

Lecture 3

Crude Oil Distillation

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CRUDE OIL DISTILLATION

INTRODUCTION

Refining of crude oils or petroleum essentially consists of primary separation processes and secondary conversion processes. The petroleum refining process is the separation of the different hydrocarbons present in the crude oil into useful fractions and the conversion of some of the hydrocarbons into products having higher quality performance. Atmospheric and vacuum distillation of crude oils is the main primary separation processes producing various straight run products, e.g., gasoline to lube oils/vacuum gas oils (VGO). These products, particularly the light and middle distillates, i.e., gasoline, kerosene and diesel are more in demand than their direct availability from crude oils, all over the world.

PRETREATMENT OF CRUDE OILS

Crude oil comes from the ground, which contains variety of substances like gases, water, dirt (minerals) etc. Pretreatment of the crude oil is important if the crude oil is to be transported effectively and to be processed without causing fouling and corrosion in the subsequent operation starting from distillation, catalytic reforming and secondary conversion processes.

IMPURITIES

Impurities in the crude oil are either oleophobic or oleophilic.

OLEOPHOBIC IMPURITIES: Oleophobic impurities include salt, mainly chloride & impurities of Na, K, Ca & Mg, sediments such as salt, sand, mud, iron oxide, iron sulphide etc. and water present as soluble emulsified and /or finely dispersed water.

OLEOPHILIC IMPURITIES: Oleophilic impurities are soluble and are sulphur compounds, organometallic compounds, Ni, V, Fe and As etc, naphthenic acids and nitrogen compounds.

Pretreatment of the crude oil removes the oleophobic impurities.

PRETREATMENT TAKES PLACE IN TWO WAYS:

- Field separation
- Crude desalting

Field separation is the first step to remove the gases, water and dirt that accompany crude oil coming from the ground and is located in the field near the site of the oil wells.

The field separator is often no more than a large vessel, which gives a quieting zone to permit gravity separation of three phases: gases, crude oil and water (with entrained dirt).

CRUDE DESALTING

It is a water washing operation performed at the refinery site to get additional crude oil clean up.

- Crude Oil Desalting consists of
 - Purifying process
 - Remove salts, inorganic particles and residual water from crude oil
 - Reduces corrosion and fouling

Desalting process is used for removal of the salts, like chlorides of calcium, magnesium and sodium and other impurities as these are corrosive in nature. The crude oil coming from field separator will continue to have some water/brine and dirt entrained with it. Water washing removes much of the water-soluble minerals and entrained solids (impurities). There are two types of desalting: single & multistage desalting. Commercial crudes, salt contents 10-200 ppb, earlier 10-20 ppb were considered satisfactorily low. However, many refiners now aim at 5 ppb or less (1-2 ppb) which is not possible through single stage desalting, hence two stage desalting is required.

Desalting process consists of three main stage: heating, mixing and settling.

Crude oil is heated upto 135-141°C in the train of heat exchanger operating in two parallel section. The temperature in desalting is maintained by operating bypass valve of heat exchanger. Single stage desalting with water recycle is usually justified if salt content in crude is less than 40 ppb. Two stage desalting involves dehydration followed by desalting. Double stage desalting is better for residuum hydrotreating. Fuel oil quality is better.

Desalting process is two stage process: forming emulsion of crude and water and demulsification in which emulsion is broken by means of electric field and demulsifying chemicals. Desalting is

carried out by emulsifying the crude oil and then separating the salt dissolved in water. Two phases water/oil is separated either by using chemicals to break down the emulsion or by passing high potential electric current. By injecting water the salts dissolved in the water and solution are separated from the crude by means of electrostatic separating in a large vessel.

Operating Variables in Desalter: Some of the variables in the desalter operation are crude charge rate, temperature, pressure, mixing valve pressure drop and wash water rate, temperature, and quality, desalting voltage. Crude oil temperature charged to the desalter is very important for the efficient operation of desalter. Lower temperature reduce desalting efficiency because of increased viscosity of oil while higher temperature reduce desalting efficiency due to greater electrical conductivity of the crude. Pressure in the vessel must be maintained at a high value to avoid vaporization of crude oil pressure which result in hazardous ondition, erratic operation and a loss of desalting efficiency. Flow diagram for crude oil desalting is given **Figure MIV**

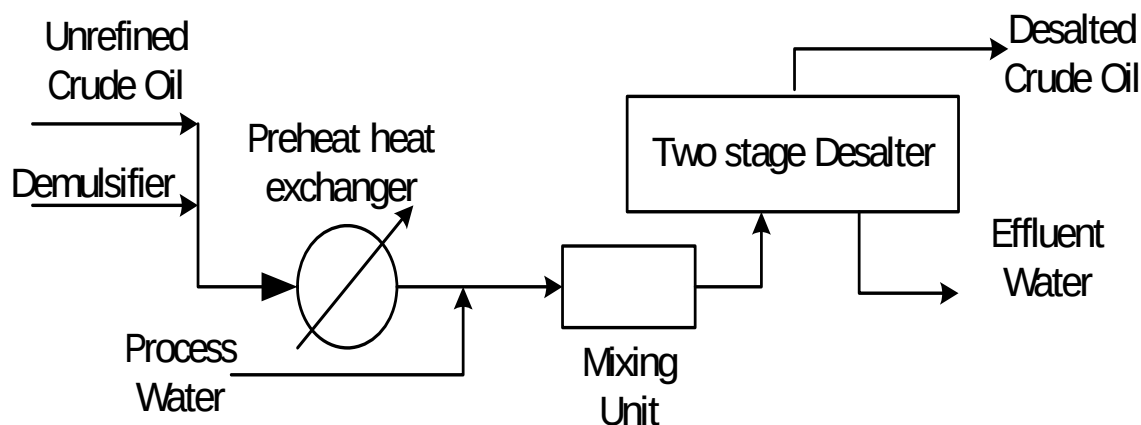


Figure M-VI 2.1 Crude oil Desalting

CRUDE OIL DISTILLATION

Desalted crude flows to atmospheric and vacuum distillation through crude pre flashing section. Atmospheric distillation column (ADU) and Vacuum distillation column (VDU) are the main primary separation processes producing various straight run products, e.g., gasoline to lube oils/vacuum gas oils (VGO). These products, particularly the light and middle distillates, i.e., gasoline, kerosene and diesel are more in demand than their direct availability from crude oils, all over the world.

Crude oil distillation consists of atmospheric and vacuum distillation. The heavier fraction of crude oil obtained from atmospheric column requires high temperature. In order to avoid cracking at higher temperature the heavier fraction are fractionated under vacuum. Typical flow diagram of crude oil distillation is given in Figure M-VI 2.2. Various Streams From Atmospheric And Vacuum Distillation Column is given in Table M-VI 2.2

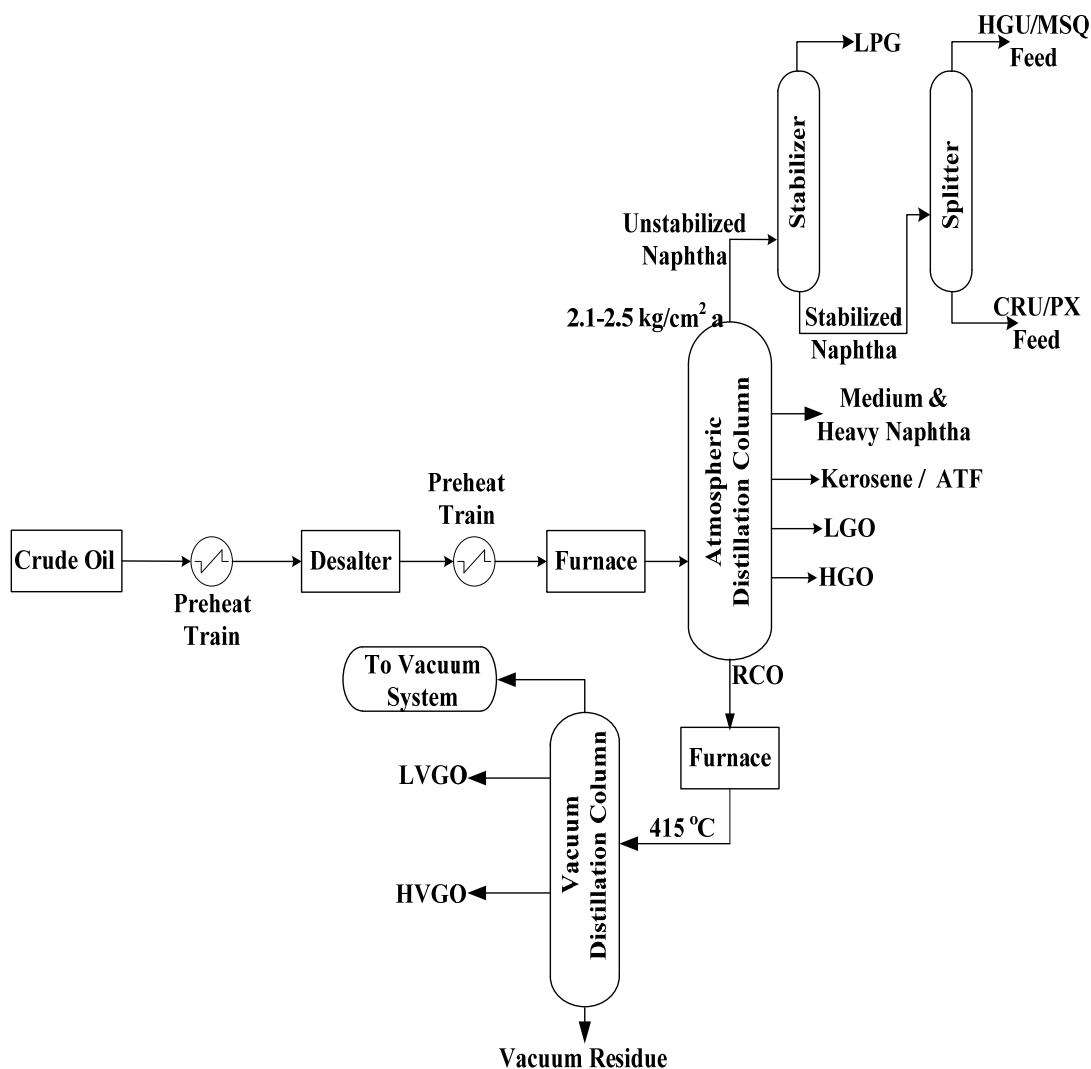


Figure M-VI 2.2: Atmospheric and Vacuum Crude oil distillation

Table M-VI 2.2: Various Streams From Atmospheric And Vacuum Distillation Column

Column	Fraction	Temperature	Carbon range	Uses
Atmospheric column	Fuel Gases	>40	C ₁ -C ₂	Fuel
	LPG		C ₃ -C ₄	Domestic fuel
	Straight run gasoline/	20-90	C6-C10	Gasoline pool
	Naphtha (Medium and heavy)	130-180	C6-C10	Catalytic reforming and aromatic plant feed stock Steam cracker, synthesis gas manufacture
	Kerosene	150-270	C11-12	Aviation turbine fuel, Domestic fuel, LAB feed stock (paraffin source)
	Light gas oil	230-320	C13-C17	High speed diesel component
	Heavy gas oil	320-380	C18-C25	High speed diesel component
Vacuum column	Light vacuum gas oil	370-425	C18-C25	Feed to FCC /HCU
	Heavy vacuum gas oil	425-550	C26-C38	Feed to FCC /HCU
	Vacuum slop	550-560		RFCCU feed
	Vacuum Residue	>560	>C38	Bitumen/ Visbreaker feed

ATMOSPHERIC COLUMN: Various steps in atmospheric crude oil distillation are

- Preheating of Desalted crude
- Preflash
- Distillation
- Stabilization of Naphtha

The desalted crude oil from the second stage desalting process is heated in two parallel heat exchanger. The preheated crude having temperature of about 180°C is goes to pre flash drum where about 3-4percent of light ends are removed. The preheated crude from the preheater section is further

heated and partially vaporized in the furnace containing tubular heater. The furnace has two zones: radiant section and convection section. The radiant zone forms the combustion zone and contains the burners. In convection zone the crude is further heated (inside the tube) by the hot flue gases from the radiant section.

Heated and partially vaporized crude from the fired heaters enters the flash zone of the column and fractionated in the atmospheric column. The distillation section consist of overhead section, heavy naphtha section, kerosene section, light gas oil section, heavy gas oil section and reduced crude section each section contains circulating reflux system.

Naphtha stabilizer, caustic wash and naphtha splitting section: The unstablised naphtha from the atmospheric distillation column is pumped to the naphtha stabilizer section for separation of stabilized overhead vapours which is condensed to recover LPG which is treated in caustic and amine treating unit. The stabilized naphtha is further separated into light, medium and heavy naphtha.

PRODUCTS of ADU: Major product from atmospheric column are light gases and LPG, light naphtha, medium naphtha, heavy naphtha, kerosene, gas Oil (diesel), atmospheric residue.

- Unstabilized Naphtha consists of LPG, naphtha and light gases (C-5 115 °C)
- Intermediate Naphtha (Bombay High) (135°C) Solvent Naphtha
- Heavy Naphtha (130-150 °C) routed to diesel or naphtha.
- Kero/ATF (140-270/250°C)
- Light Gas Oil (250/270-320°C)
- Heavy Gas Oil (320-380°C)
- Reduced Crude Oil

Major products separated in atmospheric column:

Operating Variables in ADU unit are

- Furnace coil outlet temperature
- Crude distillation Column top pressure and top temperature
- Stripping Steam flow
- Product withdrawal Temperatures

VACUUM DISTILLATION COLUMN (VDU)

The bottom product also called reduced crude oil, from the atmospheric column is fractionated in the vacuum column. Reduced crude oil is very heavy compared to crude oil distilling under pressure requires high temperature. Distillation under vacuum permits fractionation at lower temperature which

avoid cracking of the reduced crude oil and coking of the furnace tube. Vacuum is maintained using three stage steam ejector. The reduced crude oil from atmospheric column at about 360°C is heated and partially vaporized in the furnace. The temperature in the flash zone of the tower is controlled by the furnace coil outlet temperature. The preheated and partially vapourised reduced crude enters the flash zone of vacuum column where it is fractionated into various streams.

PRODUCTS FROM VDU: Various products from VDU are Light gasoil, Heavy gas oil, light lube distillate, medium lube distillate, heavy lube distillate and vacuum column residue

OPERATING PRESSURE OF VACUUM COLUMN:

- About 90-95 mm Hg at the top and
- About 135-140 mm Hg at the bottom

CHEMICAL INJECTION SYSTEM:

Chemical injection system consist of caustic injection and ammonia injection and use of corrosion inhibitor, use of demulsifier, addition of trisodium phosphate in boiler feed water.. Corrosion in the atmospheric tower overhead system is a common phenomenon and the problem is increasing with increasing use of the heavier crude oil. Corrosion is primarily due to hydrogen chloride, which is produced by hydrolysis of the chloride salts remaining after desalting. Other sours of corrosion are naphthenic acid and hydrogen sulphide. High caustic injection is to avoided as high caustic injection system may lead to fouling in vacuum and visbreaker furnaces. ammonia injection is done to maintain the pH. Corrosion inhibitor in kerosene and naphtha is required to combat the corrosion. De-emulsifier is used to demulsify the water and crude emulsion. Trisodium phosphate is used to maintain pH and prevent corrosion in the boiler drums

EFFECT OF CRUDE CHARACTERISTICS:

Crude oil characteristics plays important role in the product distribution, processing scheme and quality of product. Effect of Crude Characteristics on Performance of crude distillation. Effect of Crude Characteristics on Performance of crude distillation is given in Table M-VI 2.3

Table M-VI 2.3. Effect of Crude Characteristics on Performance of crude distillation

Characteristics	Effect
API	API A Measure of “heaviness” or “lightness” $API = (141.5 / \text{density}) - 131.5$ API > 30 Light Crude API < 28 Heavy Crude
Viscosity:	A measure of resistance to flow and is important parameter for effective desalting and highly dependant on temperature. High viscosity crudes need high temperatures for effective desalting. There is a limit for temperature in desalters.
UOP K(Characterisation factor)	It is measure of parafinity vis-à-vis aromaticity of Crude High UOP K is desired for high conversion in FCC High UOP K is desired for high conversion in FCC Aromatic molecules can not be cracked in FCC. They will simply take ride through the plant.
Total acid number(TAN)	Total Acid Number: A measure of Naphthenic Acid contents in Crude leads to corrosion in various sections of the unit Over 1,500 known NA species are present in crude. All Nap. Acids are not corrosive. Latest research indicates that TAN is not a complete Corrosion Index TAN with 2.5 may corrode at higher rate than TAN with say 6 ! Detailed metallurgical reviews & monitoring mechanism must be put in place.
BS&W Bottom Sediments & Water	BS&W Bottom Sediments & Water is a measure of water, water dissolved ,substances, mud, sand & sludge. Lower the BS&W - the higher the reliability of the Unit. BS&W is one of the major pointer for corrosive materials in crude.
Sulfur	Sulfur is a measure of “sourness” & “sweetness” of crude passed onto products as much as regulations or market accepts . It is removed in hydrotreaters by reacting with H ₂ and recovered as elemental Sulfur in sulphur recovery unit S > 2.5 Sour Crude, S < 2 Sweet Crude
Total salts	Total salts A Measure of contaminant in Crude that will cause overhead corrosion or foul-up exchangers by settling & scaling. It is removed in desalters by washing & settling
VGO metals	VGO metals is a measure of metals content in VGO fraction Ni & V are known poisons of VGO hydrotreater catalyst. Metals in VGO are controlled by controlling wash rate in Slop Wax section of vacuum column

References

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