates into Light Vacuum Gas Oil (LVGO) and Heavy Vacuum gas oil (HVGO)
- Vacuum lowers Boiling Point of Crude.
- Critical Pumps:
 - Bottoms Pumps:
 - 700-800 F Operating Temperature
 - Low NPSH (BB-2)
 - Coke Particles Present
 - Vacuum Pumps
 - Steam Jets or Mechanical
- Depending on Sulfur content , Special Materials may be needed

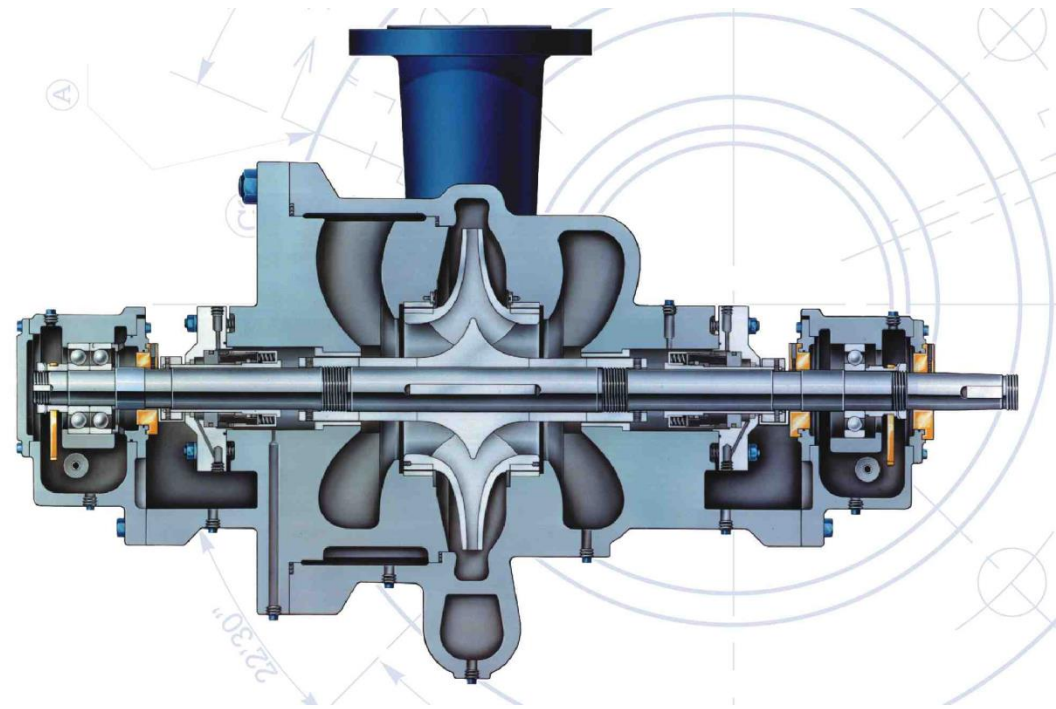
Vacuum Unit

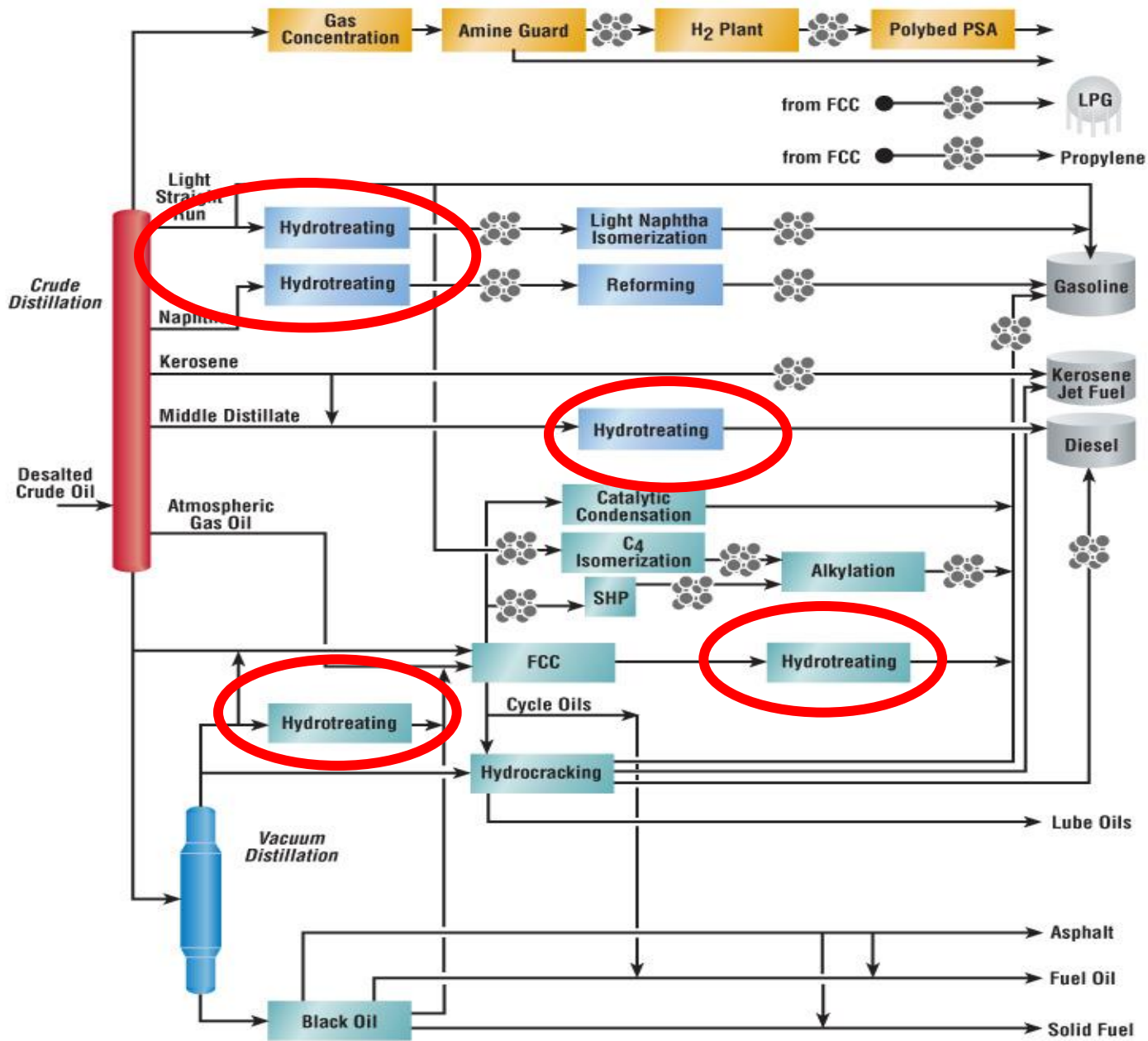


Steam Jet Vacuum Pumps



BB-2





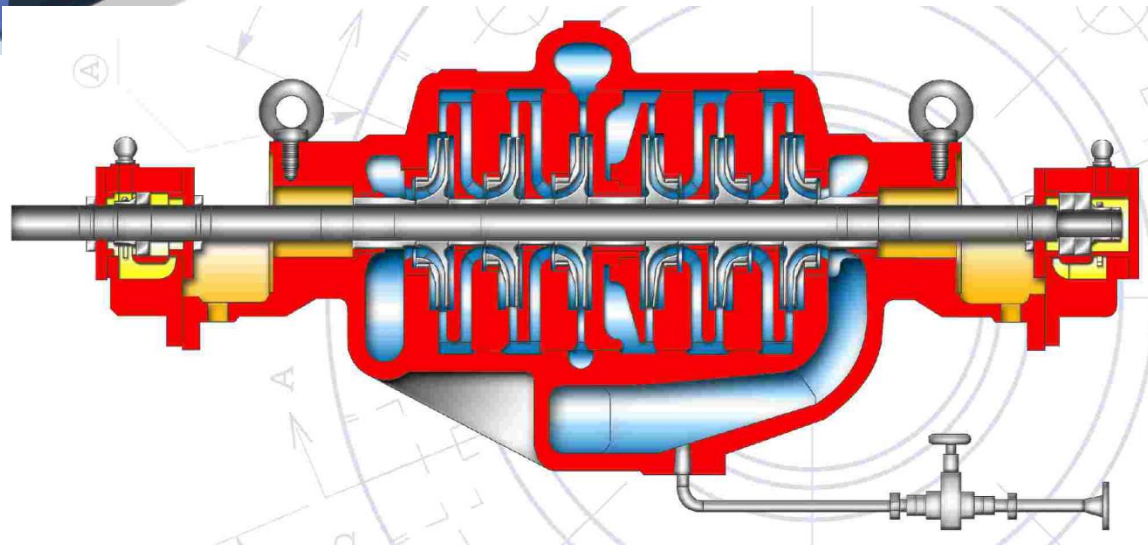
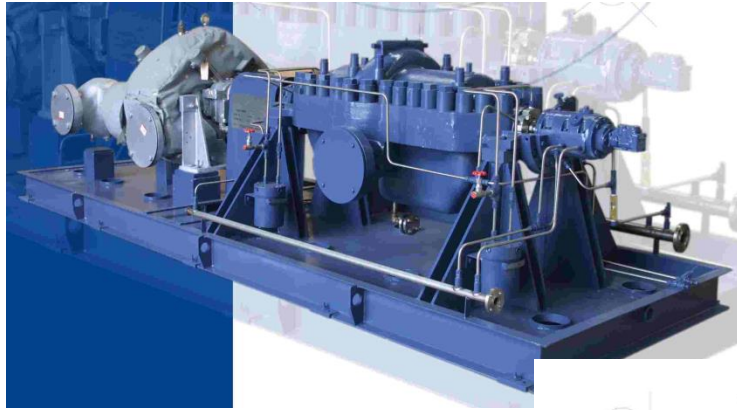
Refinery Adsorbent Locations for Contaminant Removal

Hydrotreating / HDS

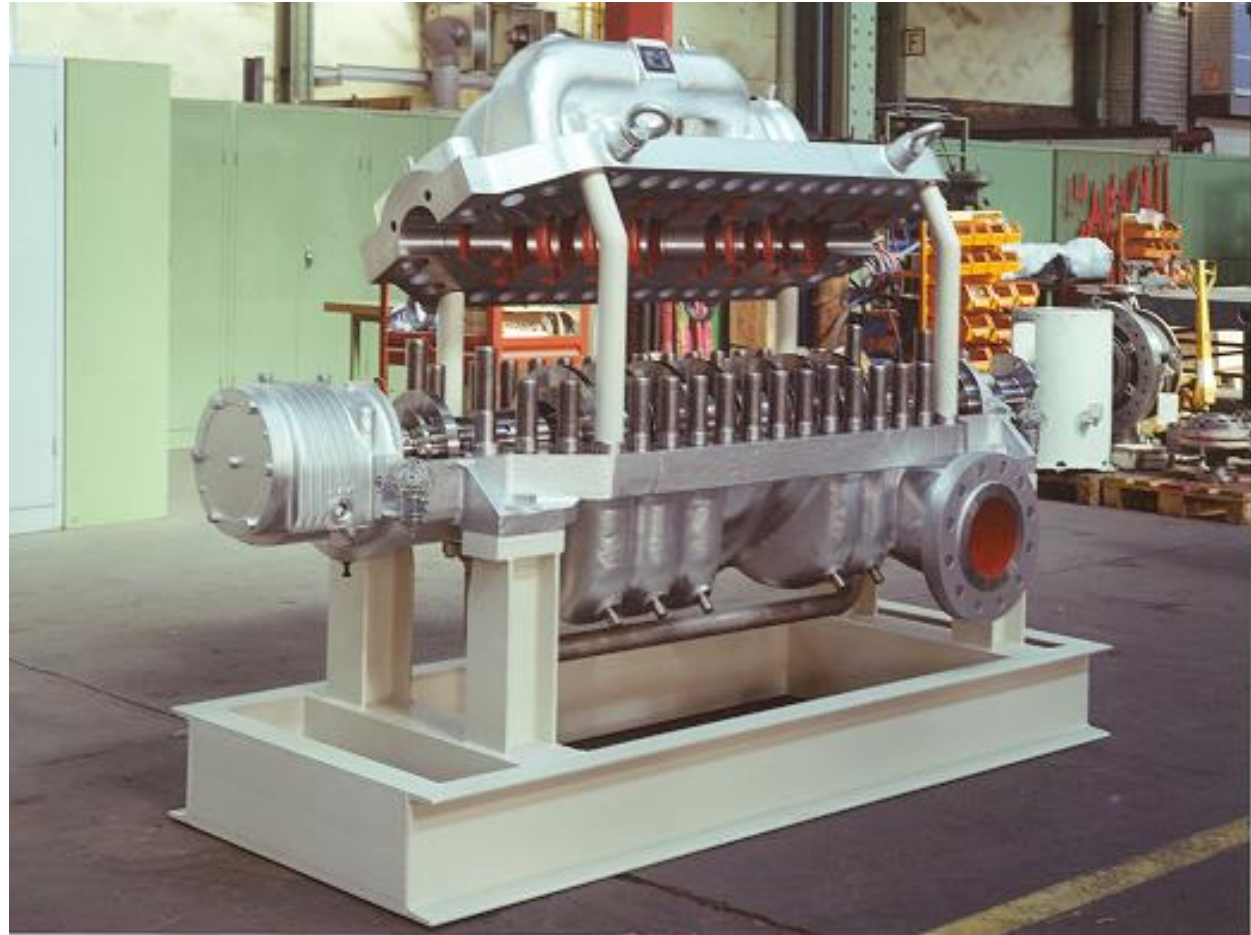
- Process of removing Contaminants (Sulfur / Nitrogen / Oxygen / Halides & Trace metals) from Products / Feed Stocks by Reacting them with **Hydrogen** in presence of **Catalyst**.
- Each Refinery has a number of Hydrotreaters. Converts Sulfur in HC into H_2S ; Nitrogen to ammonia
- 450-1800 Psig/600-700 degF
- Critical Equipment :
 - Feed Pumps. BB-2 or BB-3
 - Catalytic Reactor
 - Hydraulic Expander
 - Make up Hydrogen Compressor
 - Recirculation Hydrogen Compressor
 - Condenser and Reboiler



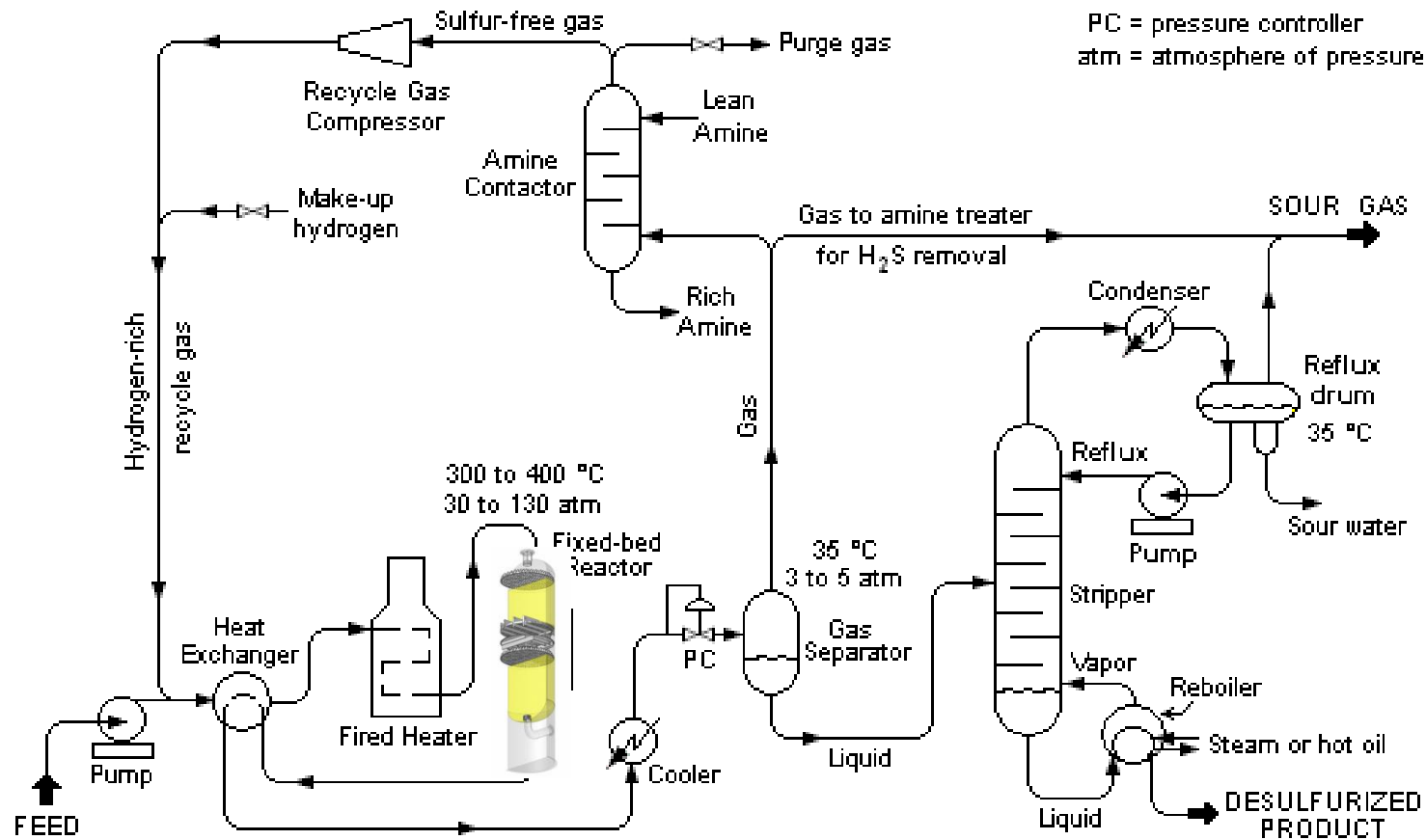
BB-3

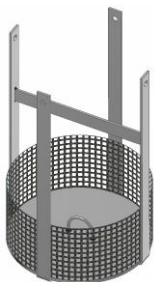


BB-3

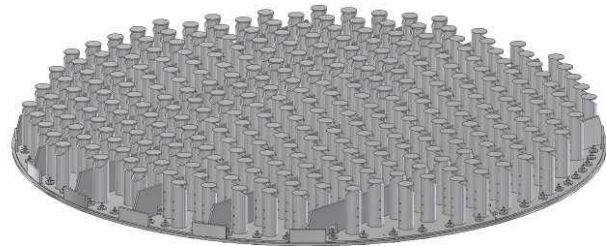


Hydrotreating

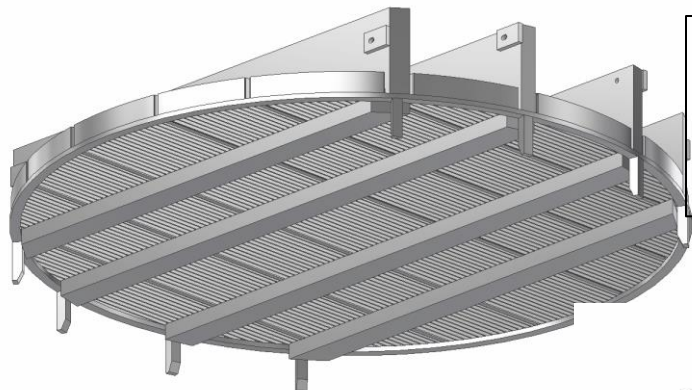




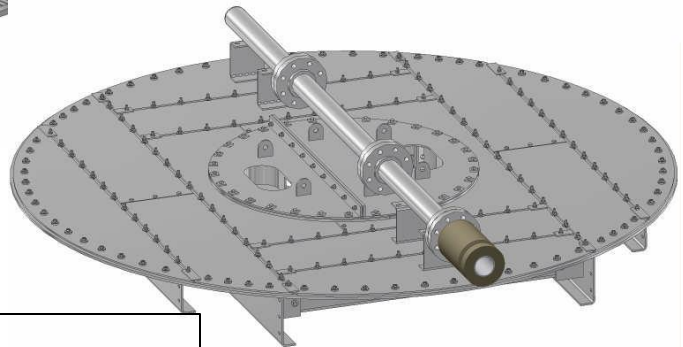
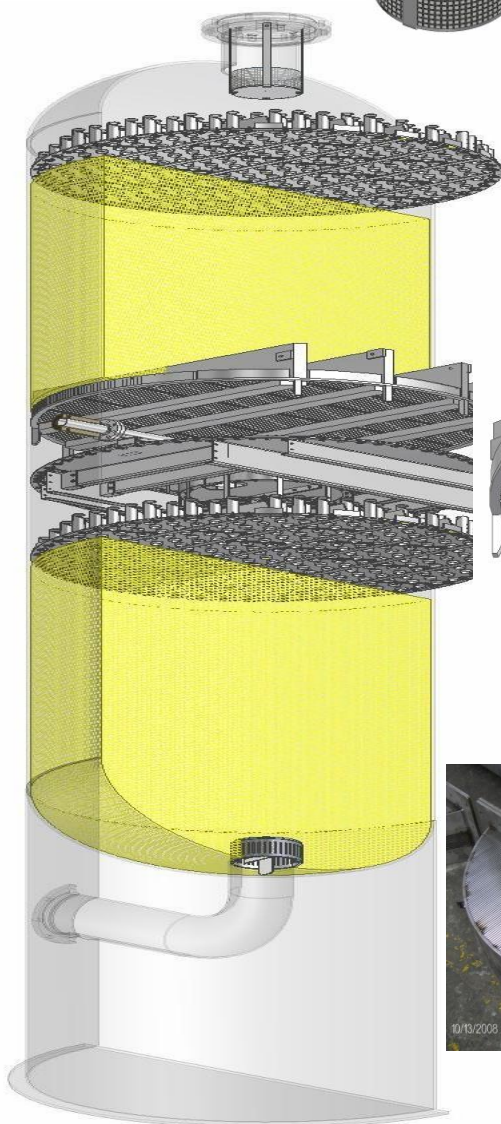
Inlet Diffuser



Distributor



Catalyst Support Plate



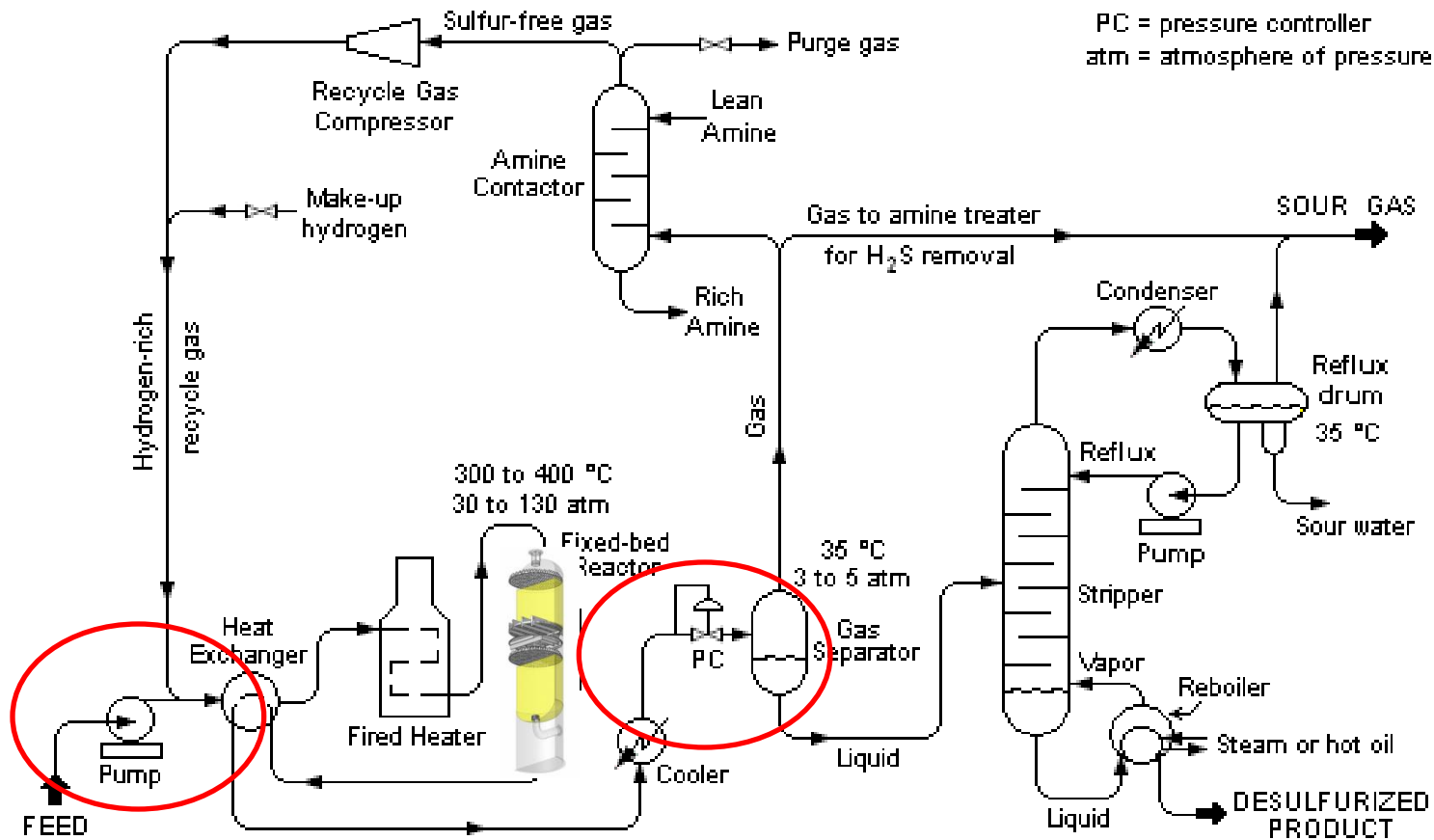
Mixing Tray



Outlet Collector



Hydrotreating



Feed Pump and Expander



Gas Oil Pump

Gas Oil from 60# to 1,850#

60,000 B/D

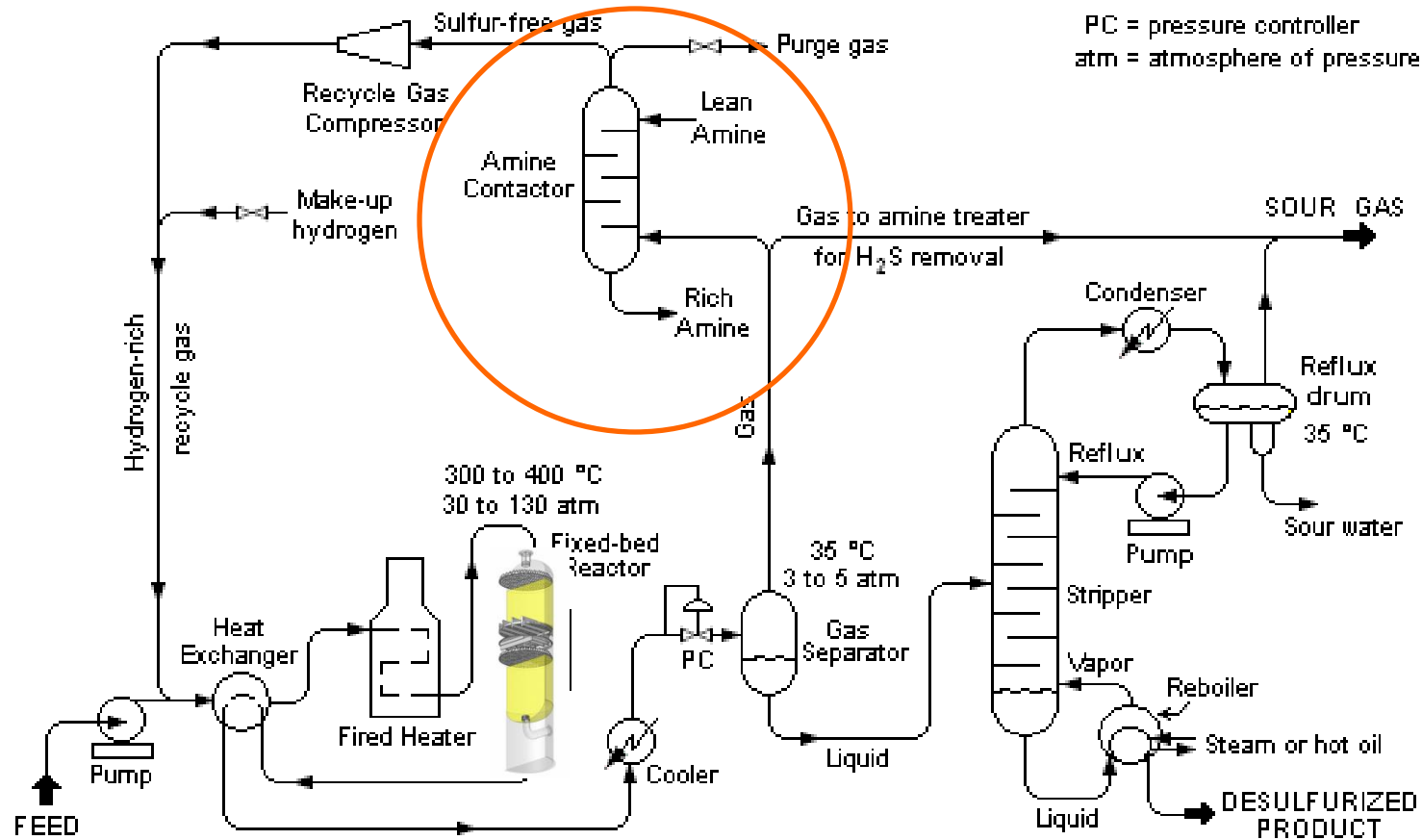
12 Stage Pump

Double Mechanical Seals

Expander

- 8-Stage Pump
- Operated Backwards
- 1,350 psig, 475F, expanding to 130 psig
- Generates 750 HP
- Double Mechanical Seals
- 2,000 HP Motor and Clutch

Hydrotreating



Amine Regeneration Plant

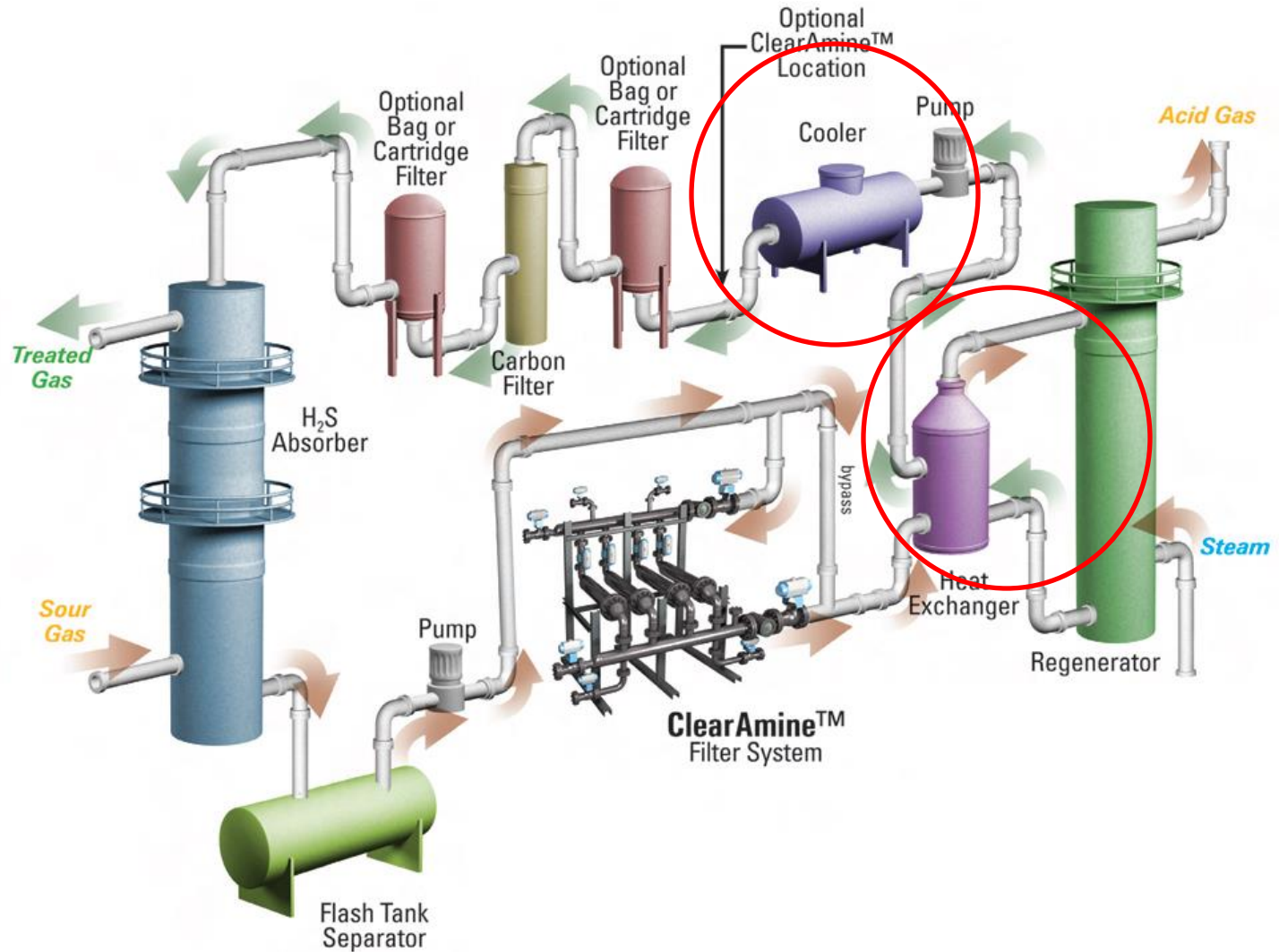
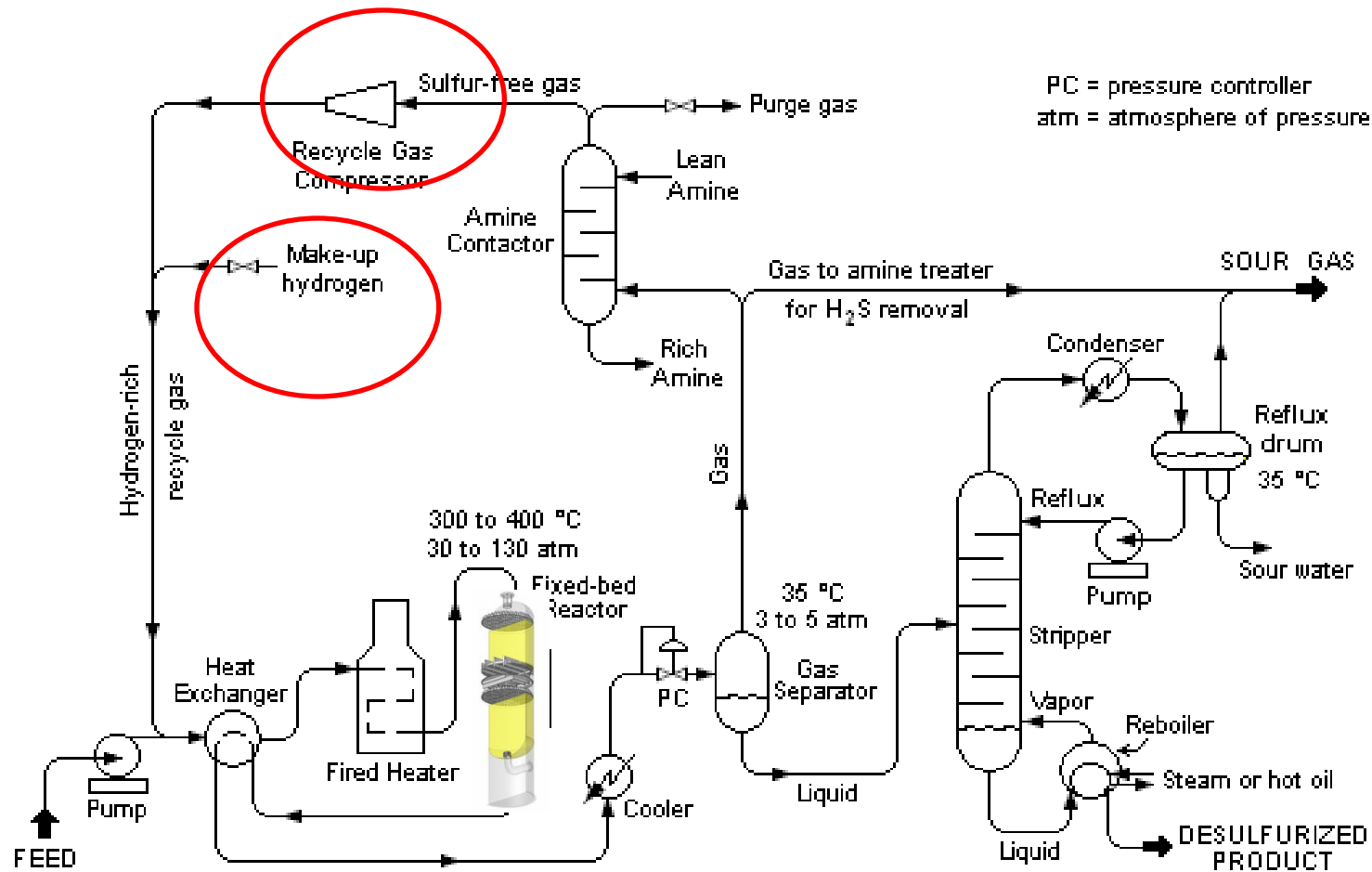


Plate and Frame HX



Hydrotreating



Compressor Applications – Hydrotreating

Reciprocating Compressors

Make-up gas service

High compression ratio 4 - 18

300-3000 psig discharge press.

Limited flow variability

High hydrogen concentration

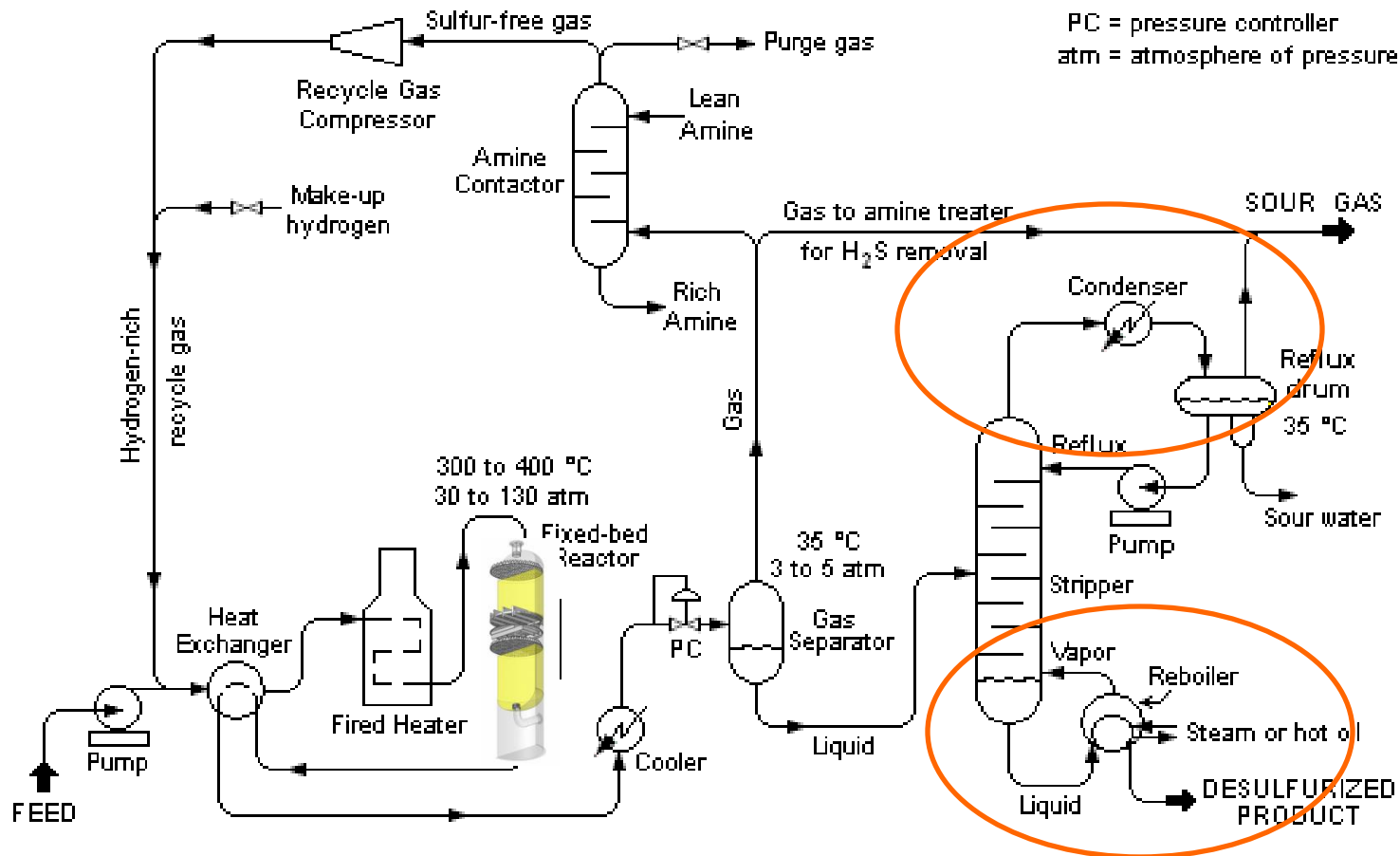
Suction temperatures $< 150^{\circ} \text{F}$



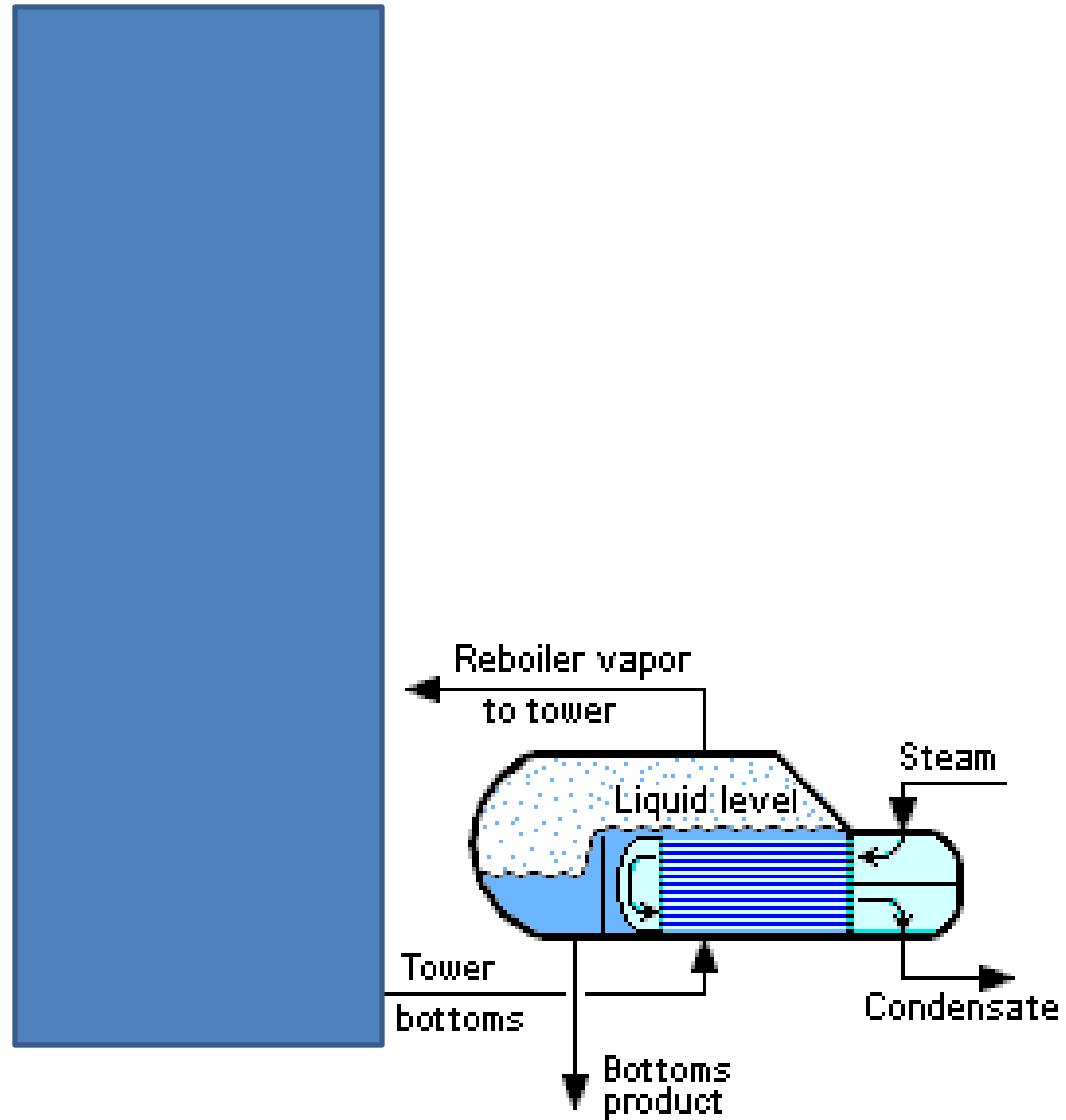
Hydrogen Recycle



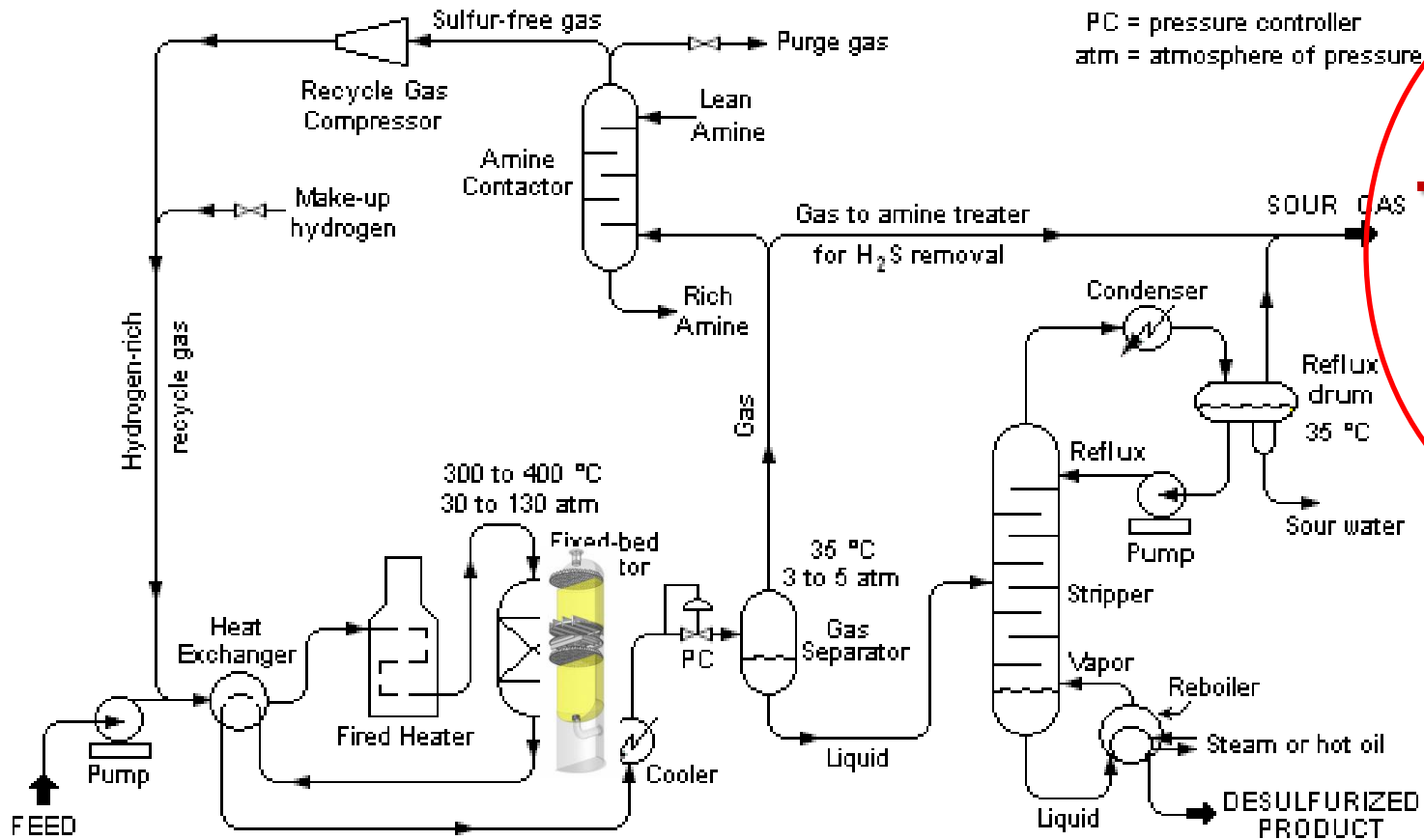
Hydrotreating



Reboiler



Hydrotreating



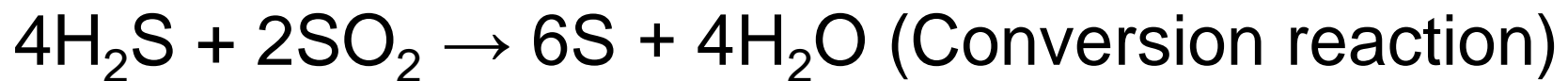
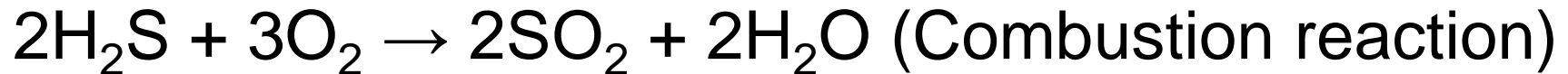
PC = pressure controller
atm = atmosphere of pressure

To SRU

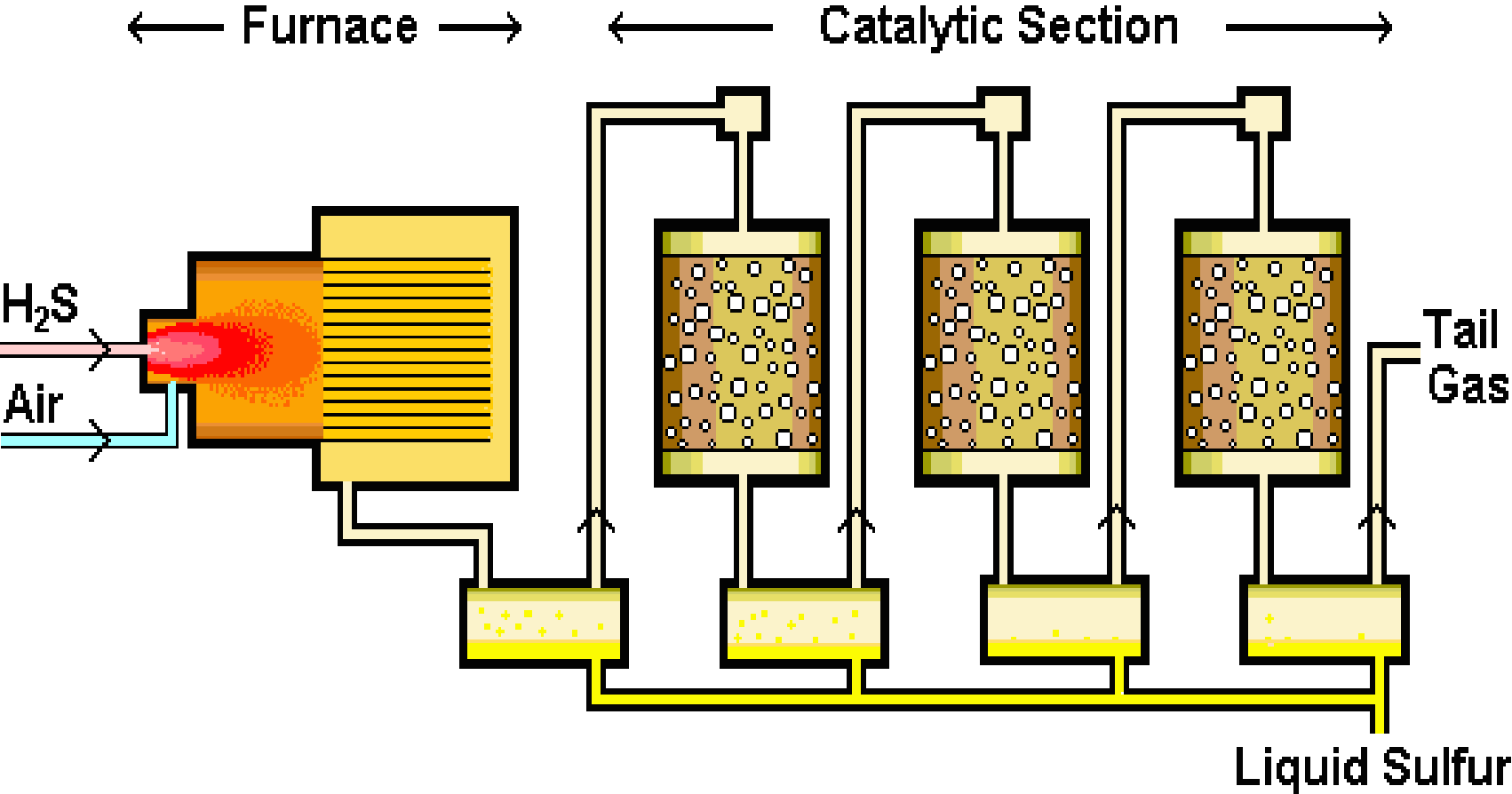


Sulfur Recovery Unit (SRU) Claus

Converts H₂S to
elemental Sulfur



Sulfur Recovery - Claus Process



Compressor Applications - Sulfur Recovery Units

Centrifugal or Positive Displacement Compressors

Combustion air

Atmospheric suction pressure

< 25 psig discharge pressure

Low flow variability - dependent on plant turndown



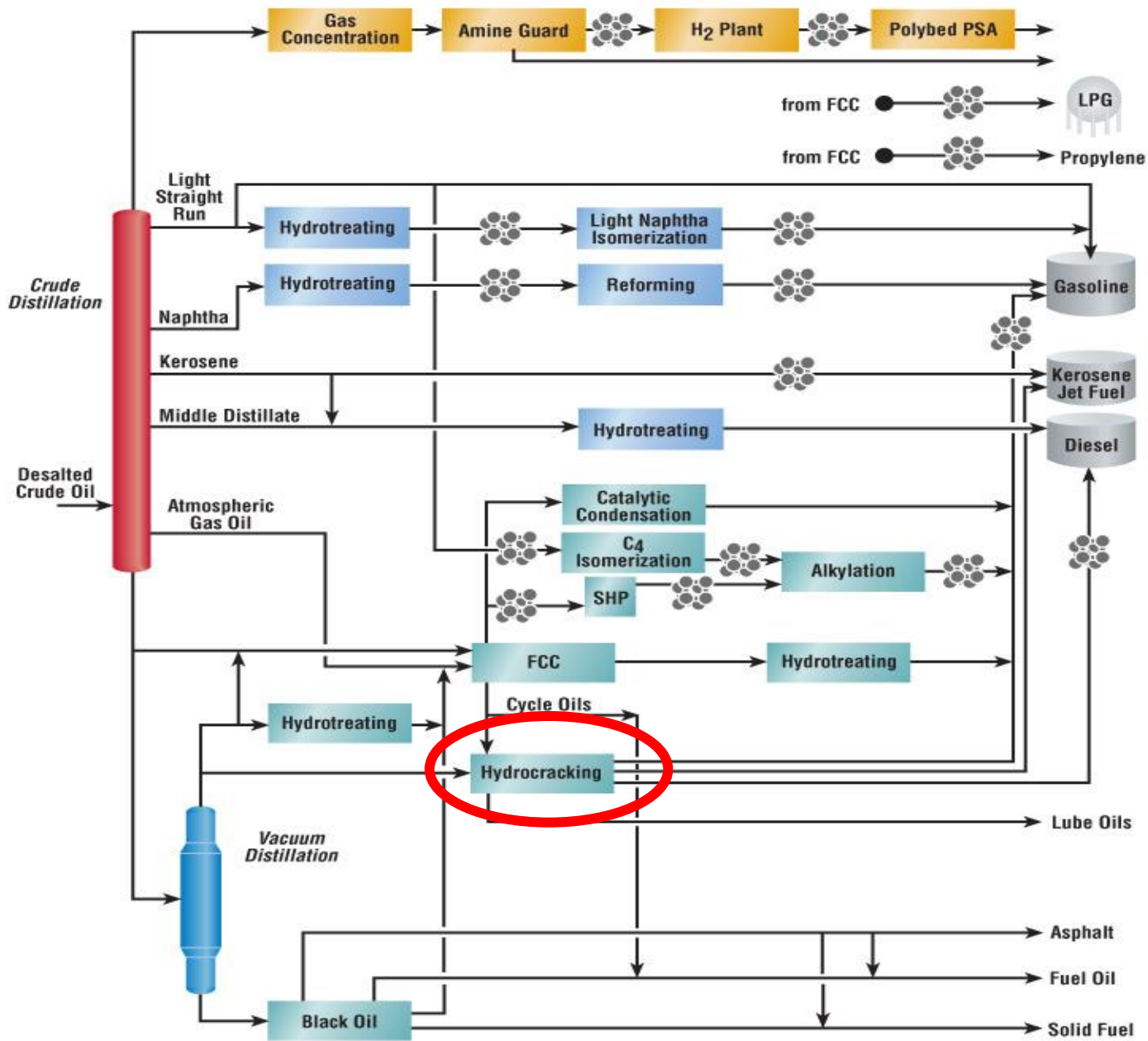
Sulfur Pumps



Liquid Sulfur Pumps

- Atmospheric Suction
- 100-150 psig discharge
- Molten sulfur
- 300 F
- Specific Gravity is 1.75
- Steam Jacketed to Keep sulfur molten





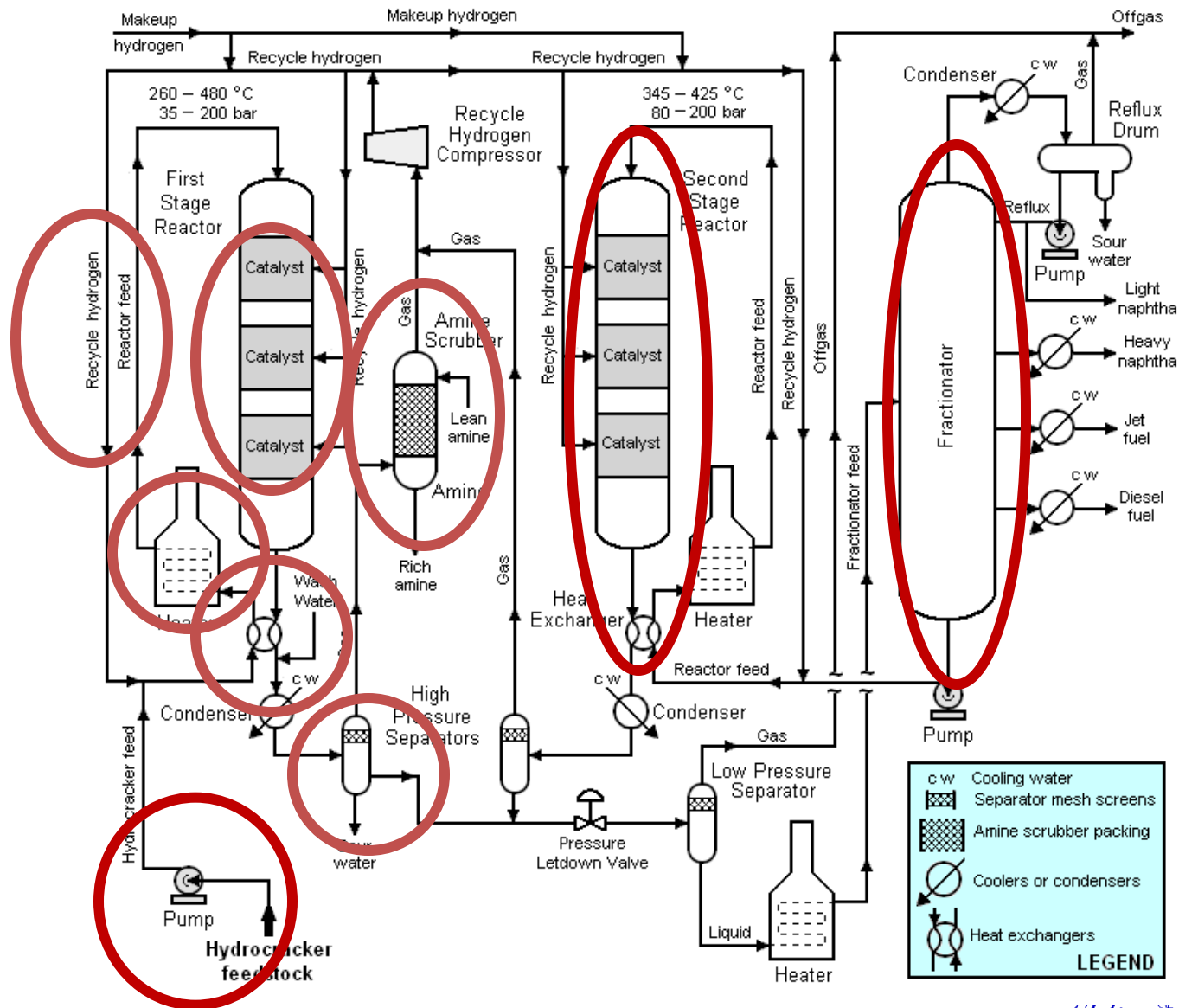
Refinery Adsorbent Locations for Contaminant Removal

HydroCracking

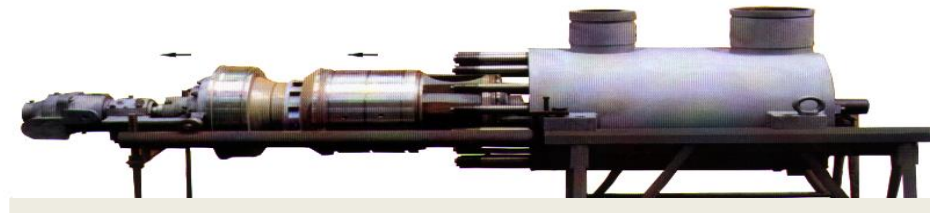
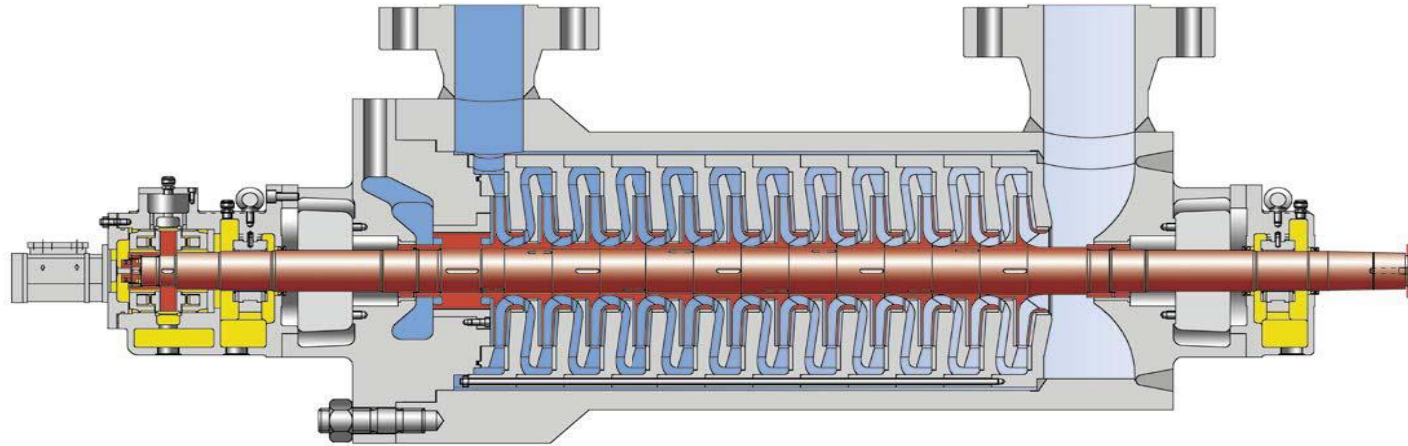
- Hydrocracking cracks VGO from the Vacuum Still into Naptha and Light distillates. (***Diesel and Jet Fuel***)
- It also removes Sulphur
- Cracking at 1000-3000 psig in presence of Hydrogen & Catalyst at 800 F. Expensive equipment/high Hydrogen consumption
- Also Hydrotreat, so ULSD
- Critical Equipment
 - Feed Pumps - Barrel (BB5 Type)
 - Hydraulic Power Recovery Turbines (BB1, BB2 or BB5 Type; driven by liquid leaving HP Separator on its way to LP Separator)

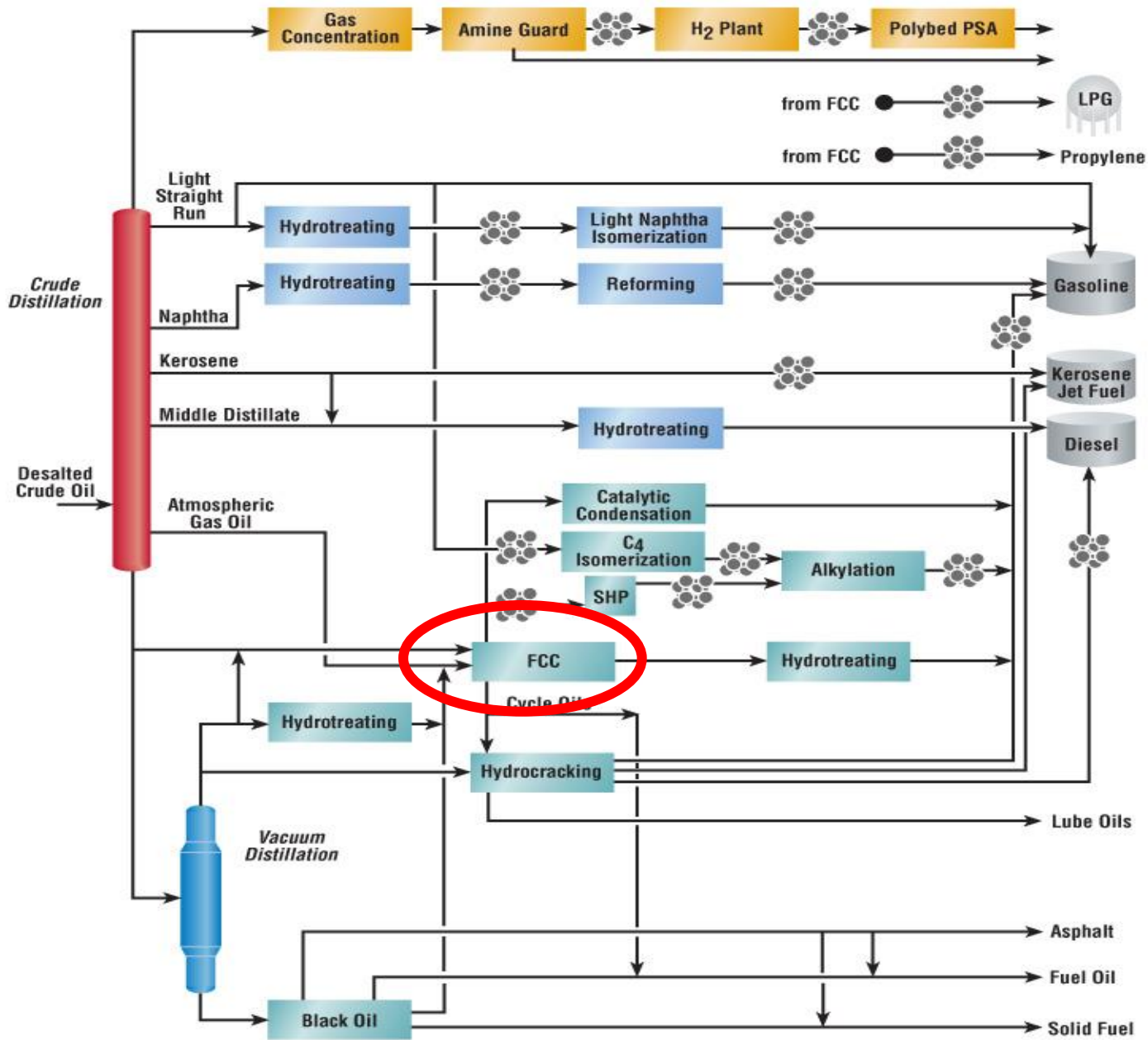


Hydrocracker



BB-5 Double Case Barrel





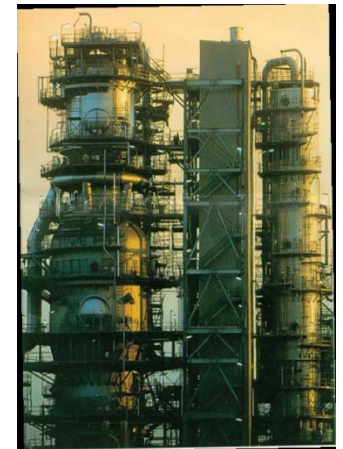
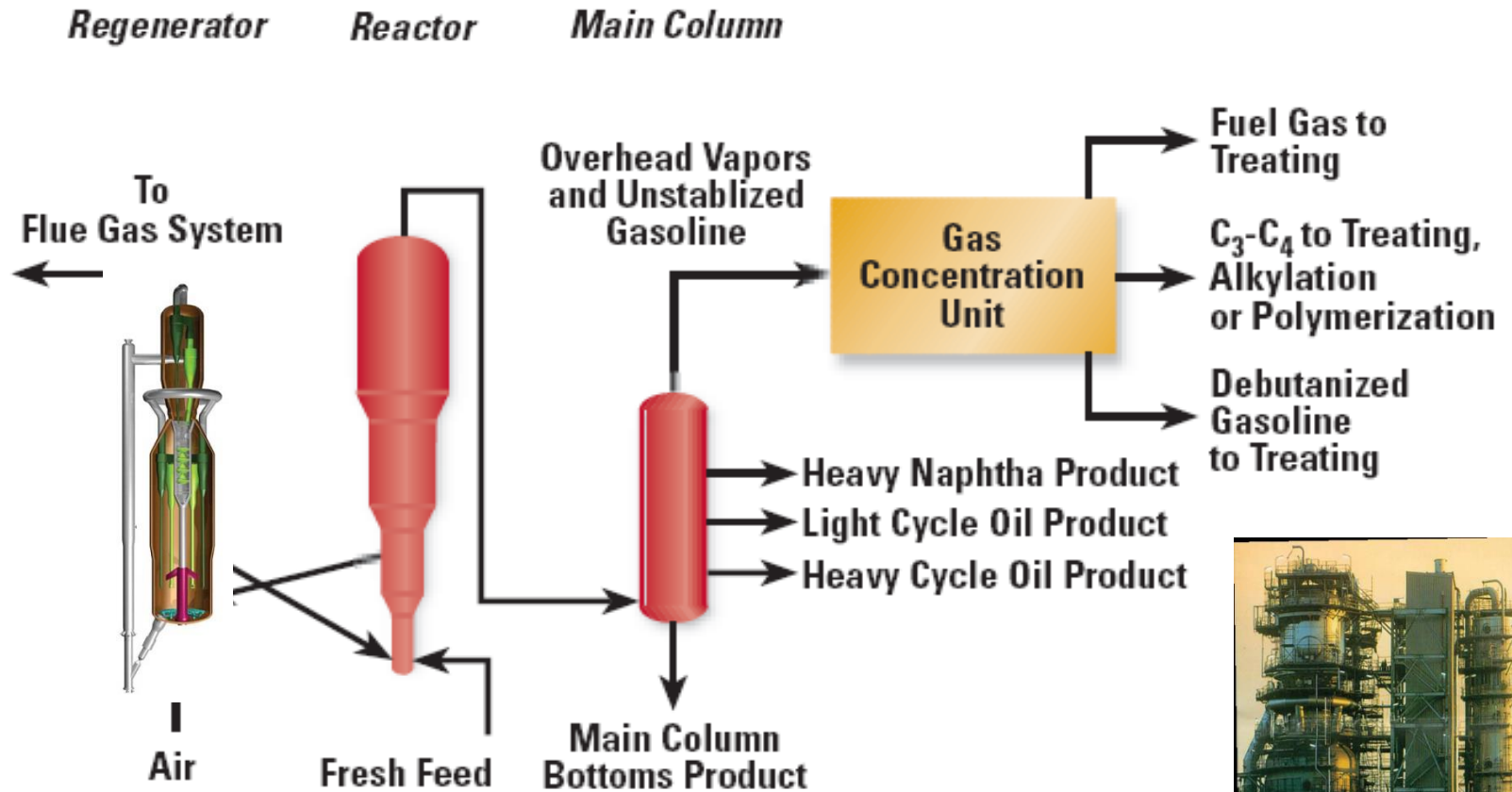
Refinery Adsorbent Locations for Contaminant Removal

Fluid Catalytic 'Cat' Cracker FCCU

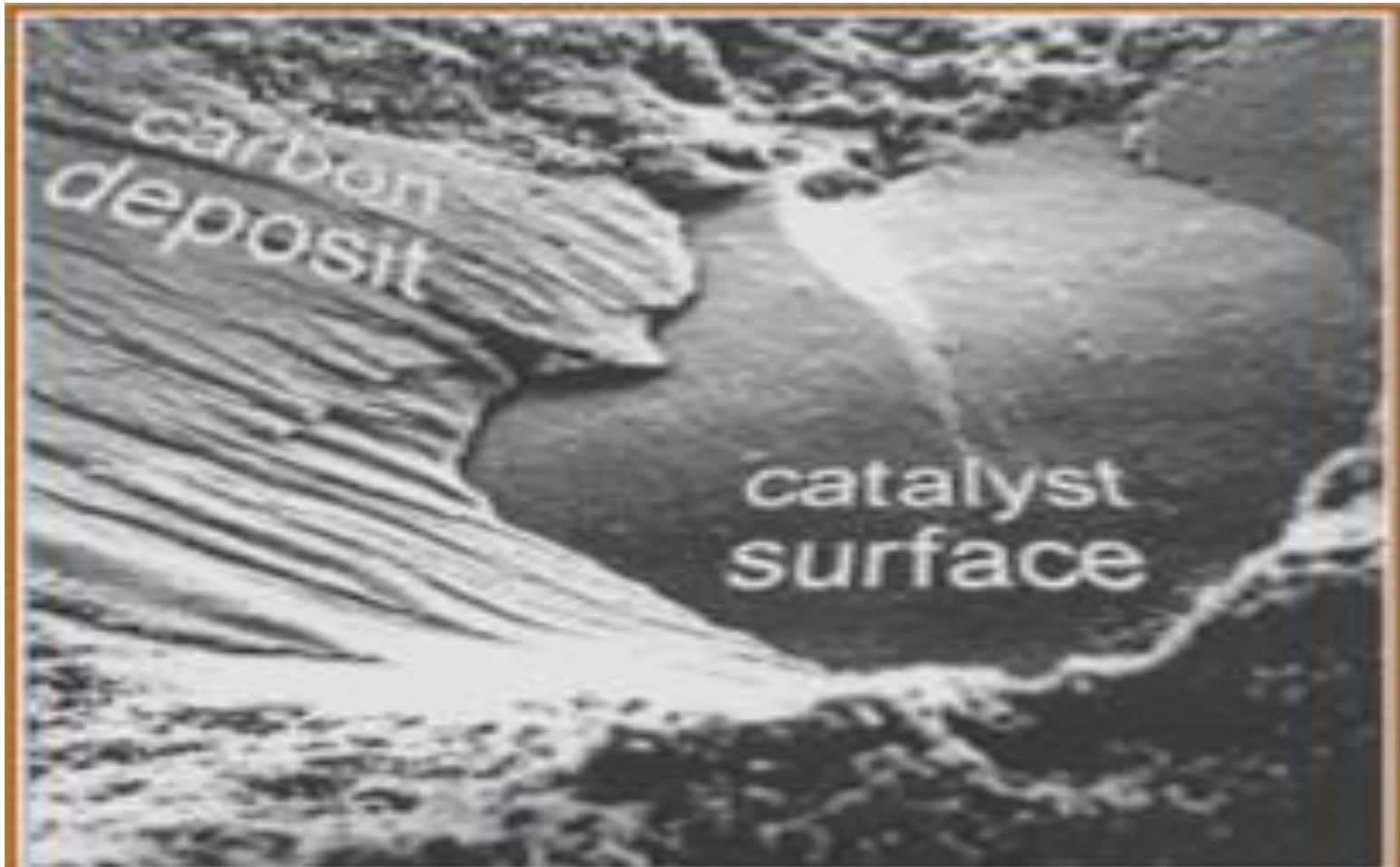
- FCCU takes long chain molecules from the Vacuum Unit (LVGO) and breaks them down into smaller, shorter chain, using Hydrogen and catalysts. Gasoline and Diesel. Generates Olefins Ethylene, **Propylene**, butylene, isobutylene, Alkanes, and BTX
- Hot Gas Expander / Air Compressor
- CO Boiler
- FCCU Scrubber
- Fractionator
- Slurry Oil Pumps Residue + Cat Fines



Fluid Catalytic Cracking Unit

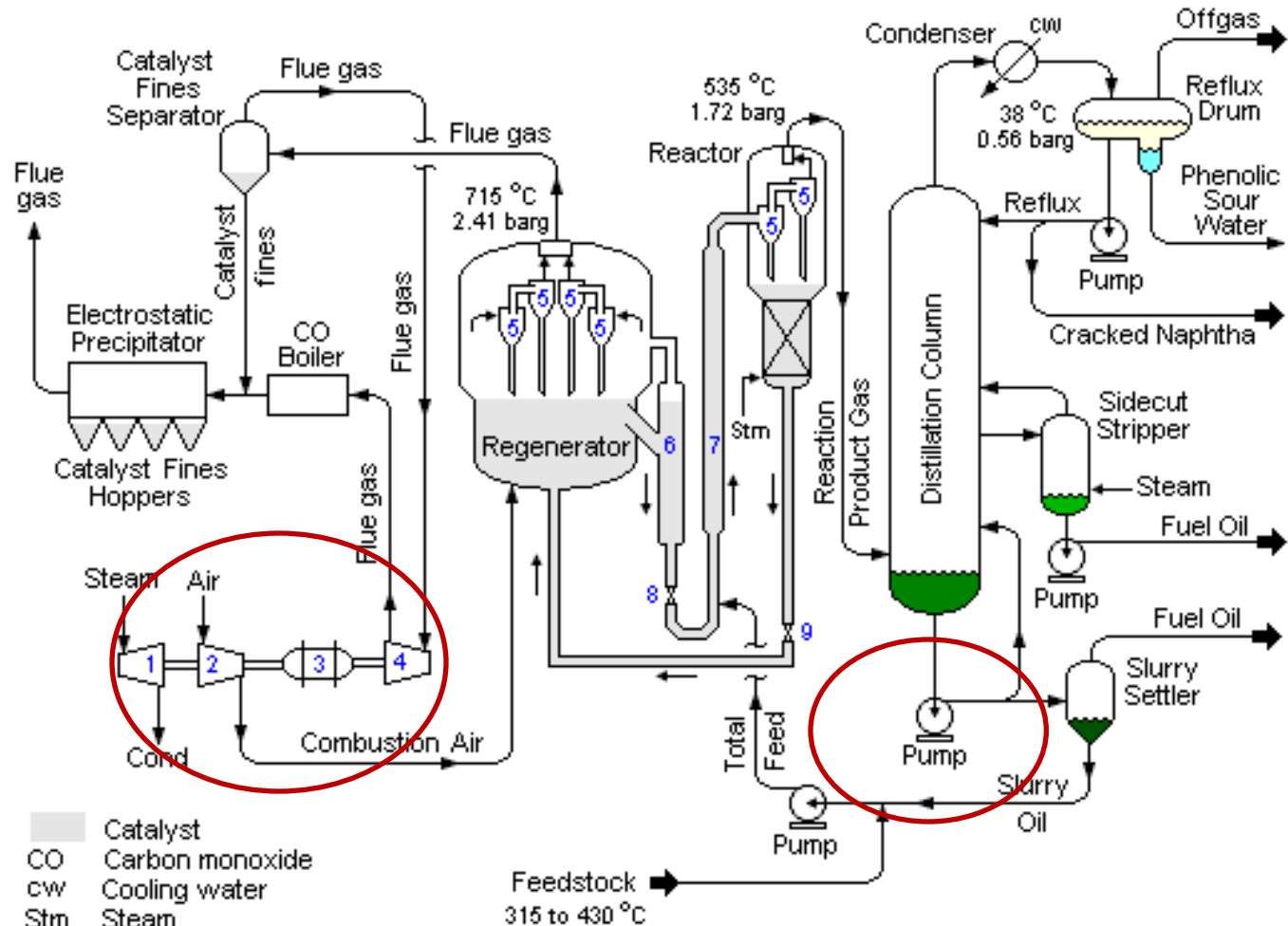


Catalyst Deactivation



Electron micrograph of carbon deposit on catalyst surface

FCCU



- | | |
|----------------------------|------------------------------------|
| ■ Catalyst | |
| CO Carbon monoxide | |
| cw Cooling water | |
| Stm Steam | |
| Cond Condensate | |
| 1 Start-up steam turbine | 6 Catalyst withdrawal well |
| 2 Air compressor | 7 Catalyst riser |
| 3 Electric motor/generator | 8 Regenerated catalyst slide valve |
| 4 Turbo-expander | 9 Spent catalyst slide valve |
| 5 Cyclones | |

Hot Gas Expander/Air Compressor

Turbo Expanders

Combustion gases nitrogen +CO₂

25-35 psig inlet pressure

Atmospheric discharge pressure

High flow, variable but gradual

Wet, but above dew point

1200 -1250 ° F inlet temperature

Abrasive particulates



FCCU Slurry Pumps

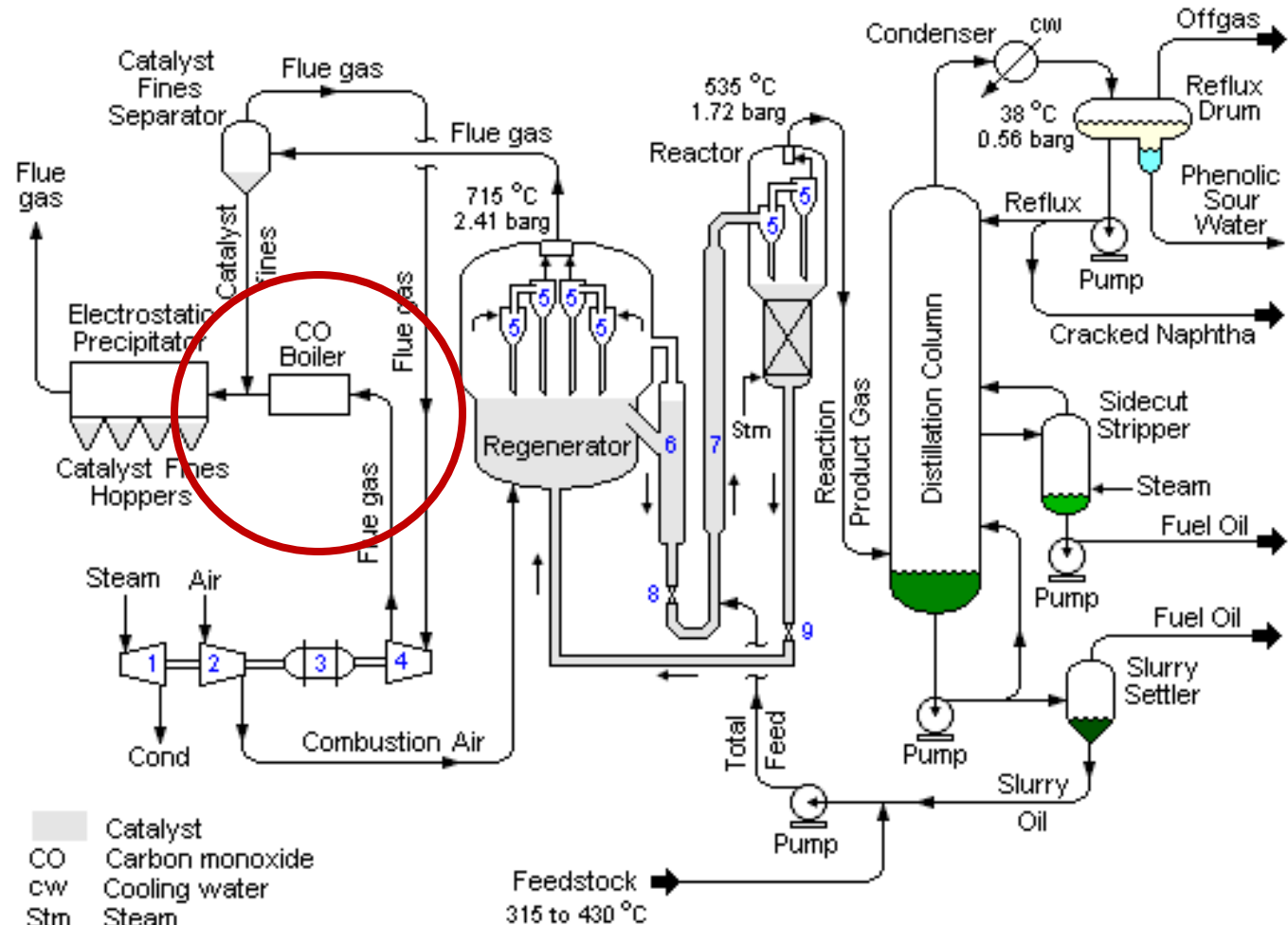


Slurry Pumps

- ◆ FCCU Decanted Oil
- ◆ 700F, 20# suction, 200# discharge
- ◆ Heavy Oil with Catalyst fines
- ◆ Abrasive
- ◆ Internal Liner for Erosion



FCCU



- | | |
|----------------------------|------------------------------------|
| ■ Catalyst | |
| CO Carbon monoxide | |
| cw Cooling water | |
| Stm Steam | |
| Cond Condensate | |
| 1 Start-up steam turbine | 6 Catalyst withdrawal well |
| 2 Air compressor | 7 Catalyst riser |
| 3 Electric motor/generator | 8 Regenerated catalyst slide valve |
| 4 Turbo-expander | 9 Spent catalyst slide valve |
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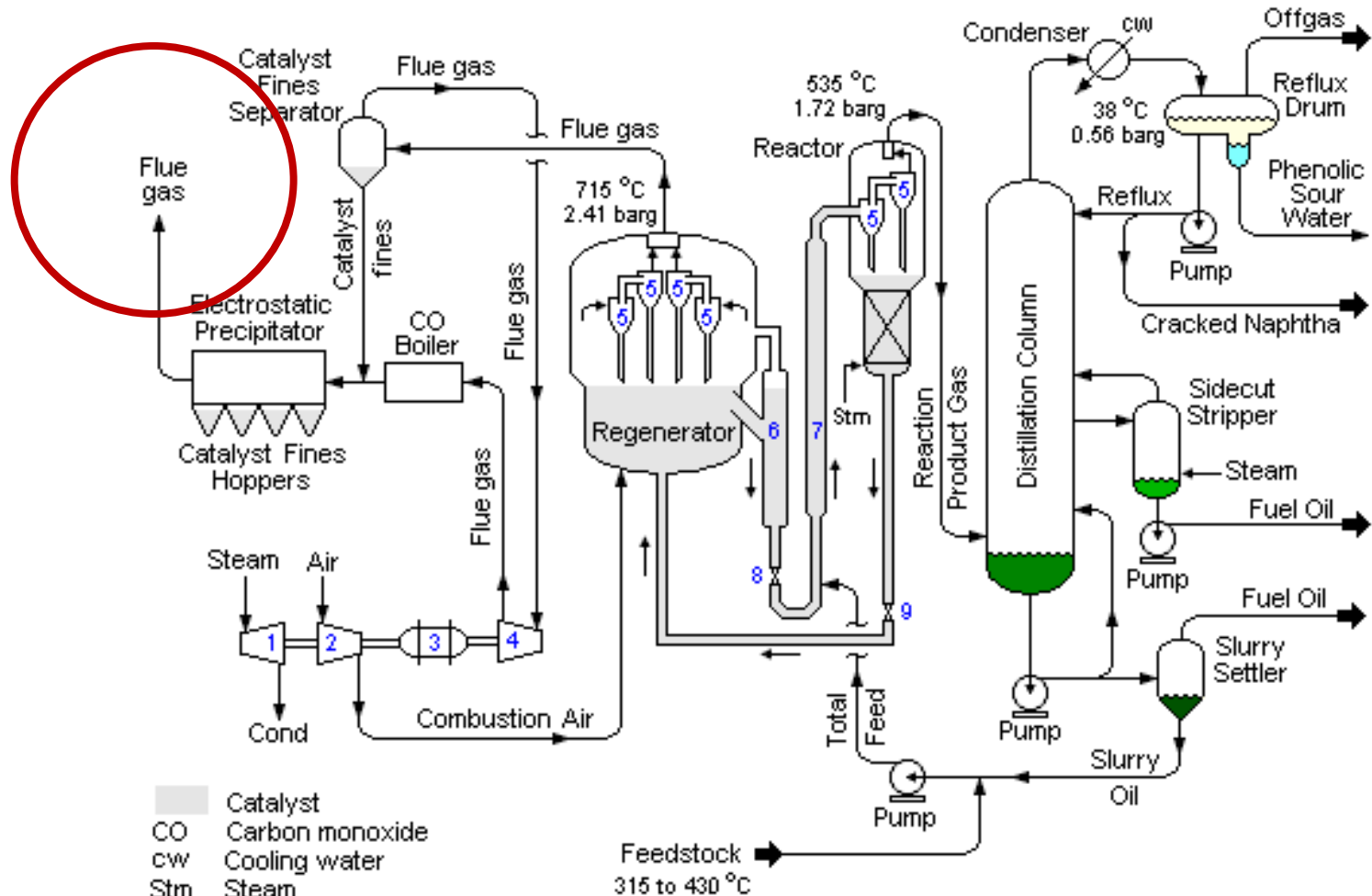
CO Boiler



Deaerator & BFWP In CO Boiler



FCCU



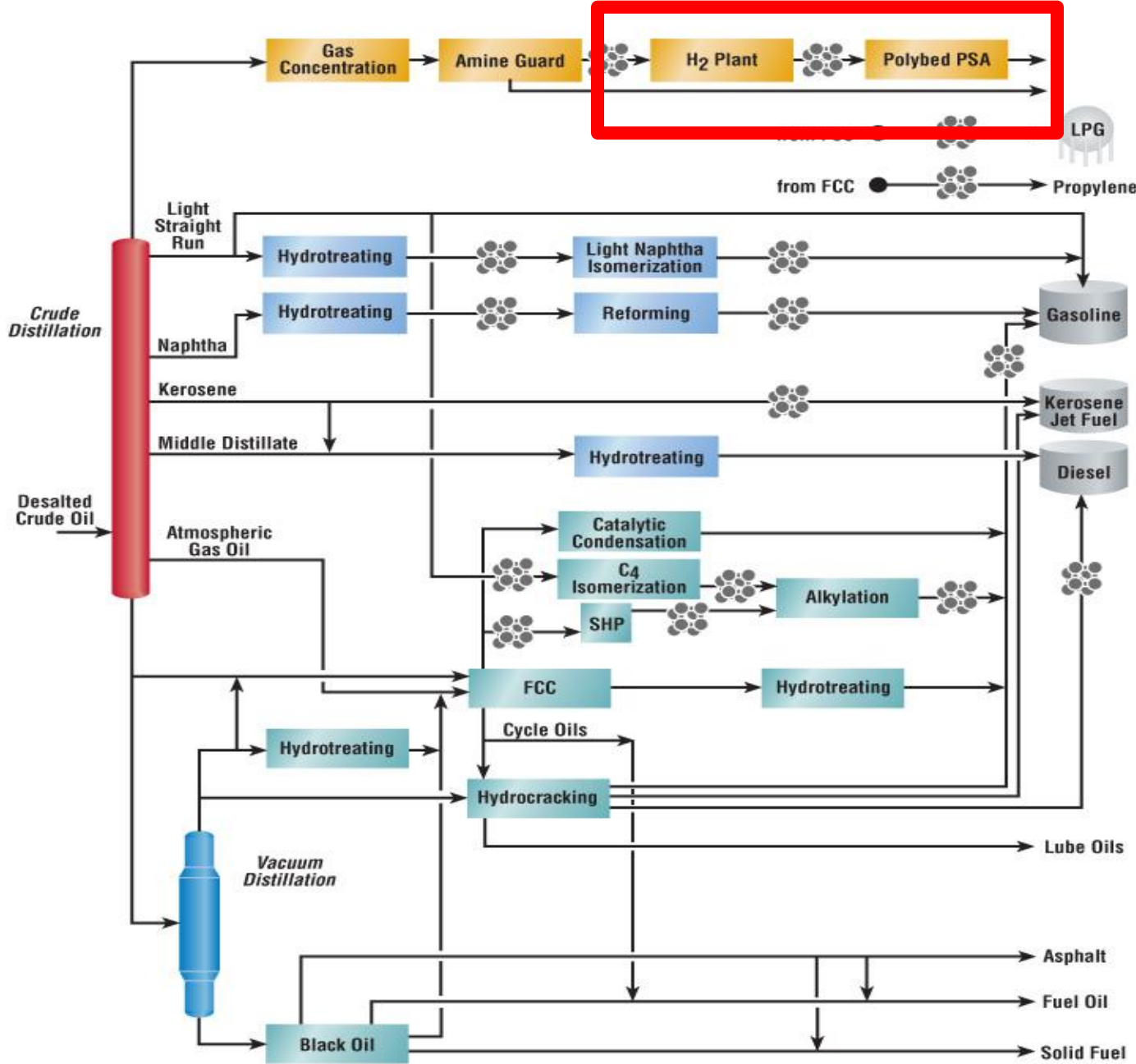
- | | |
|------------|----------------------------------|
| ■ Catalyst | |
| CO | Carbon monoxide |
| cw | Cooling water |
| Stm | Steam |
| Cond | Condensate |
| 1 | Start-up steam turbine |
| 2 | Air compressor |
| 3 | Electric motor/generator |
| 4 | Turbo-expander |
| 5 | Cyclones |
| 6 | Catalyst withdrawal well |
| 7 | Catalyst riser |
| 8 | Regenerated catalyst slide valve |
| 9 | Spent catalyst slide valve |

FCCU Scrubber



Scrubber Recirculation Pumps





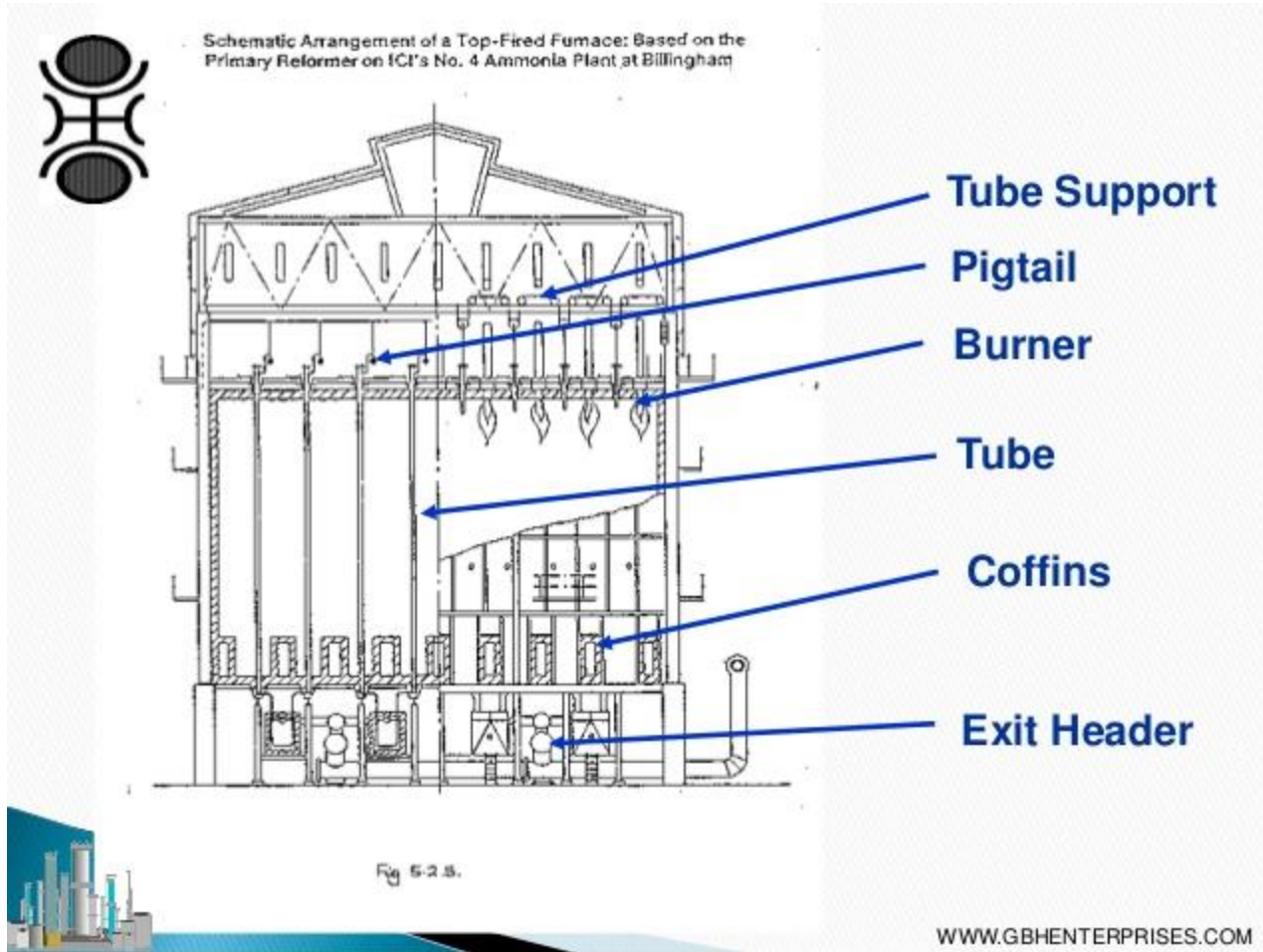
Refinery Adsorbent Locations for Contaminant Removal

Reformer (Steam/Methane) Hydrogen Plant

- Makes Hydrogen
- $\text{CH}_4 + \text{H}_2\text{O} = 3 \text{H}_2 + \text{CO}$
- High Pressure Steam and Methane pass over catalysis
- Make up water (RO)
- Boiler Feed Pumps
- Deaerator



Reformer

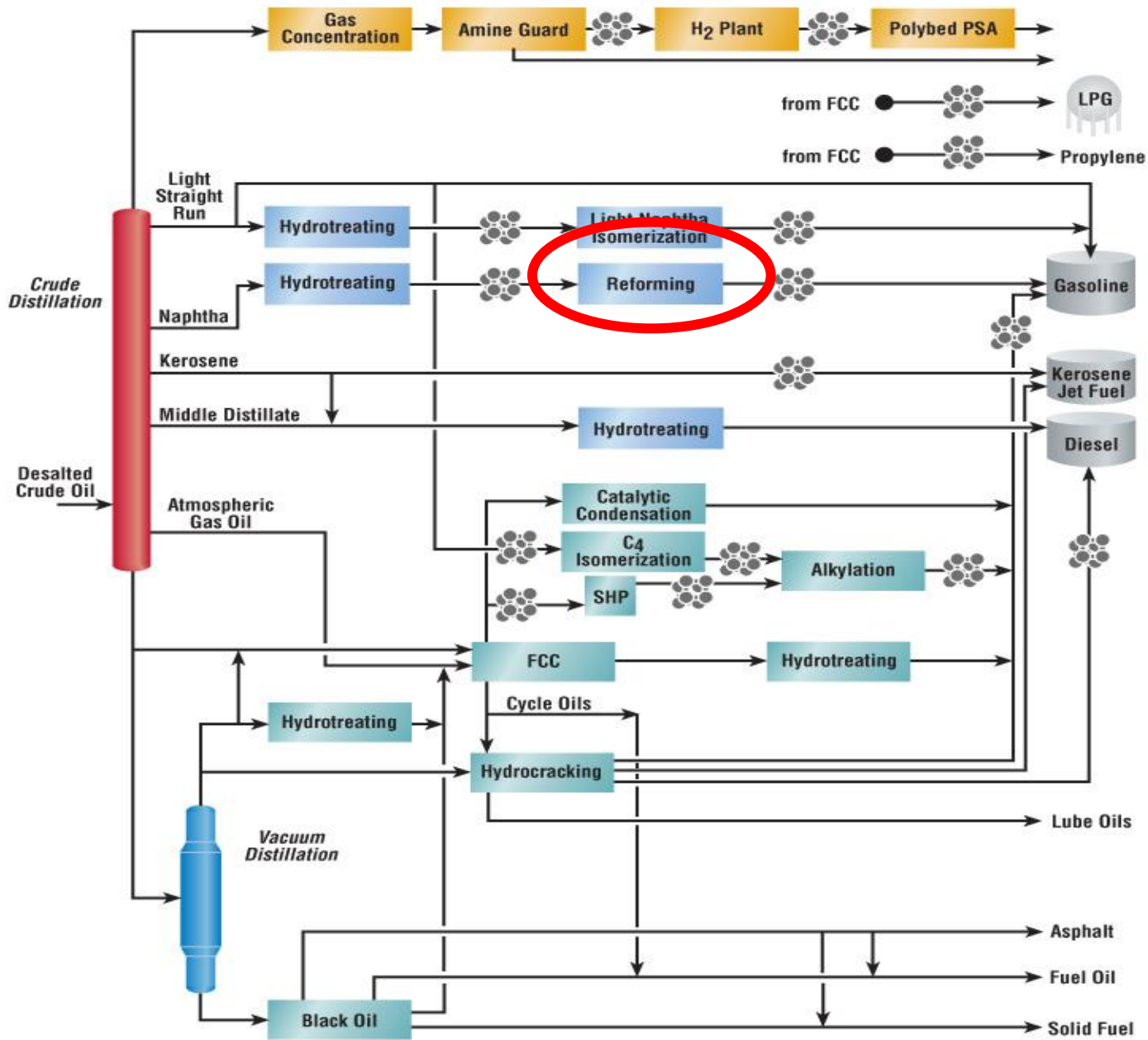


Boiler Feed Water Pump BB4



RO SKID





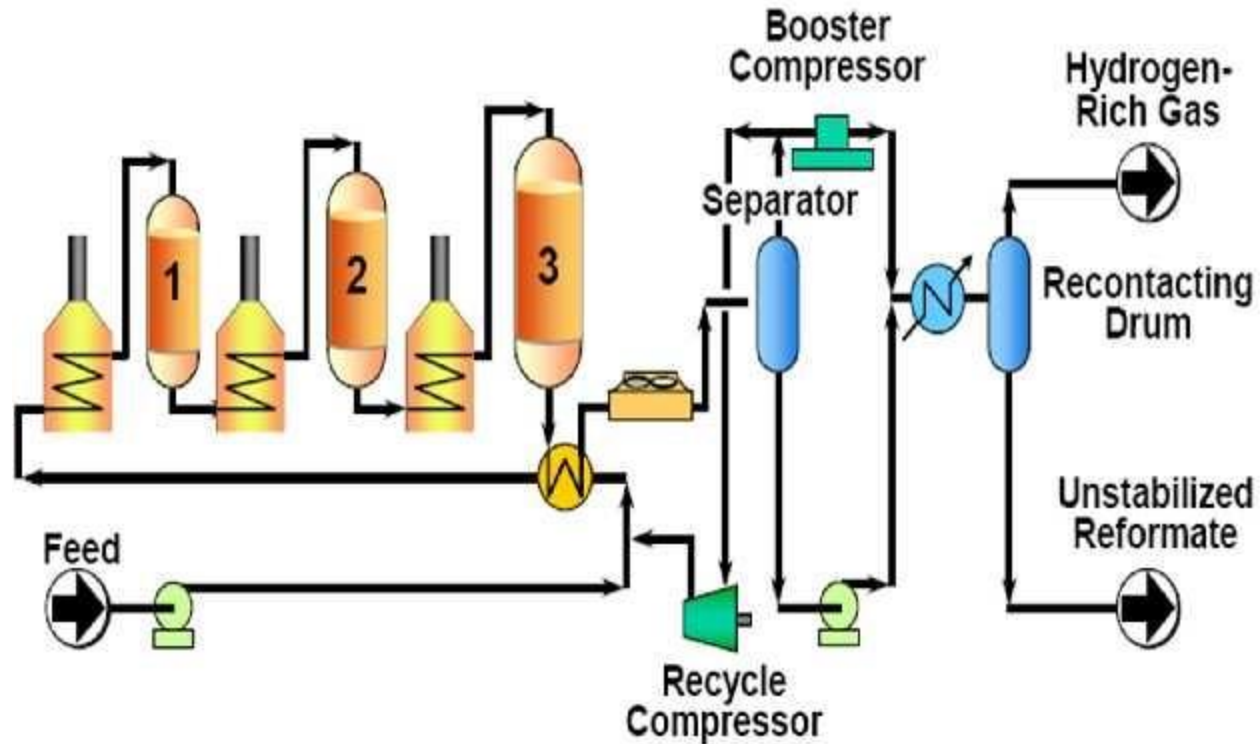

 Refinery Adsorbent Locations
for Contaminant Removal

Catalytic Reforming

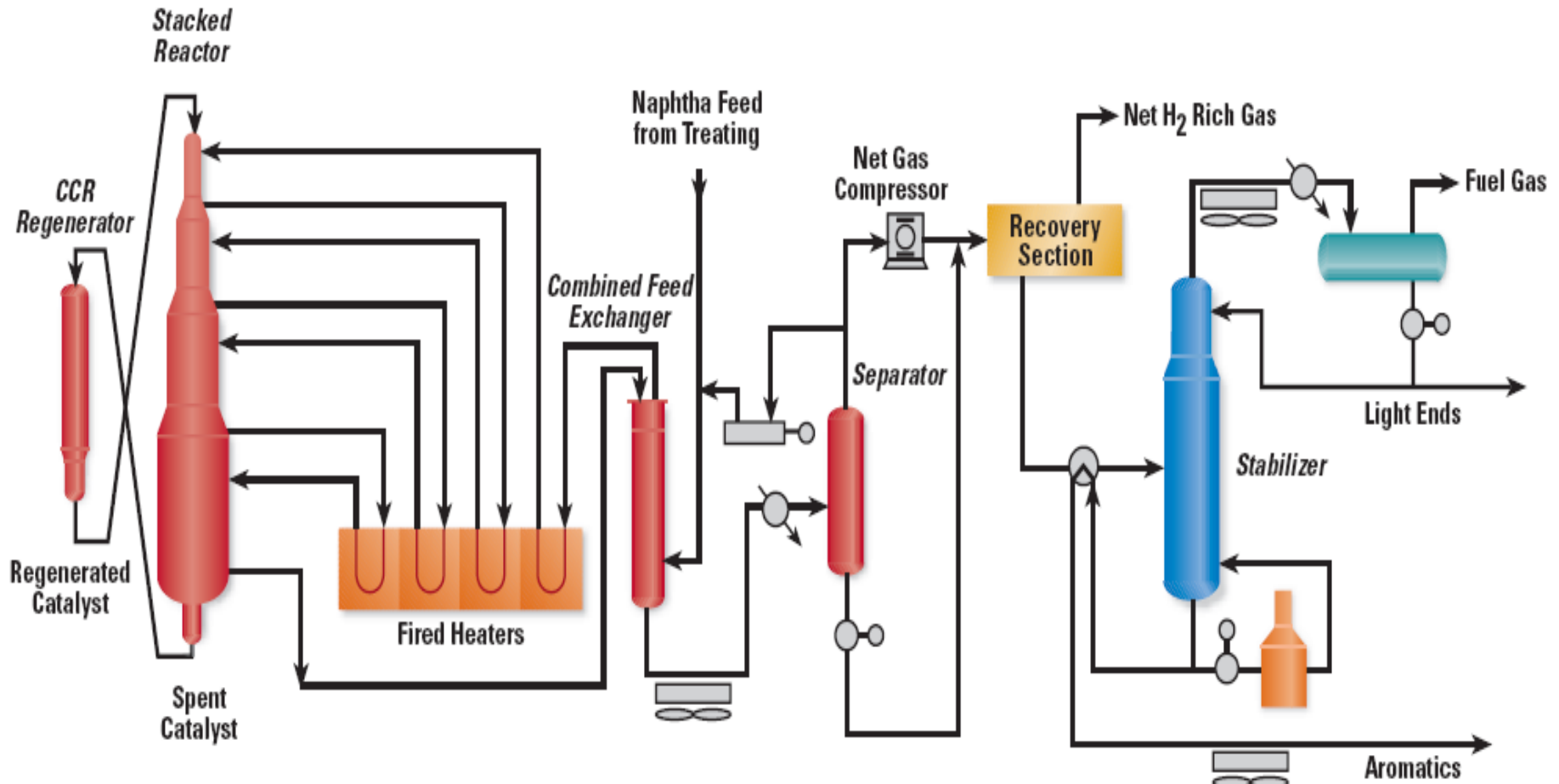


- Naphtha Feed from CDU to Boost Octane
- The Process 'Restructures' the Molecular Arrangement. C_7-C_{10}
- Changes cycloalkanes to aromatics (BTX), isomerize heptane to isoheptane, cracks heptane to isopentane, and releases H_2
- Product is Reformate 90-100 RON
- Metal (Platinum) Catalyst at 900-1000 F.
- Net Gain of Hydrogen
- Critical Pumps:
 - Charge pumps to 600 psig BB-3
 - Condensate Pumps VS-6
 - Standard Process Pumps - OH2.

Catalytic Reforming

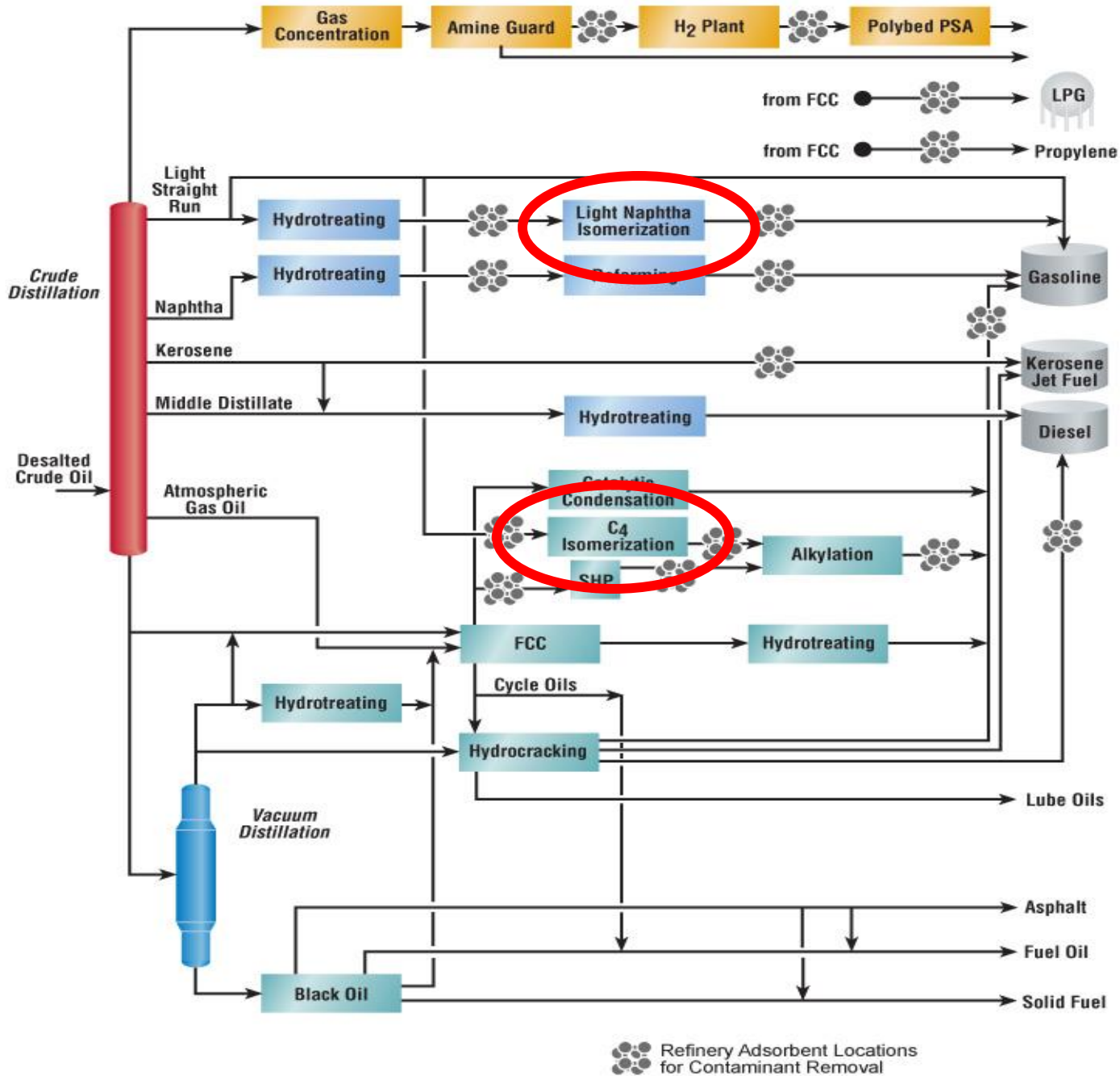


Continuous Catalytic Reforming (CCR)



Recycle H₂ Centrifugal Compressor





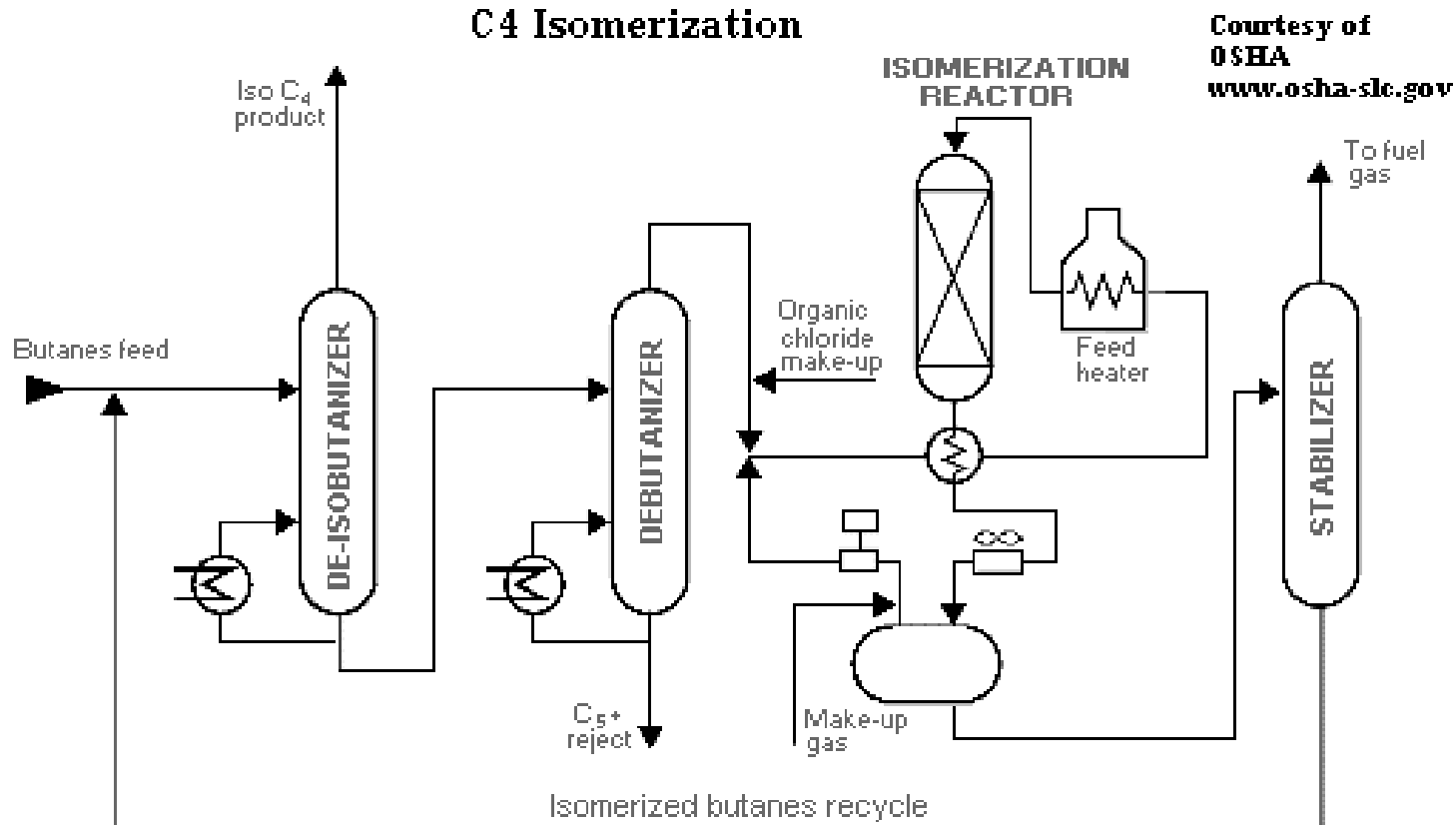
Refinery Adsorbent Locations for Contaminant Removal

Isomerization

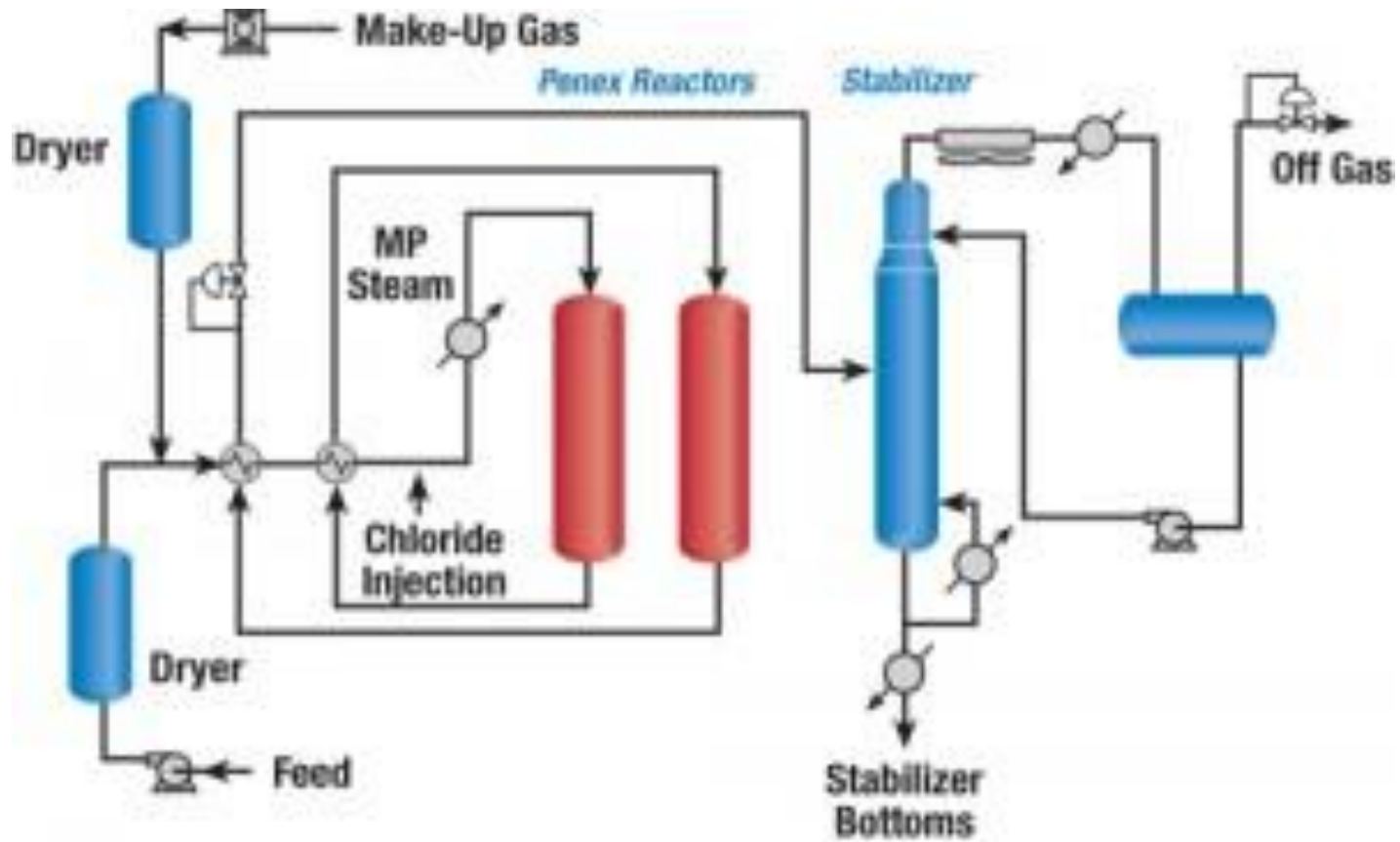
- The **C4** Isomer unit converts straight chain C4 Butane to isobutane which is then feed stock for the Alky Unit
- The **C5/6** Isomer unit
- N-pentane to I-Pentane
- N-Hexane to I-Hexane
- RON 60 to 93

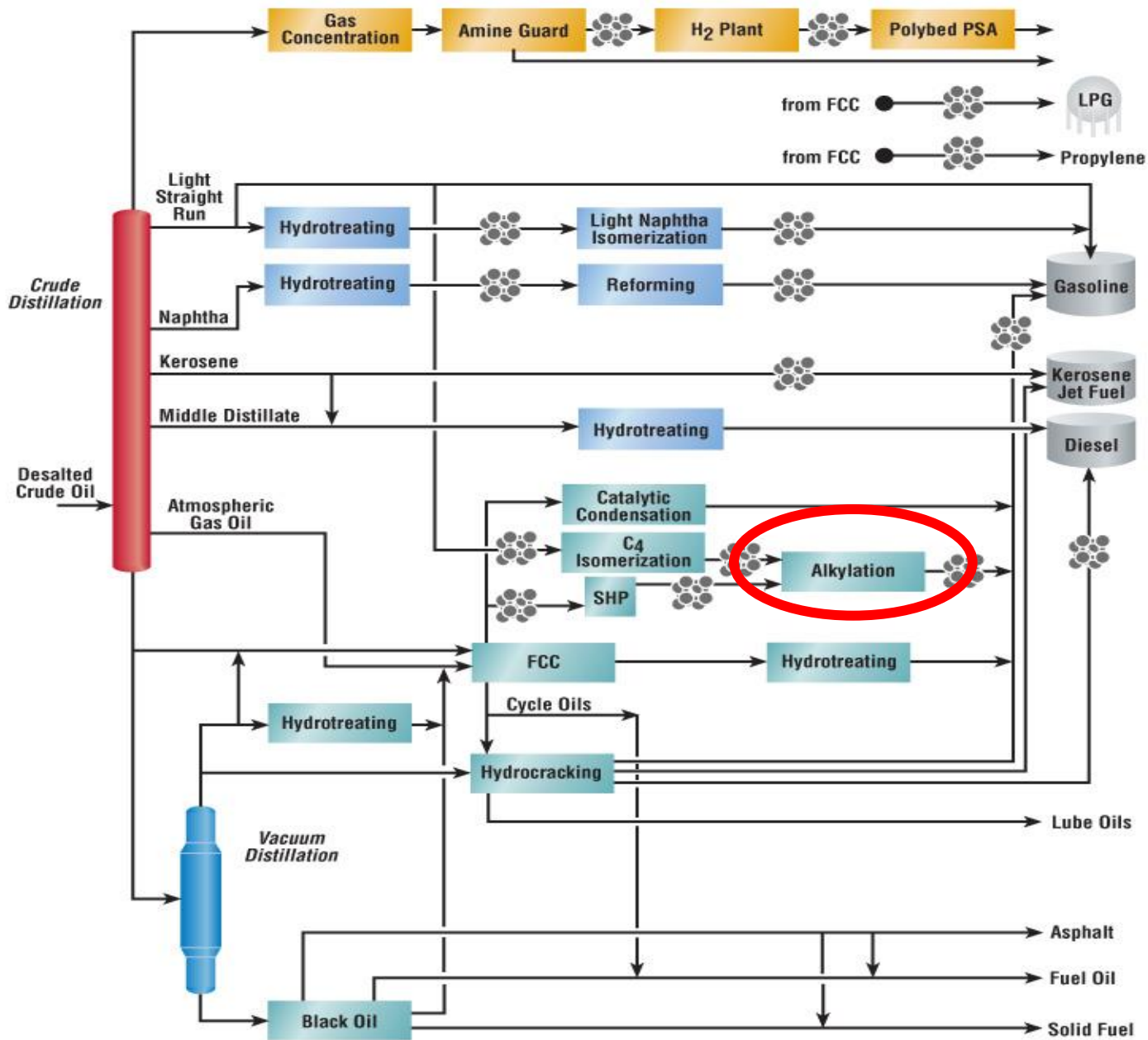


C₄ Isomerization Butane to Isobutane



C_5/C_6





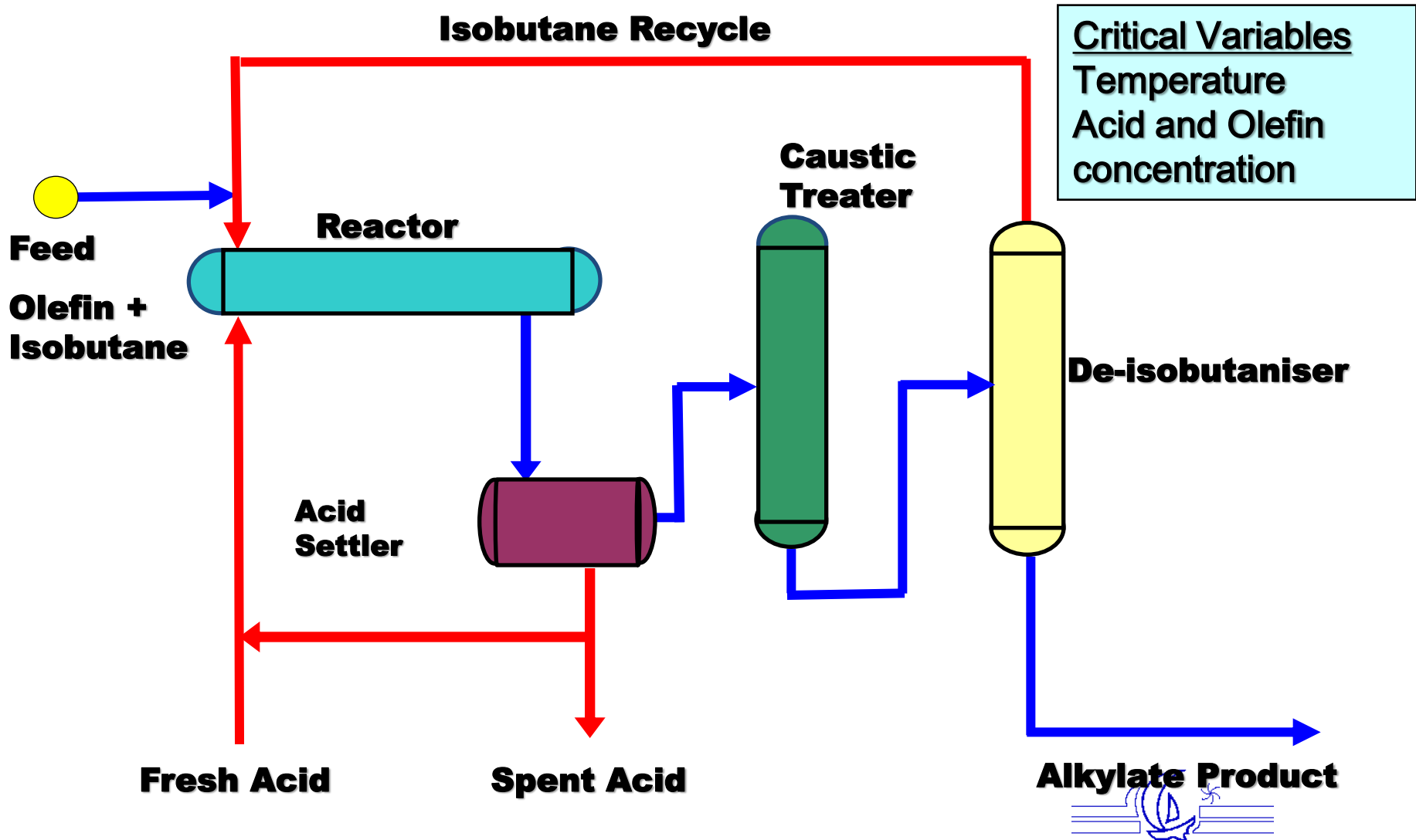
 Refinery Adsorbent Locations for Contaminant Removal

Alkylation (Alky)

- Alky Unit uses HF or H_2SO_4 to convert isobutane (from C_4 Isomer unit) and olefins (from FCC) to high octane alkylates...such as isooctane, RON 100
- This produces high octane molecules for blending
- Usually OH-2 and BB-2 with material to handle H_2SO_4 or HF (monel)



Alkylation Process - Sulfuric Acid



Compressor Applications – Sulfuric Acid Alkylation

Variable Speed

Centrifugal Compressors

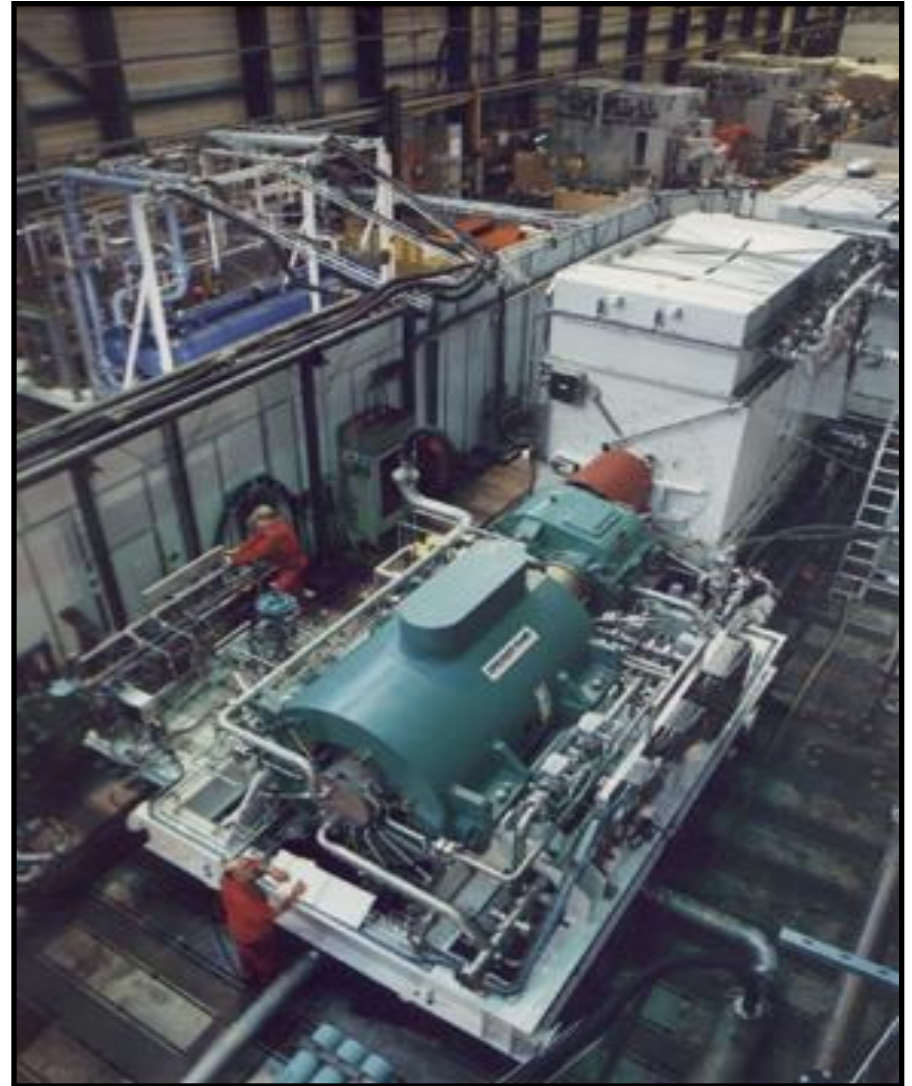
5-10 psig suction pressure

50-70 psig discharge press.

Limited flow variability

Wet, highly corrosive, reactive

Low molecular wt. variability



Spent Acid Scrubber



Alkylation -- Sulfuric Acid and Butane Pumps

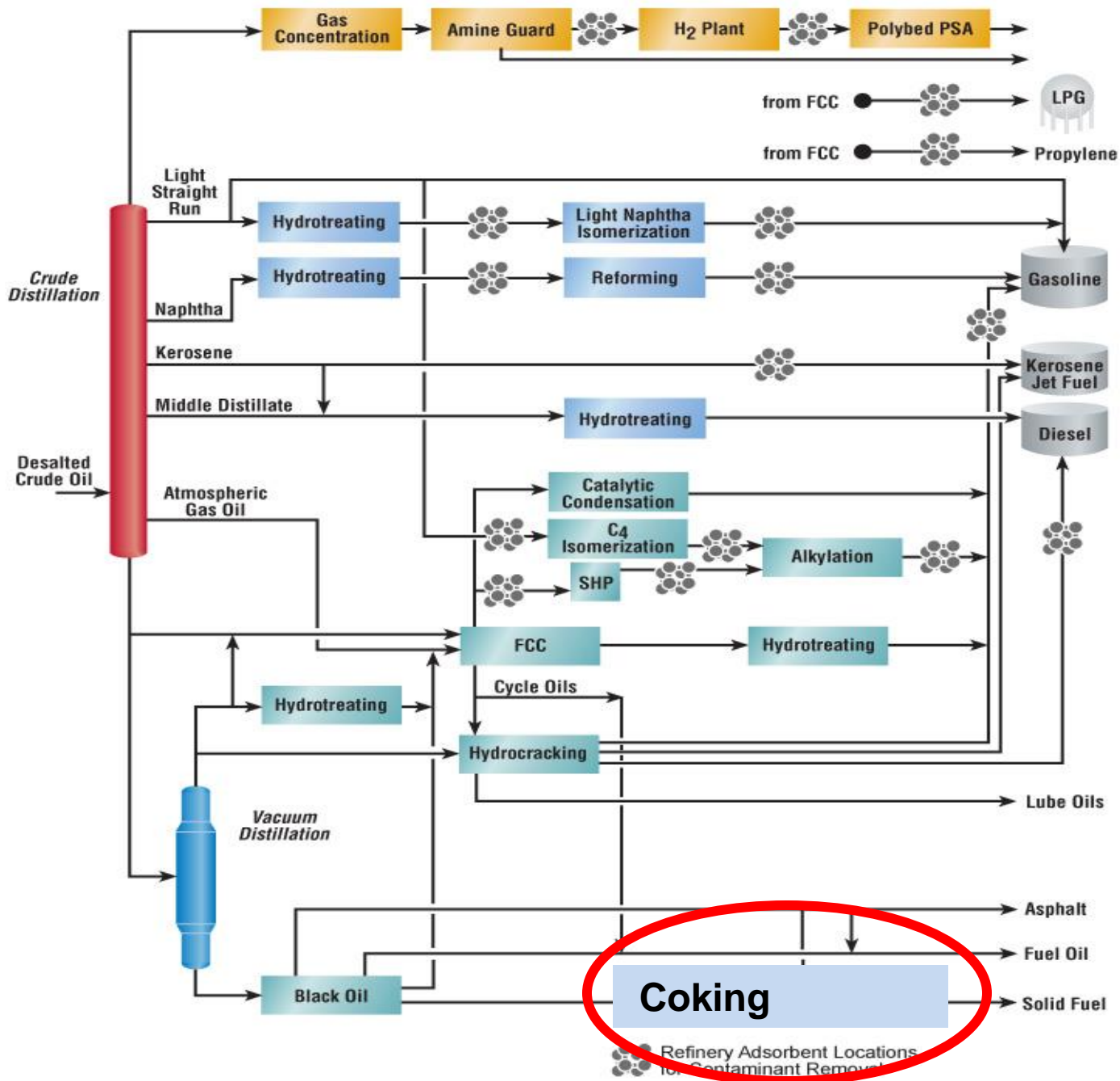
Sulfuric Acid Pumps

- 10 psig
suction



Butane Pumps

- 20-75# Suction
- 50-250# discharge
- 35-90F Temperature
- IC4 and NC4
- Double Mechanical Seals
- Carbon Steel



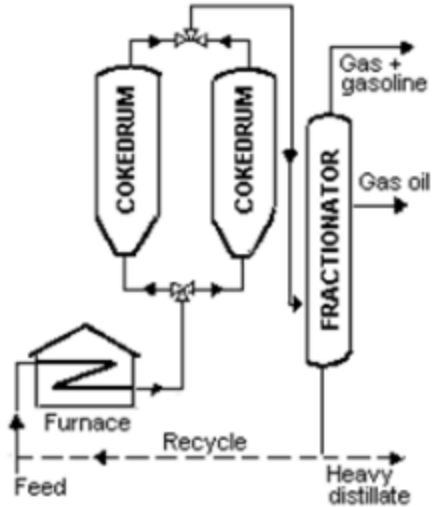
Delayed coker



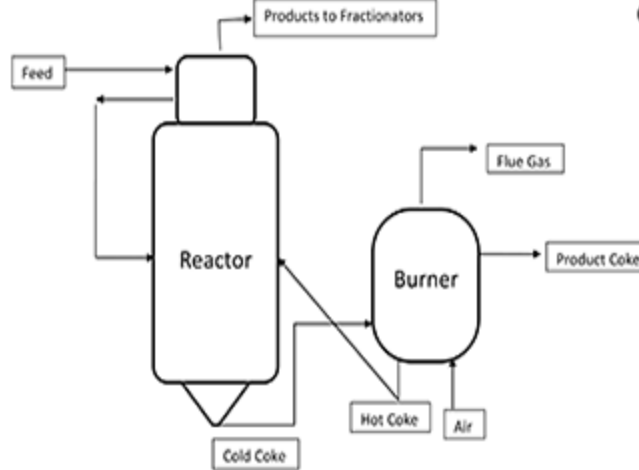
Fluid coker



Delayed Coking



Fluid Coking



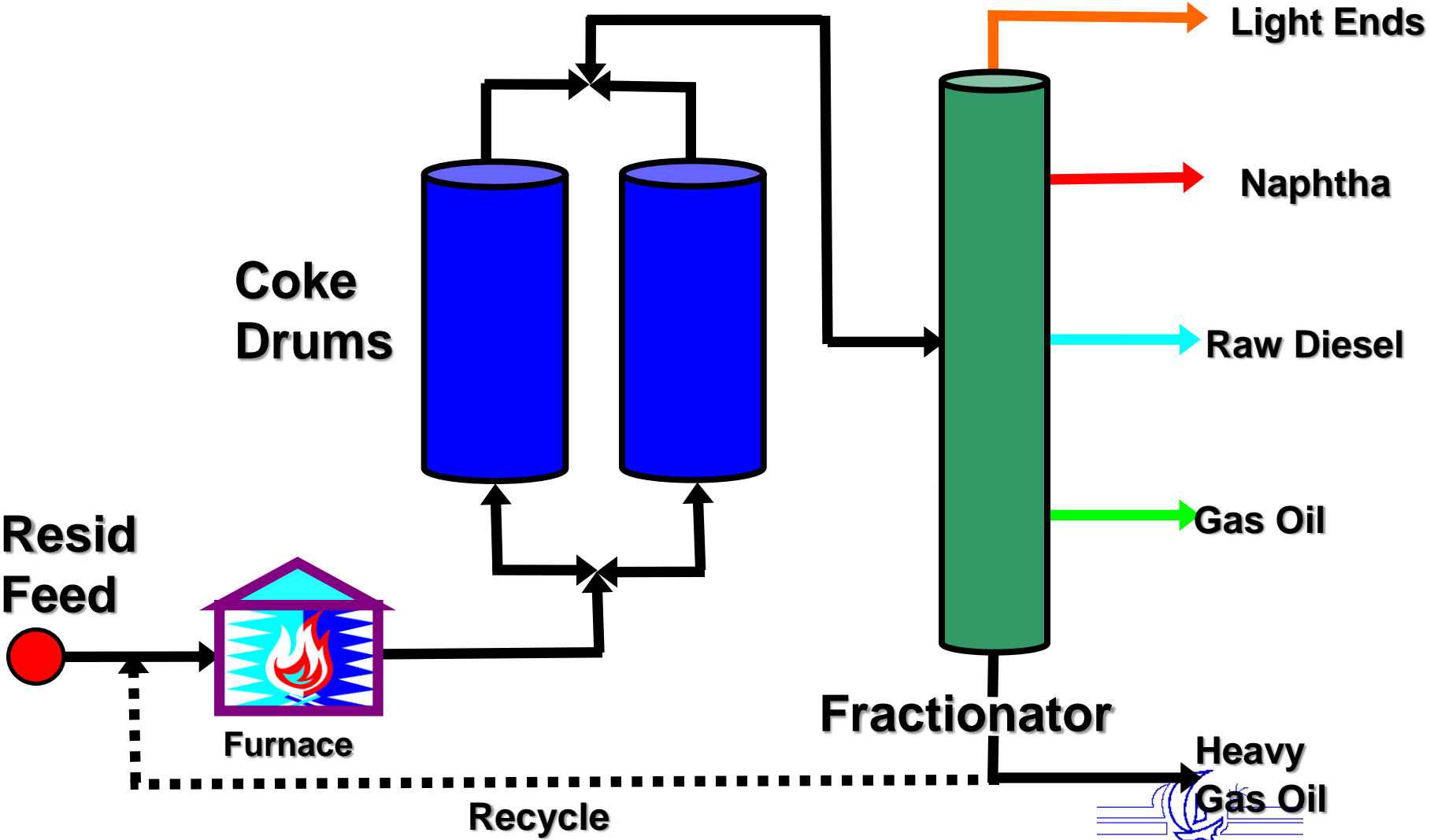
Delayed Coking

- Final Step in Refining Process
 - Heats Vacuum Still Bottoms to thermal cracking temperature, above 750 deg F to remove last possible Hydrocarbons, which go to Hydrotreater and cracking.
 - Critical Pumps, Including
 - Heater Charge Pump
 - Clear Water Sump Pump
 - Jet Pump
 - Sludge Injection
 - Cooling Water

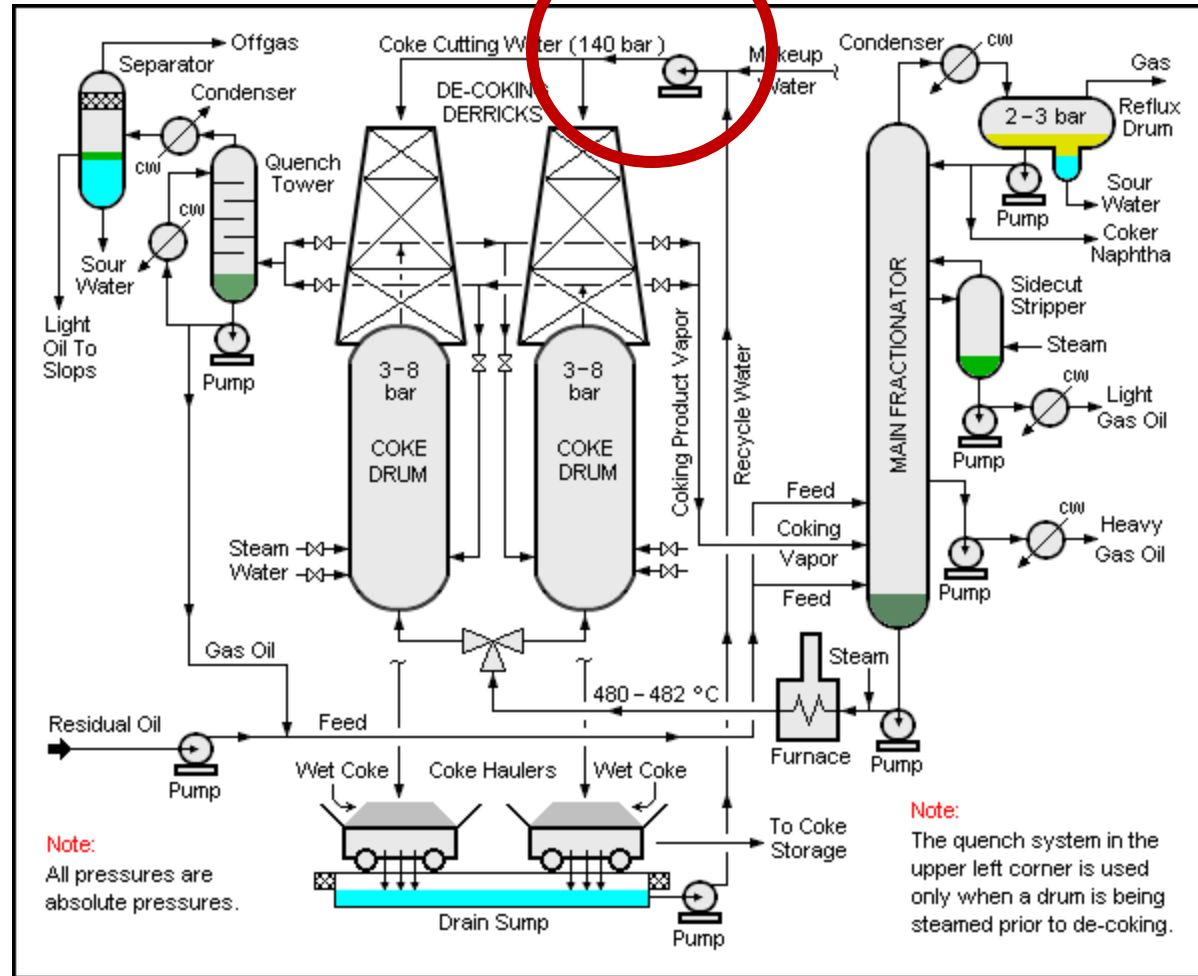
Delayed coker



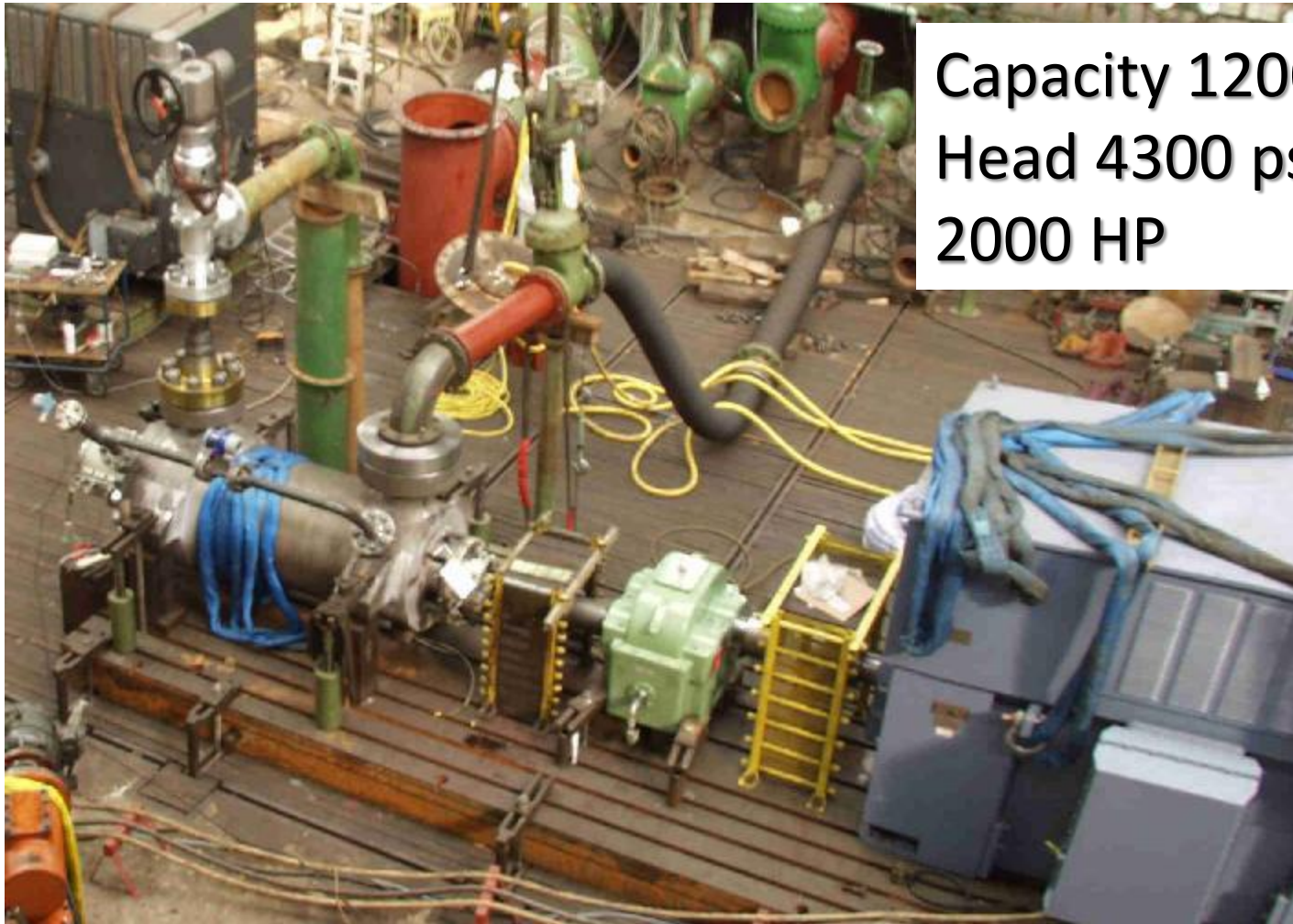
Petroleum Coking Process



Delayed Coking



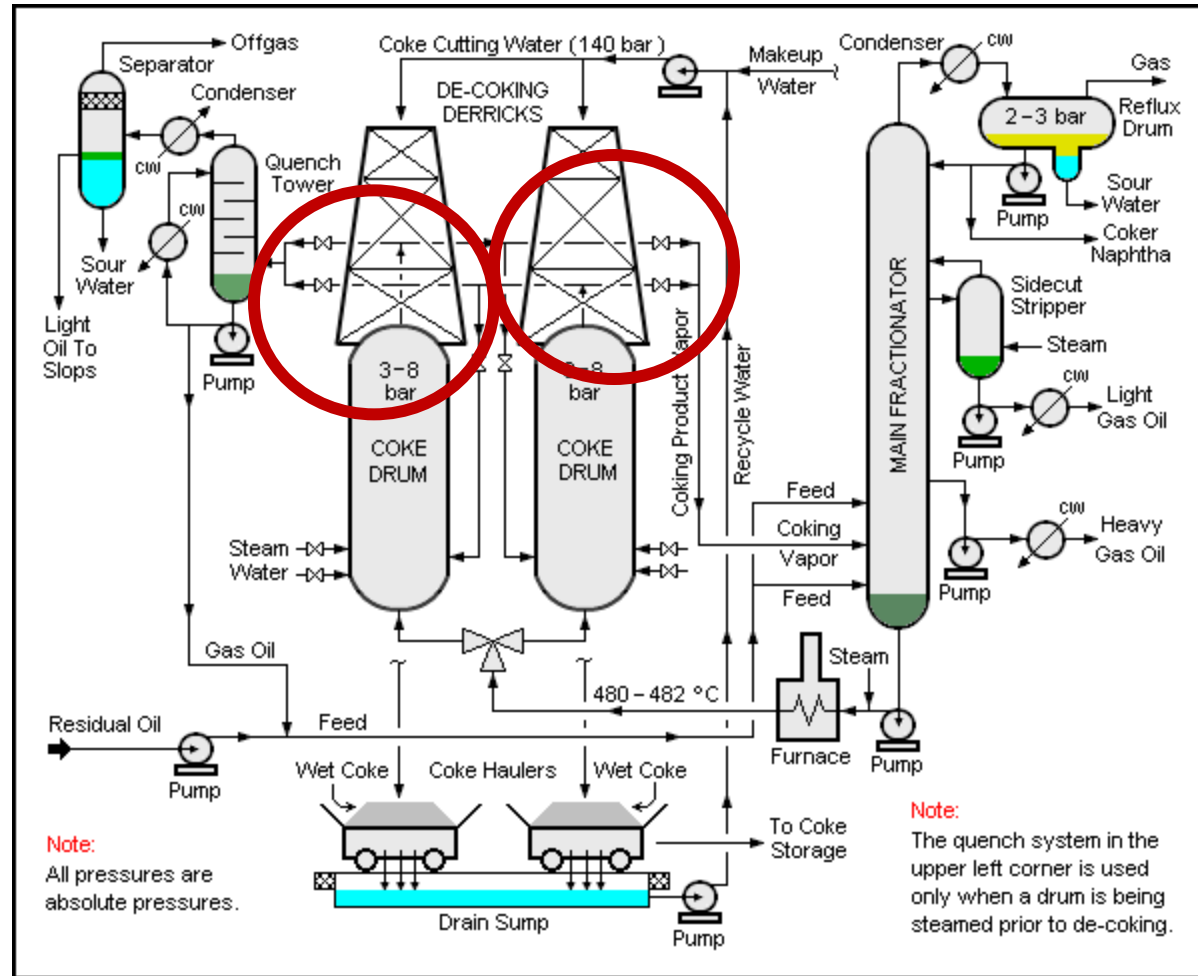
Jet Pump



Capacity 1200 gpm
Head 4300 psig
2000 HP



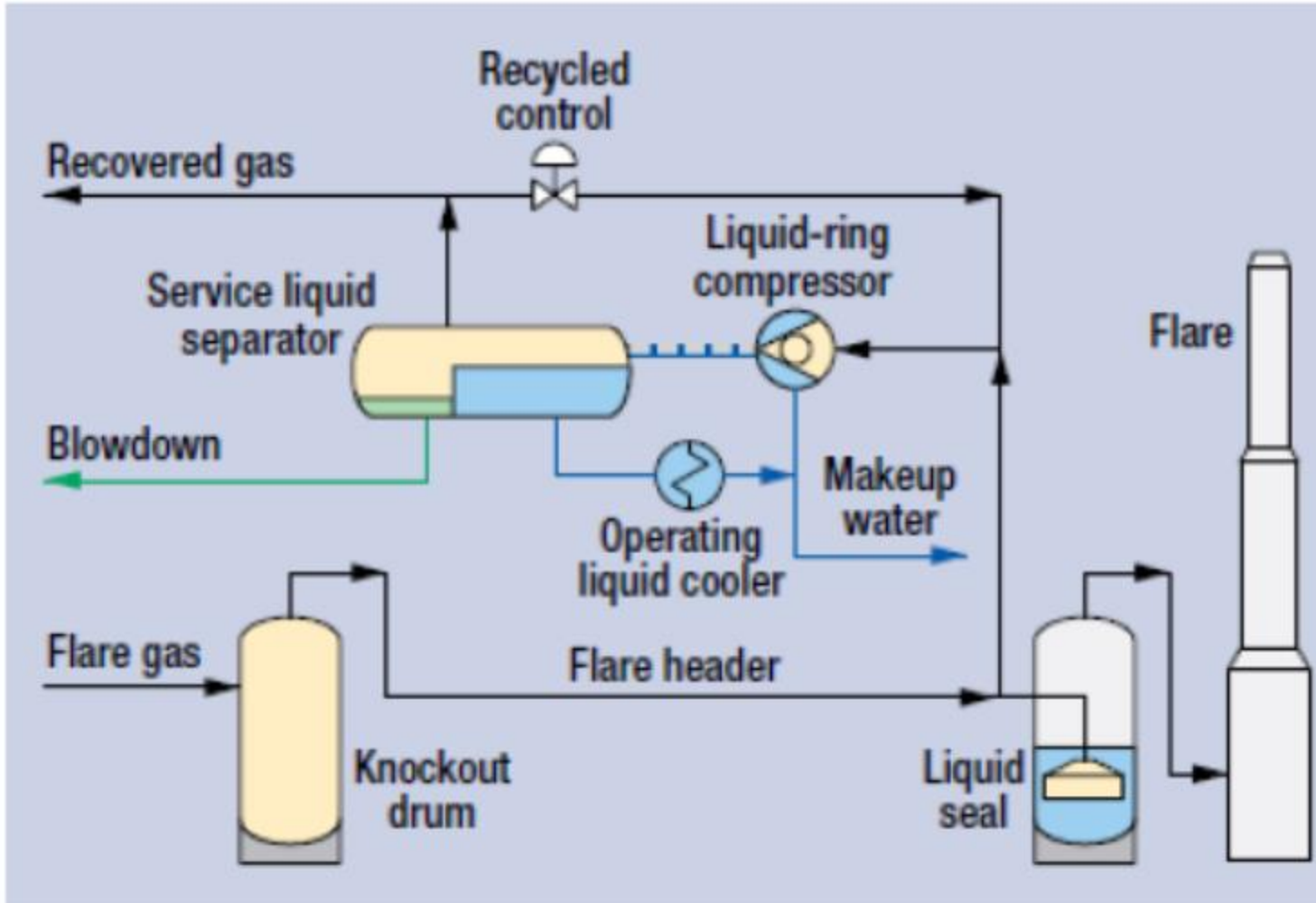
Delayed Coking



Cutting Tool



Flare Gas Recovery Unit



Liquid Ring Compressor

Engineered Compressor Systems



Other Critical Processes

- Lube Plant
- LNG Terminals & LNG Process Plants
- Cryogenic NGL (Natural Gas Liquids) Plants
 - Aromatics Benzene removal
 - Deasphalter
- Olefins Plants, Ethylene cracker
- Wax Plant
- Boiler House
- Waste Treatment Facility

The End



Refinery 101

by Doug Kriebel, P.E.

Kriebel Engineered Equipment, Ltd.

