The crude oil distillation engineering essay

Basically, the product produced in this process can be categoried into 4 group, they are: light distillates, middle distillates, heavy distillates and others. The example of light distillates are liquid petroleum gas (LPG), gasoline, and kerosene. Apart from that, the products that can be classified as middle distillates are residential heating fuel and aautomoblie diesel fuels. Additionally, bunker fuel oils is an example of heavy distillataes, while petroleum cokes, lubricating oils and carban black are the other products in this distillation process.

The brief description of crude oil distillation unit (CDU) process is as follow. First of all, the incoming crude oils is heating up before it is entering the fractionation column by heat exchanger. After that, the crude oil will pass through an equipment, called desalter, to remove water droplets and inorganic salts that contained in crude oil. Then, it will be further heating by heat exchanger.

Next, crude oil will enter a furnace. At here, it will be heating up to 330-350 °C. The crude oil then is flashed in the atmospheric distillation column. At here, it is separated into a number of fraction with a particular boiling range. When each fraction in the distillation column reaches a tray where the temperature is just below its own boiling point, crude oil will be condensed and changes back into liquid phase.

Moreover, heaviest fractions will condense on the lower trays and lighter fractions will condense on the higher trays in the column. At different elevations in the column, the fractions actually can be drawn out on gravity through pipes, for further processing in the refinery process by using a special trays called draw-off trays. The fraction is drawn out from the top, side and bottom of the distillation column. These fraction is the products that produced in this distallation process.

Vacuum Distillation Unit (VDU)

For vacuum distillation unit (VDU), its main purpose is to separate the heavier end products such as vacuum gas oil and slop wax that is from the atmospheric distillation unit. The brief description of the process is as follow. First of all, heavy crude oil is heated by a series of heat exchanger and crude furnace to the desired temperature, which is 350-390 °C.

After that, the crude oils flashed into the vacuum distillation column to separate the heavy crude oil. The separation is same as the separation in CDU process; light vapors rise to the top and heavier hydrocarbon liquids fall to the bottom. Next, crude steam is injected into the base of the distillation column to enhance the division of lighter boiling components from the bottom liquid.

Then, Light vapour gases are abtracted at the top of the distillation column, it is condensed and recycled back to the column as reflux. For light naphtha, it is drawn off and excess gases are sent to flare. However, vacuum gas oil (VGO) and lubricating oils are drawn off and routed for further treatment in hydrotreating units. Apart from that, vacuum residue from the bottom of the distillation column is sent to intermediate storage or typically to be further processed in fluidic catalytic cracking (FCC) process or delayed coking unit.

Fluid Catalytic Cracking

Fluid catalytic cracking is the primary conversion process in petroleum refinery. It is the unit which utilizes a micro-spherodial catalyst (zeolitic catalyst) which fluidizes when properly aerated. The purpose of this process is to convert high-boiling petroleum fractions (gas oil) to high-value, high-octane gasoline and heating oil. This process uses the instrument called Circulating Fluidized Bed. This Circulating Fluidized Bed has fast fluidization regime and also good for catalyst is the size of less than 0. 2 mm. They are also excellent in Gas-solid effective contact, Catalyst effectiveness, Catalyst internal temperature control, and Catalyst regeneration.

The operating characteristics of this instrument are;

Particle Diameter = 150 mm

Geldart Classification = A

Temperature = 650 0C

Pressure = 100 kPa

Superficial gas velocity = 10 m/s

Bed depth = 0. 85 m

Fresh feed flow rate = 300, 000 kg/hr

Catalyst to oil ratio = 4. 8

There are 6 steps of processes that occur in FCC. Reactor, Riser, Cyclones, Stripper, Regenerator, Standpipe and Slide Valve.

Firstly, the reactor performance, the feed oil enters the riser near the base and contacts the incoming regenerated catalyst. Then the cracking reactions occur in the vapor phase. The expanded volume of vapors lifts the catalyst and vaporized oil rises. This reaction occurs at a very high speed, usually about few seconds of contact time.

Secondly, the riser, which has diameter of 1. 2 meters and height of 36. 6 meters, has a plug flow with minimum back-mixing. Steam is used to atomize the feed, this increases the availability of the feed. The outlet vapor velocity would reach up to 18 ms -1. The hydrocarbon residence time is 2 seconds.

Followed by, Cyclones. It is located at the end of riser to separate the bulk of the catalyst from the vapor. It uses a deflector device to turn catalyst direction downward. It will later undergo two stage cyclones in order to separate the remaining of the catalyst. It then returns the catalyst to the stripper through the diplegs. The product vapors exit the cyclones and flow to the main fractionator column.

Then, the spent catalysts fall into the stripper. The valuable hydrocarbons are absorbed within the catalyst bed. Stripping steam, at a rate of 4 kg per 1000 kg of circulating catalyst, is used to strip the hydrocarbons from the catalyst. The catalyst level provides the pressure head which allows the catalyst to flow into the regenerator.

The regenerator basically has two functions, one, restores catalyst activity. Two, it supplies heat to crack the feed. Air is the source of oxygen for the combustion of coke. The air blower with 1 m/s (3 ft/s) air velocity to maintain the catalyst bed in a fluidized state. About 14 kPa (2 psi) pressure drops in air distributors to ensure positive air flow through all nozzles.

In standpipe and slide valve, it provides the necessary pressure head needed to circulate the catalyst around the unit. The catalyst density in standpipe is 642 kg/m3 (40 lbs/ft3). Slide valve is used to regulate the flow rate of the regenerated catalyst to the riser. Slide valve function is to supply enough catalyst to heat the feed and achieve the desired reactor temperature.

Hydrocracking process

Crude oil undergoes hydrocracking process after undergoing vacuum distillation and coking processes. Hydrocracking process is a catalytic chemical process used in petroleum refineries for converting the high-boiling constituent hydrocarbons in petroleum crude oils to more valuable lower-boiling products such as gasoline, kerosene, jet fuel and diesel oil. The process takes place in a hydrogen-rich atmosphere at elevated temperatures (260 – 425 °C) and pressures (35 – 200 bar). This process removes feed contaminants such as nitrogen, sulfur, metals. Hydrogenation occurs in fixed hydrotreating catalyst beds to improve hydrogen/carbon ratios. The size of the molecules must decrease and the atomic H/C ratio must increase if the products are to become useable as conventional fuel products. This is followed by one or more reactors with fixed hydrocracking catalyst beds to dealkylate aromatic rings, open naphthene rings, and hydrocrack paraffin chains. Major products from hydrocracking are jet fuel and diesel, while also high octane rating gasoline fractions is produced. All these products have a very low content of sulfur and other contaminants. Hydrocracking is normally facilitated by a bifunctional catalyst that is capable of rearranging and breaking hydrocarbon chains as well as adding hydrogen to aromatics and olefins to produce naphthenes and alkanes. This process cracks the high-boiling, high molecular weight hydrocarbons into lower-boiling, lower molecular weight olefinic and aromatic hydrocarbons and then hydrogenates them. Any sulfur and nitrogen present in the hydrocracking feedstock are, to a large extent, also hydrogenated and form gaseous hydrogen sulfide (H2S) and ammonia (NH3) which are subsequently removed. The result is that the hydrocracking products are essentially free of sulfur and nitrogen impurities and consist mostly of paraffinic hydrocarbons. Basically, hydrocracking process consist of the splitting or breaking of straight or cyclic hydrocarbons and hydrogenation of the broken bonds.

Example:

For futher details about the yield and disposition, refer to the table below:

Product

Yield, volume% feed

Disposition

Light ends

Varies depending upon objectives

LPG

Naphtha

Gasoline, catalytic reformer

Diesel

Diesel

Total volume yield

130 – 140

Gas oil conversion

60 – 99%

They are two stages of hydrocracking unit; Single Stage Process and Multi Stage Hydrocracker. It is called a single stage process when the treating step is combined with the cracking reaction to occur in one reactor. The catalyst used in a single-stage process comprises a hydrogenation function in combination with a strong cracking function. In the case of high/full conversion is required, it becomes necessary to switch to a multi-stage process, in which the cracking reaction mainly takes place in an added reactor. Two versions of the multi stage hydrocracker have been developed; two stage hydrocracker and series flow hydrocracker. Both two stage and series flow hydrocracking are flexible process. The two stage process is more selective because product made in the first reactor is removed from the second reactor feed. In series flow operation, this product is partly overcracked into lighter products in the second reactor.

Schematic of a two-stages hydrocraking unit

HYDROTREATING PROCESS

(Prepared by DING TIONG SOON, 10UEB01031)

Hydrotreating technology is used in refinery processes to remove contaminants such as sulfur, nitrogen, condensed ring aromatics, or metals to produce a clean product for further processing. Hydrotreating process includes Naphtha Hydrotreating, Gasoline Hydrotreating, Mid-Distillate Hydrotreating and FCC Feed Pretreating. The feeds used in this process range from vacuum resid to naphtha , and the products are used as environmentally acceptable clean fuels. In the hydrotreating process oil fractions are reacted with hydrogen in the presence of a catalyst to produce high-value clean products. The operating conditions will depend on the final application. The heart of hydrotreating process is the reactor section, which features a high-pressure reactor vessel and proprietary catalyst and reactor internals technology.

Hydrotreating process began when the liquid feed stream is joined by a stream of hydrogen-rich recycle gas. The mixture is then preheated by flowing through a heat exchanger. After that, it is heated to the desired hydrotreating temperature using a fired heater where the feed mixture is totally vaporized. Hydrotreating takes place when the feed mixture flows through a fixed-bed reactor in the presence of a catalyst consisting of an alumina base impregnated with cobalt and molybdenum. The hot reaction products are cooled by flowing through a water-cooled heat exchanger before it flows through the pressure controller (PC) and undergoes a pressure reduction down to about 3 to 5 atmospheres. The resulting mixture of liquid and gas enters the high pressure separator which separates the liquid hydrocarbon from the hydrogen , hydrogen sulfide or ammonia gas. Most of the hydrogen-rich gas from the gas separator vessel is recycled by routing through an amine contractor for the removal of acid gas and is reuse in the reactor section. Any excess gas from the gas separator vessel joins sour gas from the stripping of the reaction product liquid. The liquid from the gas separator vessel is routed through a reboiled or steamed stripper distillation tower. The stripper only have two products , a top and a bottom. With a steam stripper, downstream processing, typically a salt dryer which is preceded by a vacuum dryer, is required to remove water from treated products. If multiple products are produced, then a fractionator with a fired reboiler is also used. Further separation of LPG gases occurs in the low pressure separator prior to sending the hydrocarbon liquids to fractionation. Meanwhile, the sour gas is sent to the refinery's central gas processing plant for removal of the hydrogen sulfide in the refinery's main amine gas treating unit and through a series of distillation towers.

The Importance of hydrotreating is that it helps to improve air quality by desulfurization of fuel oils. Hydrotreating prepares valueable hydrocarbon products from heavy carbon streams and the production of low-sulfer-level fuel oil from residual stocks after distillation of crude oil.

Coking

(prepared by Soo Voo Yee, 10UEB01889)

Coking is a thermal process for the conversion of low value residue to valuable products and coker gas oil. There have two types of coking process, which are delayed coking and fluid coking.

For the delayed coking process, at first, the residual oil from the vacuum distillation unit is pumped into the bottom of the main fractionators. Along the way it is pumped to the furnace, some steams are injected to heat it to its thermal cracking temperature of about 4800C. The injected steam helps to minimize the deposition of coke within the furnace tubes. Besides that velocity inside the tube of the furnace is very fast. This is to reduce the loss of heat as a waste of source.

Because of the short period in the furnace, so the coking of the feed is delayed until it reaches the large coking drum. Compared to the furnace, drum provides a longer period for the cracking process to proceed to completion. For the gas oil and the lighter components will leave from the top of the drum, left behind the components of liquids and solids. The gasses will be directed to the main fractionators to separate it into gases, naphtha and light and heavy gas oils based on each boiling points. The solid coke is deposited and remains in the coke drum in a porous structure that allows flow through the pores. 16 to 24 hours are needed to fill the drum full as a complete coke drum cycle.

The hot mixture is switched to another empty drum, when the first drum is full of the solidified coke. While the second drum is filling, the full drum is steamed out to reduce the hydrocarbon content of the petroleum coke, and then is cooled down with water. The top and bottom heads of the full coke drum are removed, and the solid petroleum coke is removed from the coke drum via hydro jetting. The pressure of the water is about 1250psig to 4000 psig and the flow rate is about 750GPM to 1250 GPM.

Fluid coking is a continuous process which consists of 2 units, reactor and furnace. In the reactor, the coke particles are fluidized by steam. The preheated feed will be injected directly into the reactor when it reached temperature of 2500C to 3500C. The temperature inside of the reactor is around 4800C to 5700C. On the surface of the coke particles, cracking process is occurred, causing the lighter components are being vaporized. To separate the entrained coke particles with the vapors, cyclones are used.

The vapor is then sent to the bottom of the scrubber and condensed into heavy tar; meanwhile the remaining coke is removed and recycled back to the coke reactor. The overhead of the vapor is directed to a fractionator where it is separated into the desired boiling point fractions. Then the coke particles flow to the stripping zone to remove any product vapor between the coke particles. After that, the coke particles are sent to the burner. A part of the coke is burned to remain the average bed temperature. Hot coke is then sent back to the reactor. To maintain the coke inventory in the burner, coke which is one of the products, required to withdraw from the burner. The large coke particulate will be replaced by the smaller seed particles to prevent the circulating coke is too coarse.

Compare to delayed coking process, fluid coking will be carried out at a more uniform and higher temperature and shorter contact time. The products produced by using fluid coking process are more valuable and less coke.