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HNC Process Operations
Engineering Year 2

Operation of Processes

Process Engineering Practice PCPO4007

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Task 1

Introduction

Pumps are a fundamental part of the refinery operation as they are responsible for moving liquid materials from one place to another. More precisely a device that increases the liquid pressure in order for the liquid to flow, liquid leaving the pump must be of higher pressure than when it entered the pump. Approximately 80-90% of the pumps are centrifugal pumps, which increases the velocity which therefore creates an increase in pressure and transfers large amounts of liquid product to its desired point.

Theory & Principle of Operation

A centrifugal pump converts mechanical energy to kinetic energy which is the energy the liquid retains due to motion. The transfer of energy is achieved by accelerating the liquid to the outer rim of an impeller, the amount of energy given to the liquid corresponds to the velocity at the edge of the impeller. The faster the impeller turns or the bigger it is the greater the energy imparted to the liquid. Kinetic energy of the liquid coming from the impeller is created due to a resistance to the flow. The resistance is created by the pump volute, which slows the liquid down, when slowed down inside the pump casing some kinetic energy is converted into pressure. The pump creates the flow not the pressure increase, the measurement of pressure is the resistance to the pump's flow. The second type of resistance to flow is the fluid's viscosity, the degree to which a fluid can resist flow under an applied force. For example, gasoline has a low resistance flow due to the viscosity of the liquid traveling through the pump.

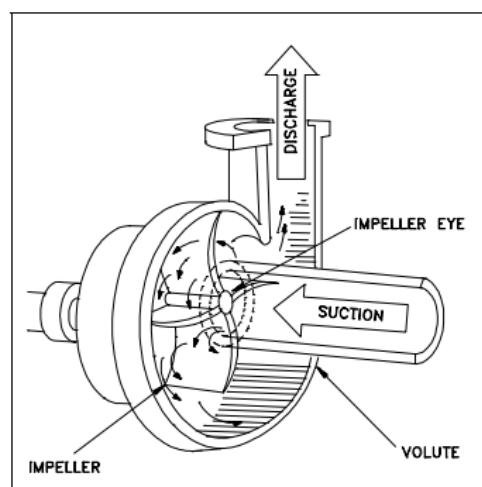


Figure 1 – Centrifugal Pump

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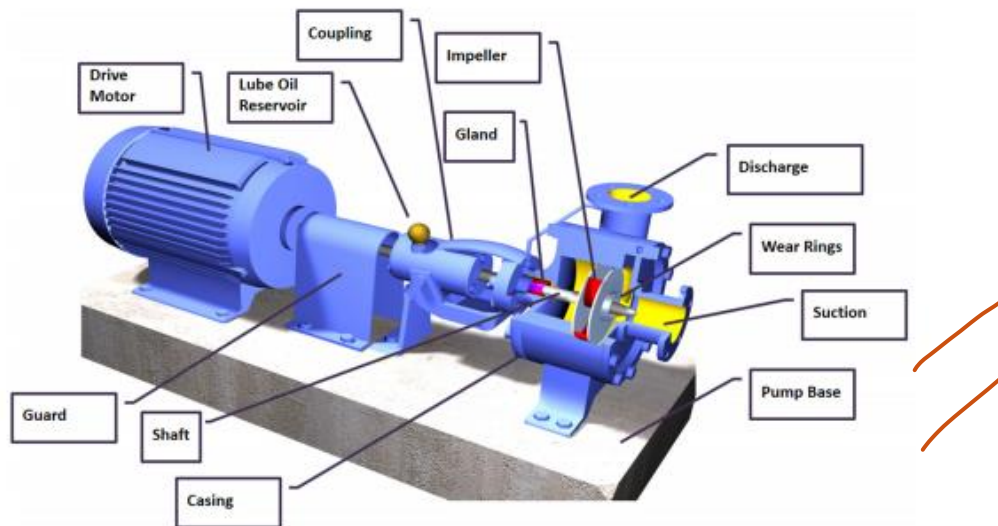


Figure 2 – Centrifugal Pump Components

- Suction Line – Flow enters into the centre of the impeller through the suction line.
- Discharge Line – Liquid exits at a higher pressure.
- Impeller- Scoops a volume of liquid with the suction eye blades and increased the velocity.
- Shaft – The impeller is attached to one end of the shaft and the other end is connected to the coupling.
- Coupling- Connects the pump shaft to the driver.
- Driver – Electric motor or steam turbine.
- Seals- Ensures product does not exit the pump case.
- Bearings- Used to maintain the rotor position.
- Bearing Housing – Holds lubrication and supports the bearings.

Condition Failure

Indication of failure could be identified when carrying out area checks on the process unit, sensory checks can be used to establish deterioration of process equipment. Frequently, monitoring the equipment helps the operator to notice a change in its performance and therefore reporting any findings to maintenance could prevent complete failure. For example, vibration and temperature checks on pumps can indicate abnormal running, further checks such as checking lubricate levels and the condition of the pump seals can also help when

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trying to identify a flaw. From an outside operator's perspective sensory checks are vitally important to indicate abnormal conditions, the variables being monitored such as constant flow, temperature and pressure are predicted off instrumentation, which may not always indicate an issue with the pump.

Like pump cavitation, the damage that occurs when vapour bubbles are present in the centre eye of the impeller as shown below. Common causes of cavitation can be issues with a blocked suction strainer, low liquid level in the column or a change in the vapour pressure of the liquid. Cavitation is identified through fluctuation of either suction or discharge pressure, the pump becomes extremely noisy.



Figure 3 – Cavitated Pump Impeller

Health and Safety Risk

The plant operator's duty is to report any abnormal findings on their routine checks of the process unit. Each process unit has its own specific procedure which states the checks that need to be carried out three times a shift to help identify potential failing equipment. Below in figure 4 is a work request stating findings of a potential failure that was picked up on a unit walk around. The work request is a detailed description to what was found, a pump was found to be leaking from the outboard bearing seal causing a small puddle of oil to gather around the pump. The work request entered into the 'Operation Excellence System' alerts maintenance that there is a problem, and it needs to be assessed to prevent complete failure. As much detail should be included, the P&ID below was also attached to help assist maintenance with their enquires into what the problem could be. Informing and updating the unit log notifies every one of the problems and to be aware.

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Work Request

Work Request #: 889169
Status: Fix it Myself
Notification #: 14768771

Created By: Reynolds, Imogen
Reported By: Reynolds, Imogen
Changed By: Vickery, Alan
Changed On: 03/31/2020 12:08 PM
Expand All Collapse All

Short Description: Lube oil leak on 7-P-341S
Detailed Description:
7-P-341S lube oil skid pump for 7-C-301. Leak found on outboard bearing seal of pump. Oil level in Denco bottle dropping quite a lot due to this there is also a small pool of oil around the pump.

Asset Information
Plant: PL25 - Pembroke
Functional Location:
PL25-01-0607-17-7P341S
7P341S, Lube Oil Pump For 7CM301
Planner Group: ME

Equipment:
10925355
7P341S, Pump (Lube Oil) - Lube Oil
Main Work Center: MF

Figure 4 – OES Work Request

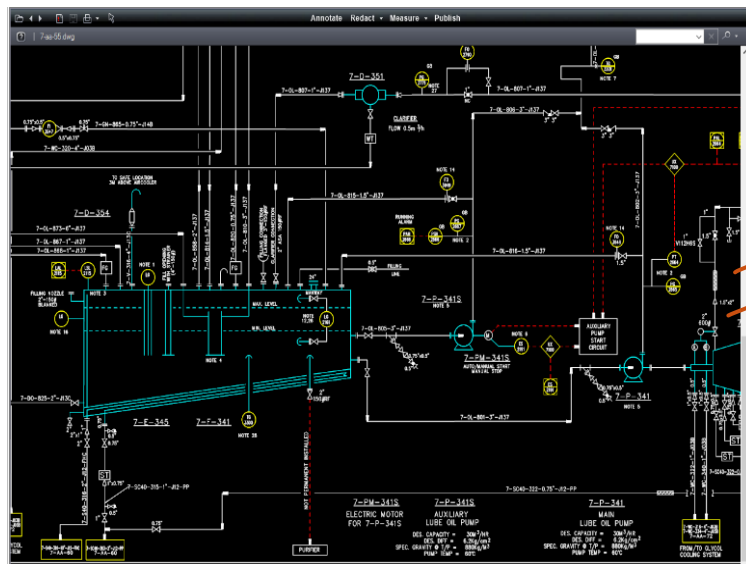


Figure 5- P&ID of Lube Oil System.

The system is there to report findings in order to reduce the risk posed by the hazard. “A good starting point is to walk around your workplace and think about any hazards (things that may cause harm).” (HSE, 2021). Following HSE practices and company policy to ensure findings are reported.

Measures in place to prevent, control or mitigate accidents involving pump failures (HSE, 2021):

Prevention

- Operation Procedures
- Design Codes

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Control

- Inspection
- Alarms
- Trips
- Training

Mitigation

- Response
- Isolation
- Plant layout
- PPE
- Contamination

Task 2

A refinery includes a number of different processing units which all help with converting imported crude oil into finished petroleum products. Processing units can be categorised like so:

- Conversion Units
- Treating Units
- Non-hydrocarbon processing unit
- Separation Units.

Crude oil contains 84% carbon, 14% hydrogen, 3% sulphur and less than 1% nitrogen. Below in figure 6 shows the three types of imported crude oil for petroleum refineries.

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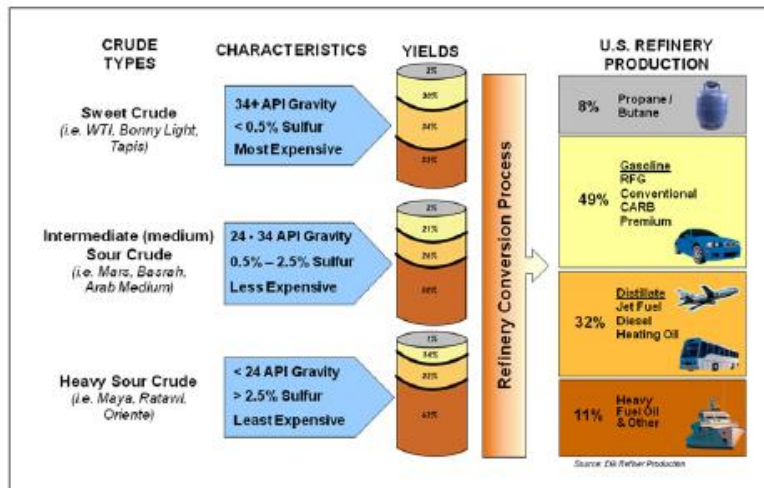


Figure 6 – Crude Oil Types.

At Pembroke Refinery the three complex areas deal with importing and exporting of products 24/7. Within the complex areas processes happen to convert the products into the desired goods that the company therefore want to produce.

The Refining complex:

No need to highlight

Crude Distillation Unit –

Imported crude oil is sent to the crude distillation unit (CDU) and fed into the crude distillation column, where it is split into its distillate fractions. This is the first step in the refining process. These main fractions are obtained by heating the column to specific boiling point ranges, where the crude separates in terms of its decreasing volatility into gases, light distillates, middle distillates, gas oils, and residuum.

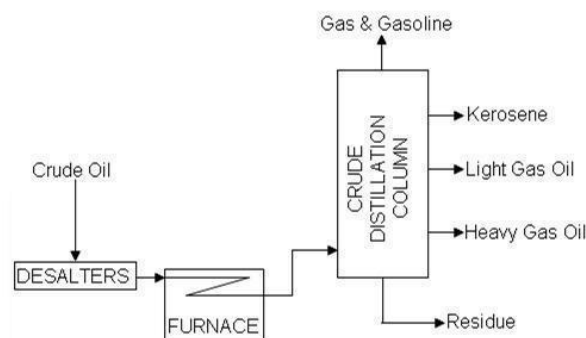


Figure 7 – Basic PFD of CDU

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Vacuum Distillation Unit-

Distillation of the reduced crude from the CDU occurs under a vacuum so that the column can operate at a lower temperature and avoid thermal cracking. The VDU is designed to remove gas oil fractions from a reduced crude feedstock to provide a low carbon and low metal content feedstock to the fluid catalytic cracking unit (FCCU).

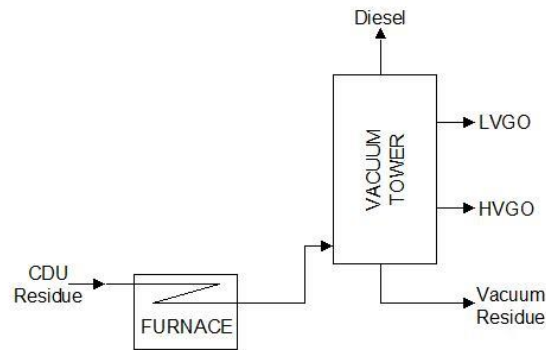


Figure 8 – Basic PFD of VDU

Viscosity Breaker Unit-

The complex compounds of vacuum residue from the VDU are broken down to recover lighter products using thermal cracking.

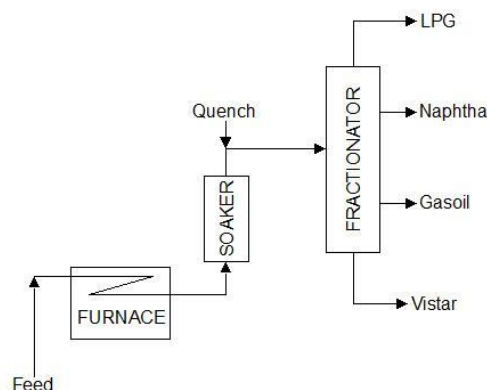


Figure 9 – Basic PFD of VBU

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Utilities-

Services provided by the Utilities section are:

- Fuel Gas for the sites fired heaters
- Steam - HP, MP & LP steam
- Nitrogen
- Instrument Air
- Potable Water
- Utility Air
- Utility Water
- Fire Water

Unifiner-

Naphtha feed from the CDU, FCCU and VBU mixes with the hydrogen from the platformer and removes sulphur and nitrogen to avoid downstream catalyst poisoning, by hydrodesulphurisation.

Catalytic Reformer with Continuous Catalytic Regeneration-

Heavy naphtha, which is mainly paraffin's and cyclic naphthenes is fed from the unifiner to the platformer. The purpose of the platformer is to increase the octane rating.

Hydrotreater Units-

The Hydrotreater Unit is designed to remove impurities from Kerosene, Diesel, Light Cycle Gas Oil (LCGO), Heavy heavy cracked naphtha (H.H.C.N.), CDHDS, Hot well slop oil and Vis breaker gas oil. Impurities such as sulphur, nitrogen, chlorine, oxygen and trace metals are removed to process products which meet required environmentally friendly standards.

Naphtha Isomerisation Unit-

The objective of the Isomerisation Unit is to process 70 m³/hr light Naphtha from the Unifiner. Converting their respective isomer, and then separates these isomers into the isomerase product. This boosts the octane number of the light naphtha from around 72 to 85. These provide an improved feed stock for gasoline production.

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LPG Recovery Unit-

The LPGRU takes gaseous light hydrocarbons streams from several distillates process units, and separates out the propane and butane by cooling and compression. The unit takes two feeds, HP and LP.

Hydrogen Recovery Unit-

Its purpose is to recover hydrogen from platformer LPG offgas and liquid petroleum gas recovery unit (LPGRU) tail gas, which contain 70-80 mol% hydrogen. Its intention is to recover 99 % pure hydrogen using a pressure swing adsorption system.

Cracker and Olefins Complex:

Alkylation Unit –

The process is one in which olefins are combined with isobutane in the presence of HF acid catalyst to yield a product in the gasoline boiling range called Alkylate.

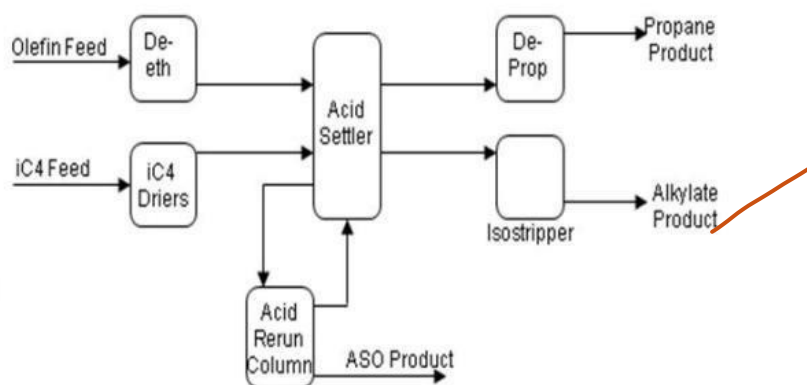


Figure 10 – Basic PFD of Alkylation Unit

Amine Recovery and Sulphur Recovery Unit-

Hydrogen Sulphide (H_2S) gas is produced in a number of units throughout the refinery and must be removed. This is done by absorbing the gas in solution of diethanolamine.

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Butamer Unit –

The purpose of the butamer unit is to make isobutane which is used as feed to the alkylation unit.

Fluid Catalytic Cracking Unit –

Vacuum gasoil from the VDU and atmospheric residue from the CDU is cracked into lighter, more valuable.

Ultra Low Sulphur Gasoline –

The function of the ULSG Unit is to reduce the sulphur content of the following naphtha streams as produced by the FCCU while minimising the amount of olefin saturation.

Blending and Shipping Complex:

All crude oil and various feed stocks are imported by sea via this marine terminal, via a complicated maze of pipelines into the Tank Farm area of Blending & Shipping. There are 141 tanks, incorporating different designs.

- 92% of all imports and exports pass over the jetty and are handled in the Blending and Shipping Tank Farm.
- 6% is pumped out via the Mainline system which connects us to terminals across the country.
- 2% is taken by Road Tankers to supply garages, home heating, farms and industry across Wales.

Catalytic Reformer with Continuous Catalytic Regeneration Processes-

Gasoline fractions produced directly from the crude distillation unit do not meet the octane number requirements for gasoline you put in your car. Because of this, refineries have two processes that result in upgrading the naphtha octane number:

Catalytic Reforming

- fixed-bed catalyst reforming
- continuous catalyst reforming

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The fixed catalyst bed method is similar to isomerisation with the exception that three reactors are used instead of one. This allows the naphtha to be passed through a heater to reheat it to reaction temperature between each reactor.

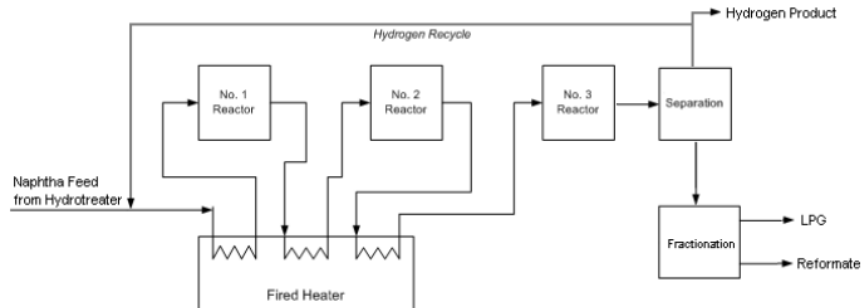


Figure 11- Fixed Bed Catalytic Reforming

The second method of catalytic reforming is to continually circulate the catalyst through the system. The flow and equipment type are identical to fixed bed catalytic reforming, with the addition of a catalyst regeneration section.

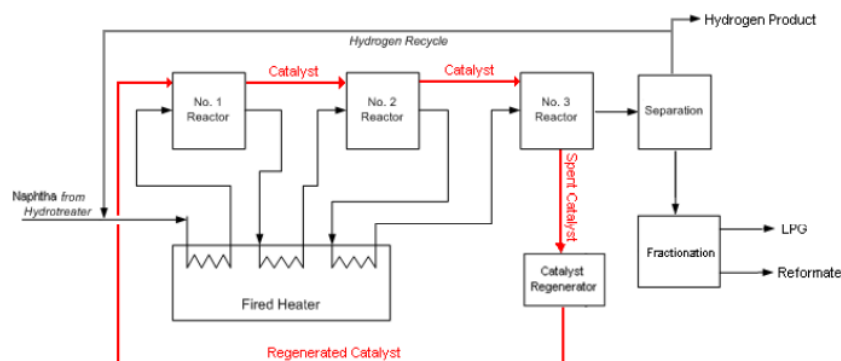


Figure 12- Continuous Catalytic Reforming

During a normal operating cycle, Platformer catalyst becomes deactivated due to coke build up. The coke reduces the active surface area of the catalyst and prevents the chemical reactions taking place. By continuously regenerating the catalyst the deactivation effect is kept under control.

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Catalyst regeneration takes place in four operations:

- 1 Regeneration: burning off the coke
- 2 Chlorination: re-chlorinating the catalyst and oxidising the metal promoters (i.e. platinum)
- 3 Drying: removing moisture from the catalyst
- 4 Reduction: reducing the metal promoters to offset the oxidation process that took place in the regenerator.

The basics of a CRU is a reforming unit that consists of the following sections:

- Reaction
- Separation
- Stabilization
- Regeneration

The process uses three reactors which allows the naphtha product to be passed through a heater to reheat it to the reaction temperature between each reactor.

After the last reactor, the hydrogen gas byproduct is separated from the liquid reformat in the high pressure separator. A portion of the hydrogen is recycled back to the first reactor and the reformat is sent to the fractionation tower. In the fractionator, the light gases that formed in the high temperatures of the reactors are separated from the reformat by distillation.

Products of Catalytic Reforming

- Hydrogen that is sent to other processes requiring hydrogen, such as hydrotreating and hydrocracking.
- LPG sent to the gas plant.
- Reformate sent to gasoline blending.

The heavy naphtha feed from the Unifiner is composed of three main component ranges:

- Paraffin's - straight chain saturated hydrocarbon molecule
- Naphthenes - saturated ring type molecule

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- Aromatics - unsaturated ring type molecule

Aromatics present in the heavy naphtha feed are higher in octane number than the other components. They are generally unaffected by the process and pass through the unit without change.

The catalyst used in the reformer unit at Pembroke is composed of an alumina base, a metallic compound (platinum) and a halogen (chlorine). They are called bi-functional, since they promote catalytic reactions through a metal and an acidic function. The four main reactions that take place in the reactors are:

- Dehydrogenation: the breaking off of hydrogen atoms from the saturated naphthenes to form an unsaturated aromatic. Naphthenes are a very desirable feed component because of the ease with which this reaction takes place and the resultant increase in octane number.

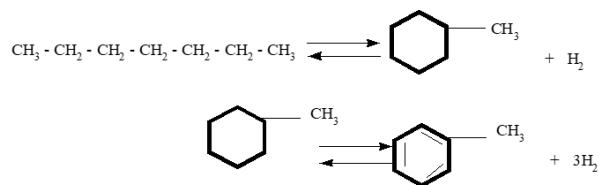


Figure 13- Dehydrogenation

- Isomerisation, the rearranging of the molecular shape of the hydrocarbon without changing its molecular formula – branching increases octane.

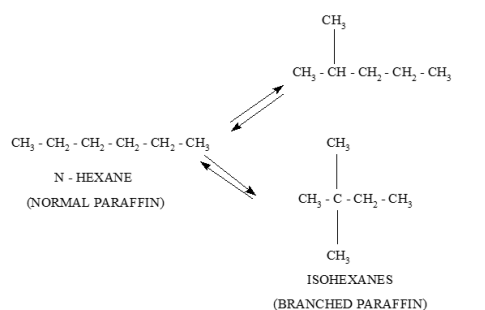


Figure 14- Isomerisation

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- Hydrocracking, the breaking up of large paraffinic molecules into smaller ones. The smaller molecules usually have a higher octane number. Cracking reactions form the precursors for coke.

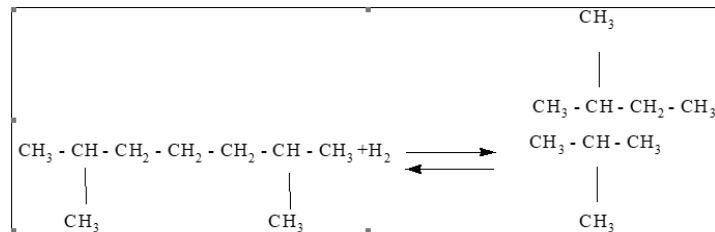


Figure 15- Hydrocracking

- Dehydrocyclisation, a two stage reaction. In the first stage, the straight chain paraffin is changed into a ring chain naphthene (this reaction is called cyclisation) the second reaction changes the unsaturated naphthene into a saturated aromatic. These reactions are very desirable because of the huge increase in octane number attained; however, they are more difficult for the catalyst to perform.

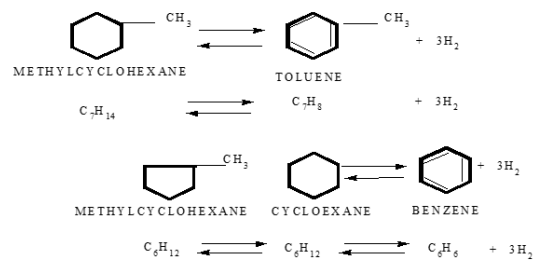


Figure 16- Dehydrocyclisation

The challenge of reforming is to maximise the desirable reactions, especially dehydrocyclisation, whilst minimising the cracking which reduces yield and makes more coke.

Below in figure 17 is a PFD of the reactor section of the Catalytic Reformer with Continuous Catalytic Regeneration at Pembroke Refinery, figure 18 explains the important and purpose of the main equipment within the reactor section.

Operation of Processes

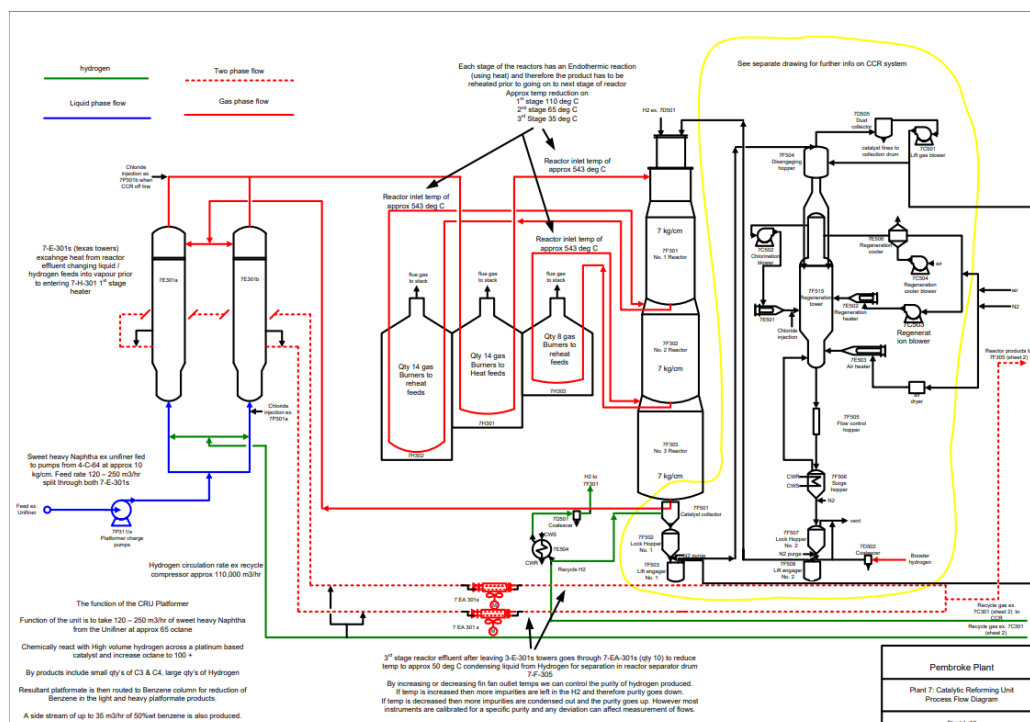


Figure 17- PFD of Reactor Section

Equipment No.	Description	Purpose
Feed Section		
7-P-311/s	Charge Pump	Platformer charge pump feeding the naphtha to reactors
7-E-301a/b	Heat Exchanger (Texas Towers)	Vertical mounted, single pass shell and tube heat exchangers arranged in parallel. Combined heavy naphtha feed and hydrogen rich recycle gas is fed tube-side and the shell is the product from the 3 rd stage reactor.
Reactor Section		
7-H-301/302/303	Fired Heater	Supply heat to the reactor feed. The reaction that takes place is endothermic and after each reactor stage, requires re-heating. The reactor requires an inlet temperature of 543°C.
7-F-301/302/303	Reactors	This is where the reaction occurs with the catalyst to reform the paraffinic and naphthenic feed into aromatics. The reactors are stacked on top of one another, allowing the downward flow of catalyst. As the reactions are endothermic, at each stage, more heat is required. Approximately a reduction of 110°C at the first stage, 65°C at the second stage and 35°C at the third stage.
7-EA-301/s	Fin fan condensers	The third stage reactor effluent leaves the shell side of the 7-E-301a/b and goes through the fin fans to reduce the temperature to approximately 50°C. This allows the liquid to condense from the hydrogen for separation.
7-F-305	Reactor Products Separator	The cooled reactor stream separates into condensed liquid hydrocarbon product and hydrogen-rich gas. The hydrogen gas mainly enters the compressor suction drum 7-F-306. The condensed hydrocarbon liquid is pumped by 7-P-303/s to increase its pressure from 7kg/cm ² to 42kg/cm ² for recontacting with the 2 nd stage hydrogen to extract residual LPG.
7-C-301	Recycle Gas Compressor	After exiting the compressor suction knockout drum, approximately 110,000m ³ /hr recycled by the compressor at approximately 7kg/cm ² for use in the CCR and reactor circuit.

Figure 18- Description of CRU equipment at Pembroke Refinery

Table of Figures

Figure Number	Source
1	Fundamentals of Pumps - https://d6s74no67skb0.cloudfront.net/course-material/ME910-Fundamentals-of-pumps.pdf
2	Centrifugal Pump – CENTRIFUGAL-PUMP.jpg (924×587) (mectips.com)
3	Cavitated Pump Impeller - caviated pump impeller - Bing images
4	OES Work Request - Valero Intranet
5	P&ID of Lube Oil System - Valero Intranet
6	Crude Oil Types - Crude Oil Types. - Bing images
7	Basic PFD of CDU - Basic PFD of crude unit - Bing images
8	Basic PFD of VDU - Basic PFD of VDU - Bing images
9	Basic PFD of VBU - Basic PFD of vbu - Bing images
10	Basic PFD of Alkylation Unit- Basic PFD of alkylation unit - Bing images
11	Fixed Bed Catalytic Reforming – CRU manual
12	Continuous Catalytic Reforming – CRU manual
13	Dehydrogenation - Dehydrogenation chemical formulas - Bing images
14	Isomerisation - isomerization chemical formulas - Bing images
15	Hydrocracking- Hydrocracking chemical formula - Bing images
16	Dehydrocyclisation- Dehydrocyclisation - Bing images
17	PFD of Reactor Section – CRU training manual
18	Description of CRU equipment at Pembroke Refinery – Excel

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