

HNC Process Operations Engineering Year 2

2020 - 2021

PROCESS ENGINEERING PRACTICE ASS. 2

SAMUEL LEWIS

Table of Contents

Task 1.....	2
Introduction.....	2
Theory	2
Combustion theory.....	3
Operation	4
Failure Conditions	4
Health & Safety Risk	5
Task 2.....	7
Pre-Heat & Desalters	7
Flashed Crude System	8
Distillation Column.....	8
Naphtha System	10
Kerosene System	11
Diesel Systems.....	12
Reduced Crude System.....	13
Table of Figures	15
Bibliography.....	16

Task 1

Introduction

Refineries separate crude oil into more valuable components. To do this a great deal of energy is required, which is supplied as thermal energy. As no other method of heat transfer can supply this large need for energy, fired heaters are the chosen method. This thermal energy is used to heat the process before it can enter a distillation column, where the constituents are separated.

Theory

Fired heaters are indirect fired equipment, as the products of combustion are prevented from encountering the process contained within the pipework.

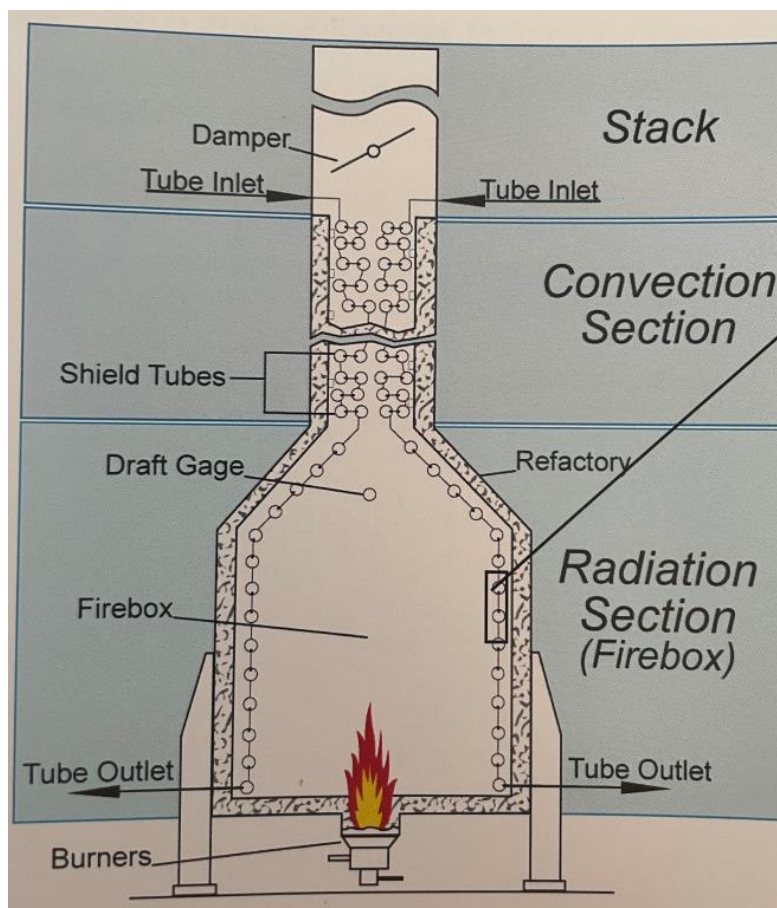


Figure 1 - Illustrated Diagram of Typical Fired Heater

At the base of the heater is the burner, where the fuel and air are introduced to the heater to maintain combustion. This section is known as the radiant section, or firebox. In the firebox the burner flame is visible as well as the radiant pipework and pass outlets. Above is

the convection section, where the convection tubes and shield tube layers are housed as well as the pass inlets. Finally, above this is the stack and damper.

Feed entering the heater is split into parallel flow paths known as passes, from here control valves are used to conduct the flow. Passes enter the heater at the top of the convection section and proceed down the heater in a side to side motion. The convection sees hot air produced from combustion rise through the heater and contact the outside wall of the pass, where heat transfer takes place. The process is heated and the combustion air is cooled. The shield section sits between the two sections of the heater and the tubes here act as a shield from the direct radiation of combustion to the remainder of the convection section. Continuing down the heater, the radiant section, heats tubes by the direct radiation produced from combustion. The process exits the heater via the pass outlets.

The combustion products passed through the convection section, then enter the stack and are vented to atmosphere. The stack damper controls draft, which is the pressure differential between the outside air and the flue gas. Draft is required to discharge the combustion products from the heater to allow the combustion gases to be drawn into the heater.

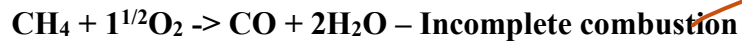
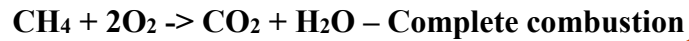
Combustion theory

To obtain combustion all 3 elements of the fire triangle must be present.



Figure 2 - Fire Triangle

Heat is supplied by a pilot flame, which is kept alight. Once the main burner is lit, the heat from the main burner will then be sufficient to support its own combustion needs. Fuel is supplied in the form of fuel gas, a mixture of carbon, hydrogen and trace levels of sulphur and is fed into the burner where it is ignited. Finally, oxygen is supplied to the burner via an air register. Oxygen is required to ensure complete combustion, whereas incomplete combustion takes place when there is insufficient oxygen.



Complete combustion is shown to burn the hydrocarbon and air to produce CO_2 and water, while incomplete combustion shows the reactions to have insufficient air and therefore produce carbon monoxide rather than carbon dioxide, which creates thick smoke and can also cause environmental impacts.

Operation

When operating fired heaters, strict procedures should be followed to ensure safety. When firing, first carry out visual checks to ensure all is acceptable, checking the tubes for damage and ensuring the pilots are lit. The selected burner should then have its fuel gas supply slowly admitted, whilst visually checking the burner to ensure it ignites. Once a main burner flame is present the main air register should be opened slowly to ensure that the flame is not blown out, this should be done until the orange flame turns blue. If an ignition fails, the fuel gas should be isolated, and the firebox purged of combustibles before a second attempt.

When taking a burner out, the burners must be shut down in a staggered pattern ensuring equal heat distribution through the heater, tube circulation should also be maintained to allow heat transfer from the tubes. The fuel gas supply should be slowly isolated at the burner, once the flame is out the forced air can be used to purge and cool the firebox.

In the event of a heater trip, the fuel gas must be isolated to prevent the firebox filling with combustibles and the heater should then be purged for 2 minutes using the forced air to ensure the equipment is safe to approach. Once safe, the burner fuel gas valves local to the heater should all be isolated.

In the event of a major accident, such as a tube rupture, the heater should be brought offline safely and quickly. The emergency shutdown should be activated, and snuffing steam admitted into the firebox to snuff out any flames and disperse any combustibles. Tube side to the heater should then be isolated, de-pressured and purged, while also stopping all draft fans and shutting the stack damper.

Failure Conditions

When there is insufficient oxygen for combustion the flame will elongate and “hunt” for oxygen. As the flame becomes longer it can impinge the tubes. This will cause the skin temperature of the tubes to rise and potentially create hotspots as they are exposed for a

prolonged time. Unattended, this will fatigue the material and rupture, meaning the flammable process material is now exposed to the open flame.

Hot spots can also be caused by lack of pass flow. This is because the process travelling inside the tubes remove the heat from the skin of the tube. Therefore, if pass flow is low there will be less heat being removed from the tube skin. This will in turn raise the temperature of the tube and cause hotspots.

Finally, carry over can create failure conditions within a fired heater as sedimentation and liquid can create blockages within the passes restricting flow. Also, water carryover into the passes can lead to tube failure as the large expansion rate of water to steam will create a massive rise in pressure as the water evaporates. This can create shock and rupture the tubes.

Health & Safety Risk

When monitoring fired heaters, it is an operator's duty to detect and report any abnormal findings which could lead to faults such as a tube rupture, which potentially could escalate into a hazard, such as a fire. This duty is stated in the procedure for a crude unit operator, which is used throughout Valero's worldwide refineries and ensures safe firing of heaters and reduces risk or near losses and losses.

1.7	Heaters: Check Internal heater condition for the flame pattern, flame colour, debris on the floor, hot spots on the tubes, heater draft and condition of pilots. Rectify any issues.	Plant Op
-----	---	----------

Figure 3 - Subsection 1.7 of Procedure PP-OPS-GUI-0026 (CDU Operator Daily Duties)

While carrying out these duties a hot spot was located on the base of the heater at the intermediate point between two burners. The hot spot was brilliant white in colour, meaning that the temperature for that spot was extremely high. These high temperatures can lead to thermal fatigue and catastrophic failure of the base, thus the flame would be open to the atmosphere as it is no longer contained in the heater and could cause harm to equipment and workers.

This was then reported to the lead operator, who advised and assisted in the swapping of burners away from the hot spot to minimise heat exposure to the afflicted area. The area of heater would then require monitoring over time to ensure there was no deterioration. The finding and the events that followed were logged in the unit turnover to inform following shifts to also monitor the asset and a work request was created in the operations excellence

system to ensure the problem would be looked at by inspection and repaired if needs be by maintenance.

Work Request

Created By: Lewis, Samuel

Reported By: [x]

Find User

*Short Description: 1-F-1 # D Floor Hotspot

*Detailed Description: (750 Characters Maximum)

Upon carrying out routine inspection on the fired heater on the Crude Unit, there was a visible hot spot on the heaters base. The lead op was informed and the burners were swapped to minimise the hotspots exposure to heat. Shiftly monitoring of the situation has been arranged.

Figure 4 - Work Request Entered For Heater Hotspot

By carrying out the identification, treatment, monitoring and reporting of the equipment's condition, we were able to reduce risk and any hazards of keeping the asset online, while adhering to the company's stringent safety standards.

Flashed Crude System

The pressure through the desalters must be maintained to ensure that the water and crude mix effectively and this pressure is maintained up to the pre flash drum. Upon entering, there is a big drop in pressure, which then sees light ends flash off. These gases leave the pre flash drum at the top and are directed through the convection section of the fired heaters and then straight into the distillation column. The crude then exits the flash drum at the bottom and passes through the plenty filter, which removes any large deposits of coke and carbon. The crude is forced through the fired heaters, where the feed travels via passes to be heated to the optimal temperature for the fractions within the crude to be distilled, 360°C.

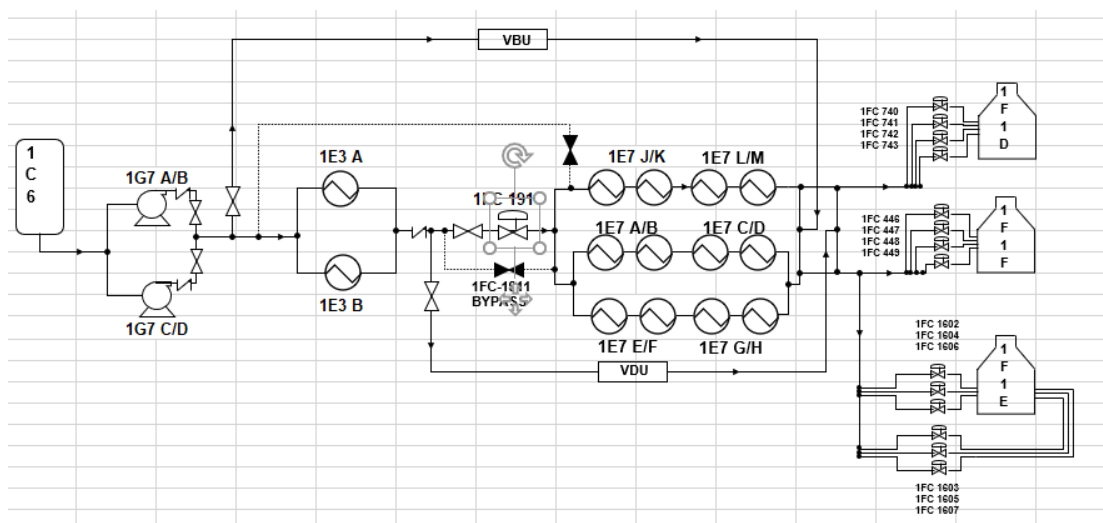


Figure 6 - Process Flow Diagram of Flashed Crude to Heaters

Distillation Column

The column receives the crude feed in the flash zone, where the lighter vapours then rise up the column. The column has over 50 trays with bubble caps and a weir to hold a level at that tray. The lighter vapour is allowed to rise up through the bubble caps and the liquid on that tray, the contact between the vapor and liquid allows for the separation as the vapor is cooled and condenses while any light ends entrained in the liquid are vaporised again and rise up the column. Condensed vapours are drawn off the column, or spill over the weir and travel down the downcomer to the tray below, where they will settle and be drawn off or re-vaporised again.

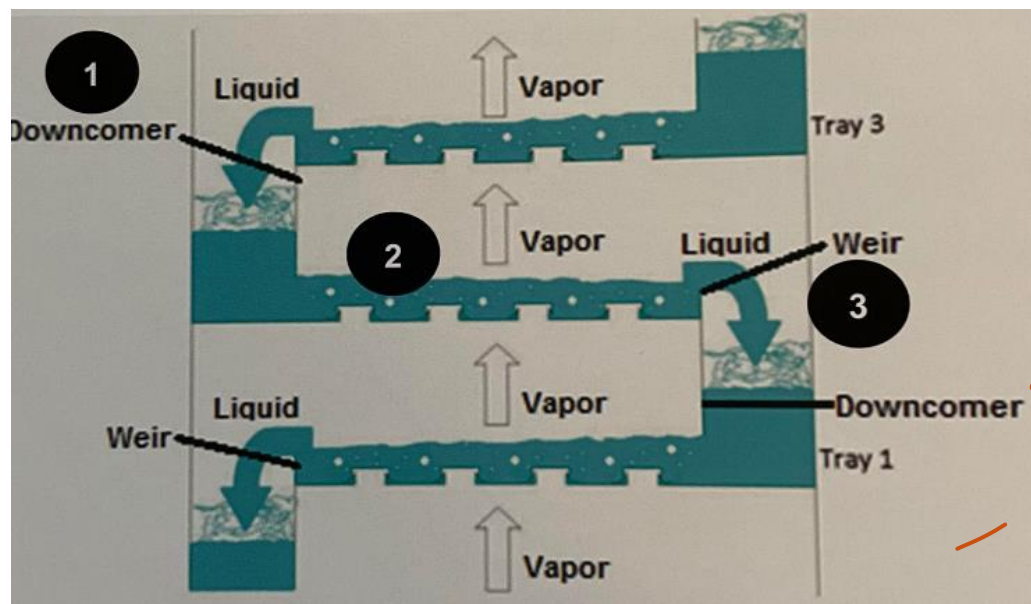


Figure 7 - Working Diagram of Distillation Column Trays

The crude column creates the following products, from lightest to heaviest:

- Un-stabilised naphtha
- Kerosene
- Light Diesel
- Heavy Diesel
- Reduced Crude

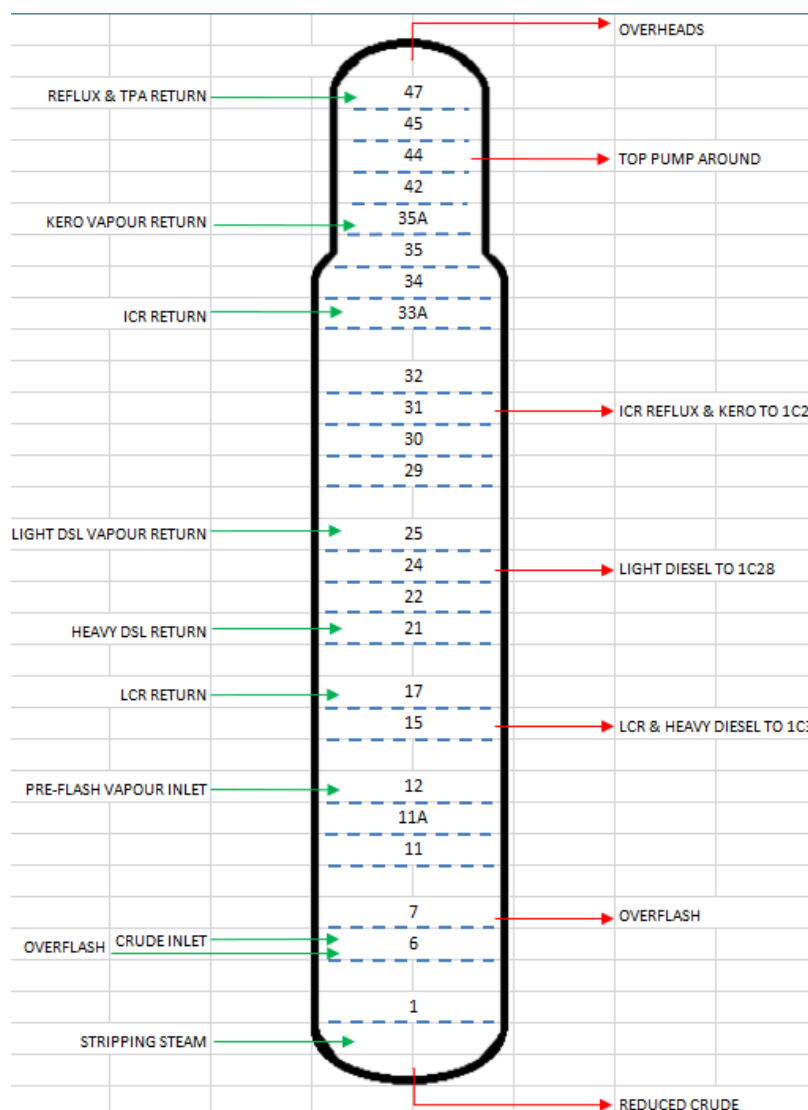


Figure 8 - CDU Distillation Column Diagram

Naphtha System

Naphtha off the top of the column and is cooled in the overhead fin fan bank to condense the vapours before it drops into an overhead accumulator. From here, it can either be used as reflux which is where the product is cooled and put back into the column to control the temperature in that area. Or it can be sent to the stabiliser, which is a smaller distillation column, which separates the LPG (Propane & Butane) from the naphtha. The uncondensed naphtha in the overhead accumulator is sent through compressors to condense it and then also sent to the stabiliser as feed. The LPG comes off the top of the stabiliser and is sent to the tartan unit, where it first goes through an amine scrubber to remove any H_2S then through a depropaniser to separate the butane and propane and send them to storage. The now stabilised naphtha off the bottom of the stabiliser then goes off as hot feed to the unfiner where impurities are removed and treated.

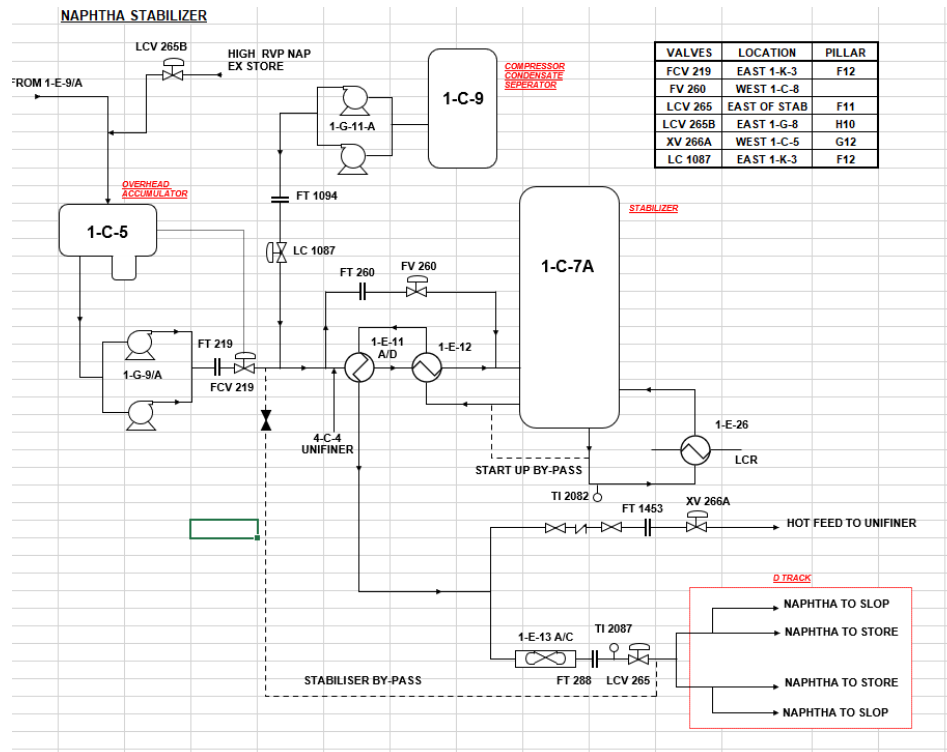


Figure 9 - Process Flow Diagram of Naphtha System

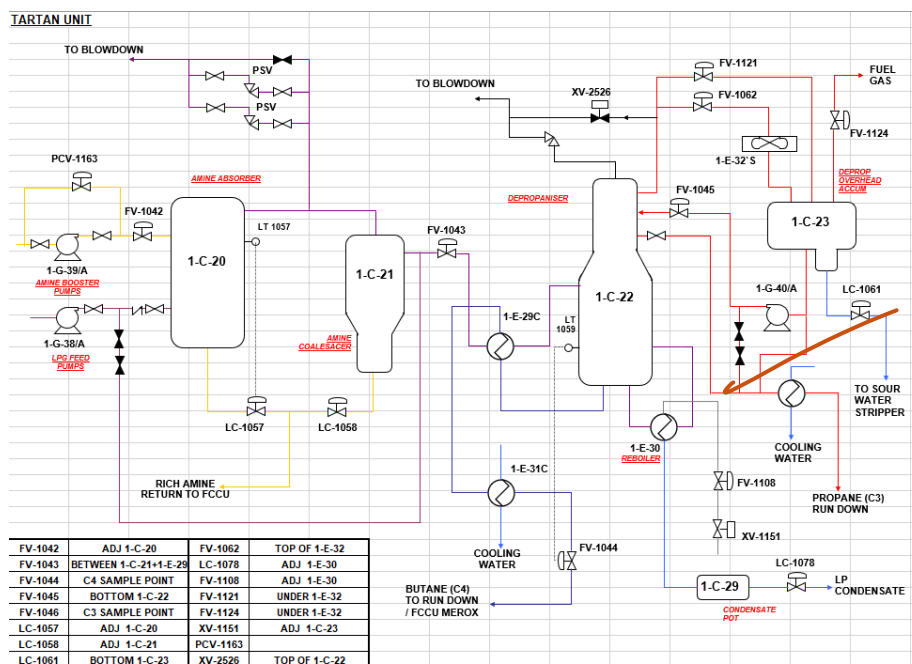


Figure 10 - Process Flow Diagram of Tartan Unit

Kerosene System

Kerosene is drawn off and is also used as reflux to control column temperature. The second path is through a side stripper, which uses steam to strip any light ends entrained in the kero and send them back to the column. The kerosene is then routed to the merox unit,

where caustic is injected along with water into the kerosene to aid in the reaction of mercaptans modified into disulphide oils which are less strong smelling, the kerosene is then washed and filtered.

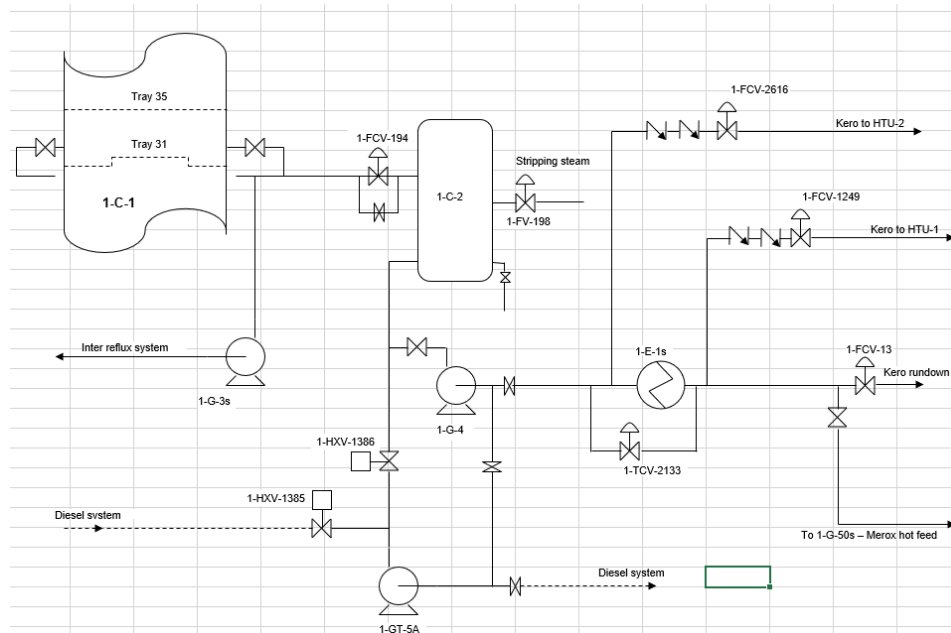


Figure 11 - Process Flow Diagram of Kero System

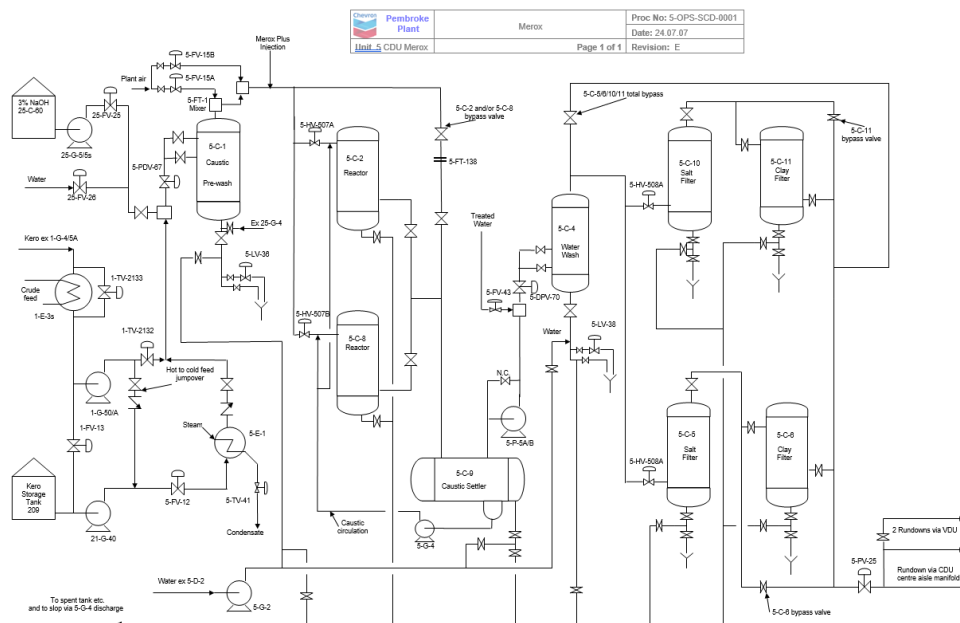


Figure 12 - Process Flow Diagram of Kero Merox Unit

Diesel Systems

Like the kero system both diesels are drawn off and put through a side stripper, while only the heavy diesel is used as reflux. The diesel can either be routed to the hydrotreaters to

remove impurities and produce high quality diesel or to the diesel drier, which ~~under~~ a vacuum, separates water vapour from the combined diesel which is then sent to storage.

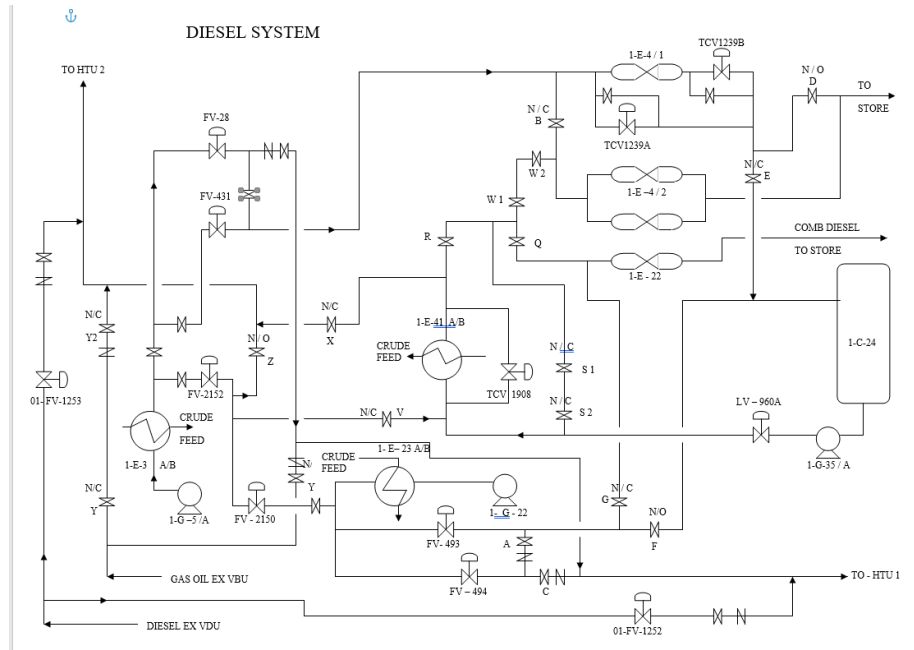


Figure 13 - Process Flow Diagram of Diesel System

Reduced Crude System

The atmospheric residue is the heaviest remains of the crude and ~~does~~ not vaporise readily and is collected at the bottom of the column. From here, ~~it is~~ pumped to the vacc unit where it is fractionated under a vacuum into further products and feeds.

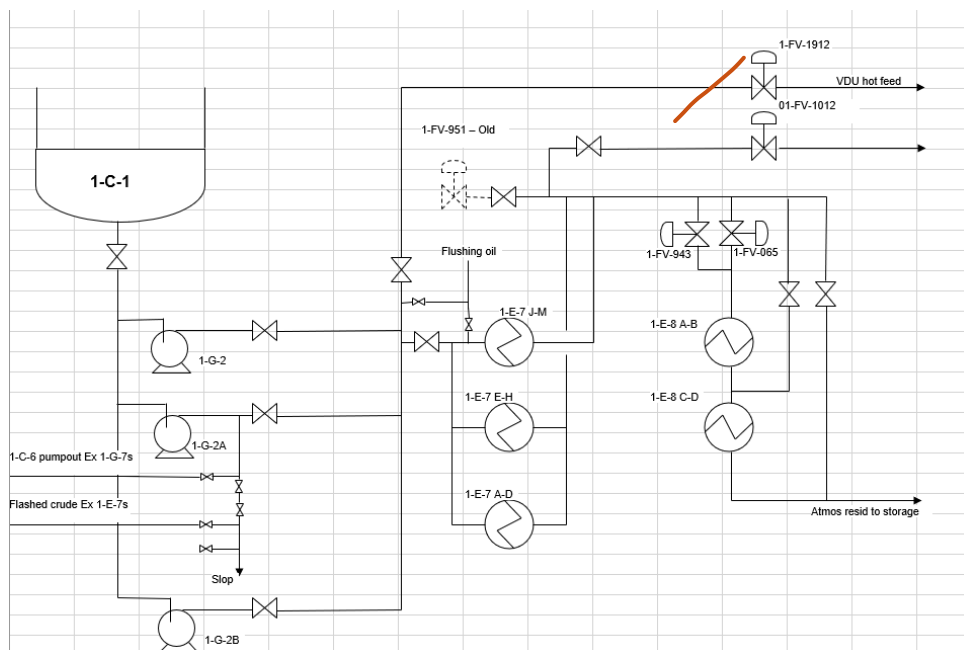


Figure 14 - Process Flow Diagram of Reduced Crude System

Word Count – 2,130 ✓

Table of Figures

<u>Figure No.</u>	<u>Source</u>
1	Valero Basic Operator Training Manuals (2015) – Volume 4.B – Fired Heaters
2	Wikipedia (2021) Fire Triangle. Available from: https://en.wikipedia.org/wiki/Fire_triangle [Accessed 02/03/2021]
3	PP-OPS-GUI-0026 – Valero CDU Daily Duties Procedure
4	Heater Work Request – Valero Operations Excellence System
5	Pembroke Refinery, (2020), CDU Training Materials
6	Valero Basic Operator Training Manuals (2015) – Volume 4.A – Distillation
7	Pembroke Refinery, (2020), CDU Training Materials
8	Pembroke Refinery, (2020), CDU Training Materials
9	Pembroke Refinery, (2020), CDU Training Materials
10	Pembroke Refinery, (2020), CDU Training Materials
11	Pembroke Refinery, (2020), CDU Training Materials
12	Pembroke Refinery, (2020), CDU Training Materials
13	Pembroke Refinery, (2020), CDU Training Materials
14	Pembroke Refinery, (2020), CDU Training Materials

/

Lit

Bibliography

- 1) FPO (2021) Damper System For Heater Stack. Available from:
<https://www.freepatentsonline.com/y2017/0198910.html#:~:text=The%20required%20stack%20height%20provides,the%20convection%20section%20and%20stack.&text=Closing%20the%20stack%20damper%20reduces,conjunction%20with%20the%20air%20registers.>
[Accessed 02/03/2021]
- 2) Clickview (2016) Difference Between Complete & Incomplete Combustion. Available from:
<https://www.clickview.co.uk/curriculum-libraries/video-details/?id=23852726&cat=11678961&library=secondary>
[Accessed 02/03/2021]
- 3) Wikipedia (2021) Fire Triangle. Available from:
https://en.wikipedia.org/wiki/Fire_triangle
[Accessed 02/03/2021]
- 4) Hassan Al-Haj Ibrahim (2010) Fired Process Heaters. Available from:
https://cdn.intechopen.com/pdfs/11623/intech-fired_process_heaters.pdf
[Accessed 02/03/2021]
- 5) Process Tech Academy (2021) Hot Spots & Coke. Available from:
<https://www.processtechacademy.com/your-mission-find-hot-spots-and-coke/>
[Accessed from 02/03/2021]
- 6) EPTQ (2012) Water Carryover On Crude Heater. Available from:
<http://www.eptq.com/qandaquestion.aspx?q=949b4553-2206-409e-8583-8d23b8fc418a>
[Accessed 02/03/2021]

- 7) Chemical Engineering (2004) Get The Most You're your Fired Heater. Available from:
<https://static1.squarespace.com/static/5659c9cde4b05079e4b0c3d9/t/572b2bbf3c44d82f781095c4/1462447063111/Get+the+Most+from+Your+Fired+Heater.pdf>
[Accessed 02/03/2021]
- 8) Fuel Oil News (2018) Draft Regulators. Available from:
[https://fueloilnews.com/2011/11/07/why-do-we-need-a-draft-regulator/#:~:text=The%20gases%20that%20are%20produced,temperature\)%20to%20an%20unsafe%20level](https://fueloilnews.com/2011/11/07/why-do-we-need-a-draft-regulator/#:~:text=The%20gases%20that%20are%20produced,temperature)%20to%20an%20unsafe%20level)
[Accessed 02/03/2021]
- 9) Valero Basic Operator Training Manuals (2015) – Volume 4.B – Fired Heaters
- 10) Mary Falkner, Sarah Hilton, Paul Jordin, Sharon Keeley, Simon Little, Andy Park (2008) AS Level Chemistry, OCR B. GCP.
- 11) Approved: K. Stone (2019) Valero CDU Plant Operator Plant & Process Knowledge Manual
- 12) Scott Golden & Steve White (2006) Digital Refining, Increasing Crude Unit Pre-Heat. Available from:
<https://www.digitalrefining.com/article/1000096/increasing-crude-unit-preheat#.YD6f3Wj7SUK>
[Accessed 02/03/2021]