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KLM Technology Group #03-12 Block Aronia, Jalan Sri Perkasa 2 Taman Tampoi Utama 81200 Johor Bahru	**Petrochemical Manufacturing Report** **Advanced Petrochemcial Refining 501**	Editor / Author Karl Kolmetz

KLM Technology Group has developed; 1) Process Engineering Equipment Design Guidelines, 2) Equipment Design Software, 3) Project Engineering Standards and Specifications, 4) Unit Operations Manuals and 5) Petrochemical Manufacturing Reports. Each has many hours of engineering development.

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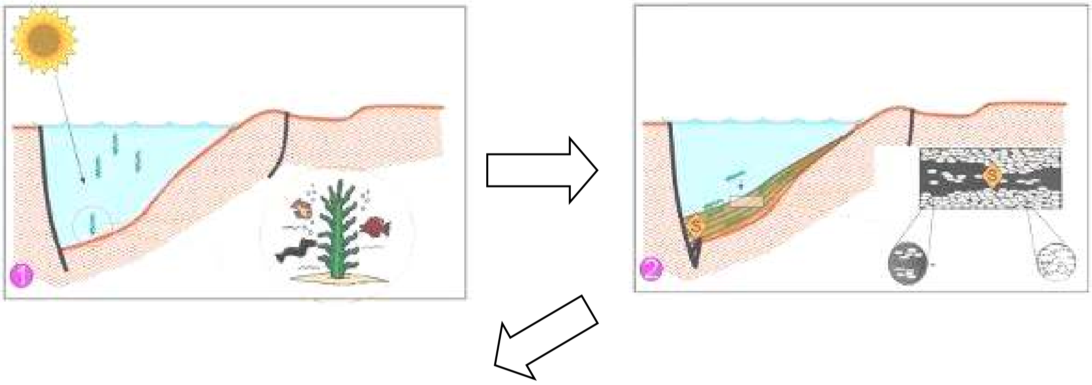
CHAPTER 1

INTRODUCTION

Crude oils or “nature petroleum” occurs as an accmulation in the subsurface of the earth. Petroleum compositions are based on its physical condition :

1) *Natural Gas*, composed from hydrocarbon-rich gases.
2) *Liquid Oil*, composed by liquid phase petroleum (crude oil).
3) *Tar and Bitumen*, formed mostly from high-molecular weight solids.

Petroleum was generated from insoluble organic material in source rocks. A biogenic origin for cabronaceous in petroleum is universally accepted. The process including organic matter which incorporated into sediments are deposited, shallow generation of biogenic methane, conversion of organic matter into petroleum-like materials according several influences (Temperature, Pressure), migration materials from the source rock through permeable carrier beds to the reservoir, then final compositional changes of petroleum caused by temperature, microorganism activities, and water washing. (Figure 1.1).



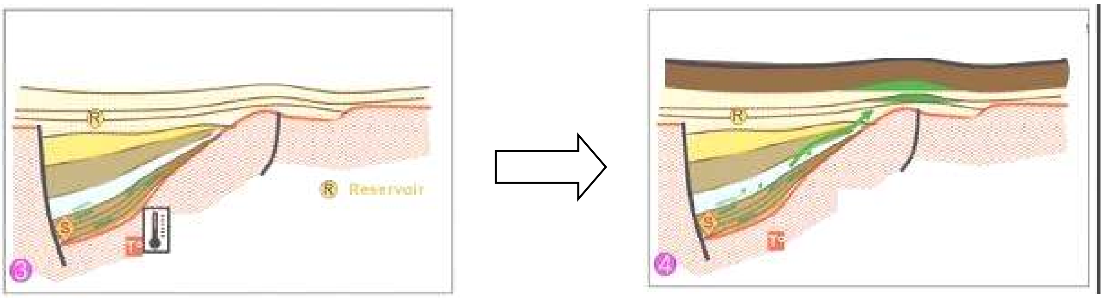


Figure 1.1 Petroleum generation.

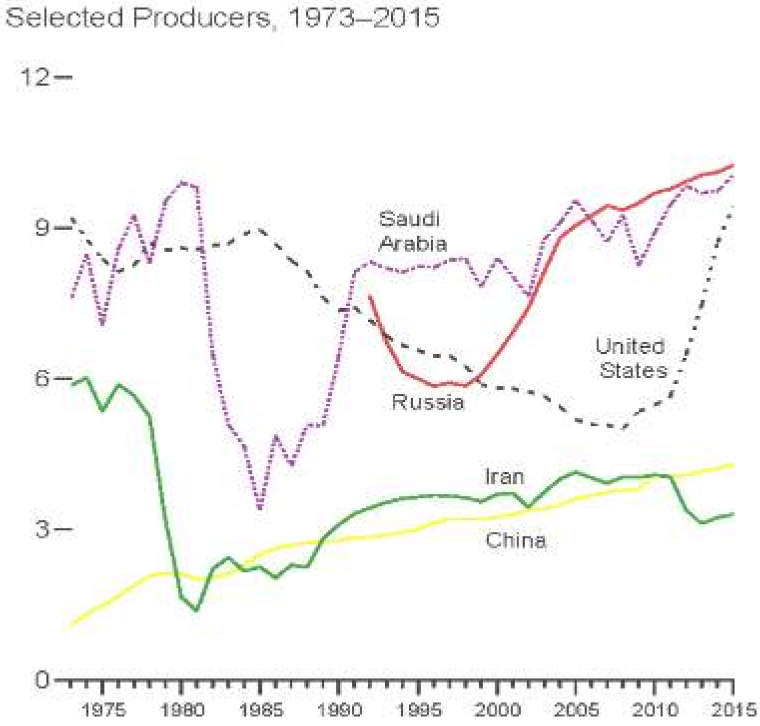


Figure 1.2. Top oil producers.

Upstream Process

After crude oil is generated, the processing of the crude oil from earth's subsurface is above the soil. One of the most important operations of upstream is drilling.

Drilling costs range from several thousand to several millions dollars for each well depending on the nature of the well itself. The length of drilling time could be only for few days to more than a year. As approximation, about 6 to 8% of the total drilling costs arises directly from the drilling fluid and additives. On 1994, total worldwide sales was estimated to be \$1.2 x 10^9. About fifty percent of the Drilling fluids could be categorized as :

1) *Gas-Based Muds*, mostly used for hard-rock drilling which consists from compressed dry air and natural gas to water-based mist and foams. No additives needed for gas drilling operations whilst aqueous additives were injected to generate mists and foams. Gas-based fluids are not recirculated and materials are added continously to reservoir.
2) *Water-Based Muds*, filled by 85% of water-based systems. The fluids depend on the composition of water phase, viscosity builders and also rheological control agents.
3) *Oil-Based Muds*, oil-based drilling fluids consists mostly of diesel and mineral oil as a continuous phase. Low or havng no content of water. Employed for high angle wells where good lubricity is necessary.
4) *Synthetic-Based Muds*, has been introduced to counteract the high costs with disposal of drill cuttings generated when oil-based muds are used. A substitute liquids operates as a pseudo-oil inside reservoir to help fluids pumped out of earth surface.

Most of drilling required an additives to run operation smoothly. The price of drilling fluids additives is vary depend to company and location. Table 1.1 valued an example price of drilling fluid additives which typically used for North Sea region consumption around late 1990's.

Table 1.1. Prices of Additives

Additive	Function	Estimated Price ($/tonnes)
Barite,	Increase density	140
Hematite		155
Attalpugite,	Increase viscosity	300
Bentonite,		165
Hydroxylethylcellulose,		11,500
Xanthan Gum		23,000
Causticized,	Reduce viscosity	1,200
Chrome-lignosulfonate,		1,150
Lignosulfonate (Chrome-free),		1,500
Pyrophosphate Lignite,		510
Carboxymethyl cellulose,	Filtrate rate reduction	11,000
Corn starch,		1,300
Modified starch		3,000
Polyacrylamide	Viscosity stabilization	13,000 (powder) 7,100 (liquid)
Lime,	Alkalinity control	220
Potassium hydroxide,		2,200
Sodium hydroxide		1,050
Cellulose fiber,	Lost circulation control	1,500
Mica,		590
Walnut shells		750

As crude oil wells operates by time, the pressure inside reservoir is also reducing time after time. Such an addition recovery system is urgently required to keep crude oil produce with the same rate. A better technology to pumped out drilled crude oil named as Enhanced Oil Recovery (EOR).

In 1994, EOR has been contributed about 3.2% of oil production (1.9×10^6 barrel/day). In U.S, approximately 10% of total production (709,000 barrel/day) at that time gained from EOR method. As the year goes by and oil production more dependent to existing fields, EOR has raise an interest in many places around the world. Oil recovery mechanisms using EOR system could summarized into two major stages :

1) Increasing volumetric sweep efficiency.
2) Increasing oil displacement efficiency.

Indeed, poor reservoir volumetric sweep efficiency becomes one of the greatest obstacle to increasing oil recovery. Both of these stage commonly used substitute fluids such as miscible gas (CO_2, natural gas), immiscible gas (Nitrogen) or Water to increase the efficiency of EOR method.

Downstream Process

Downstream process of crude oil is next after the drilled-fluids approached earth’s surface in order to chemically modify them for making the daily products and making them ready to consume. Downstream process including :

1) *Refinery Process*, aiming the recovery of usable fraction from crude oil either using physical and chemical modification to get the first derivatives petroleum products.
2) *Petrochemical Process*, aiming further modification of the first derivative petroleum products to become intermediate chemical compounds or daily basis products.

Historically, it was believed about two thousand years ago, Arabian scientists developed methods what people named : “Distillation” which later introduced into Europe through Spain. In China (approximately third century), petroleum accidentally occured when drilling for salt. Marco Polo in 1271 – 1273 has been reported a ‘commercial’ petroleum industry built in Baku region (currently Northern Iran).

Mixture of compounds boiling at different temperatures that can be separated into various different fractions which sometimes overlapped called “Crude Petroleum”. Table 1.2 showed classification of crude petroleum in order of its boiling point.

Table 1.2. Fractions of Petroleum

Fraction	Boiling Point (°C)
Light naphtha	-1 – 150
Gasoline	-1 – 180
Heavy naphtha	150 – 205
Kerosene, Stove oil	205 – 290
Light gas oil	260 – 315
Heavy gas oil	315 – 425
Lubricants	> 400
Residuum	> 600

Crude petroleum utilization had been recorded at least 500 years. Mesopotamian (currently Iraq) documents explained products that came from nonvolatie derivatives (approximately derives from asphalt compounds) which used as an adhesive for jewelry or construction purposes. The document also showed the use of bitumeous compound as medicines.

A refinery could be group as manufacturing plants that vary in number due to the variety of products produced. Refinery plant shall be flexible and able to change its operations if needed. Universally, a refinery plant obey three basic process concepts following :

1) *Carbon rejection*, in order to reduce the number of carbon compound such as coking processes.
2) *Hydrogen addition*, in order to extend the number of hydrogen compound like hydroprocesses.
3) *Catalysis*, in order to rearrange and manipulate compounds to become different structure without changing the number of carbon and hydrogen element.

Crude petroleum consisted not only liquid phase materials but also gas phase. The gas streams produced during petroleum refinery obtained many noxious elements which could affected the use of gas for further purposes such as fuel and petrochemical feedstocks. Therefore, gas purification processes are necessarily required. Purifying process for gas constituents divided into three classes :

1) *Removal of Gaseous Impurities*.
2) *Removal of Particulate Impurities*.
3) *Ultrafine Cleaning*.

Gas purification performed such a complex treating due to many variables involved. Several considerations shall be determined which generally followed the rules of :

1) Kind of contaminants and its concentrations within processed gas.
2) How much desired contaminant to be removed.
3) Selectivity of acid gas removal required.
4) Physical influence such as : Pressure, Volume, and Composition of processed gas.
5) Carbon dioxide to Hydrogen Sulfide ratio.
6) Sulphur recovery desired for economical purposes.

Both of petroleum and natural gas could be based material for petrochemical products. In general, petrochemicals separated into three different groups, following :

1) *Aliphatics*, a straight-chained carbon hydrocarbon compounds.
2) *Cycloaliphatics*, a rounded-chained carbon hydrocarbon compounds, including aromatics classes.
3) *Inorganics*, which contained inorganic elements like sulphur (S) and nitrogen (N).

Crude Oil Analysis

Petroleum exploration is largely concerned with the search for oil and gas, two of the chemically and physically diverse group of compounds termed the hydrocarbons. Physically, hydrocarbons change grades from gases, via liquids and plastic substances, to solids. The hydrocarbon gases include dry gas (methane) and the wet gases (ethane, propane, butane, etc.). Condensates are hydrocarbons that are gaseous in the subsurface, but condense to liquid when they are cooled at the surface. Liquid hydrocarbons are termed oil, crude oil, or just crude, to differentiate them from refined petroleum products.

Petroleum refineries are large, capital intensive manufacturing facilities with extremely complex processing schemes. They convert crude oils and other input streams into dozens of refined (co-) products as shown in figure 1.3.

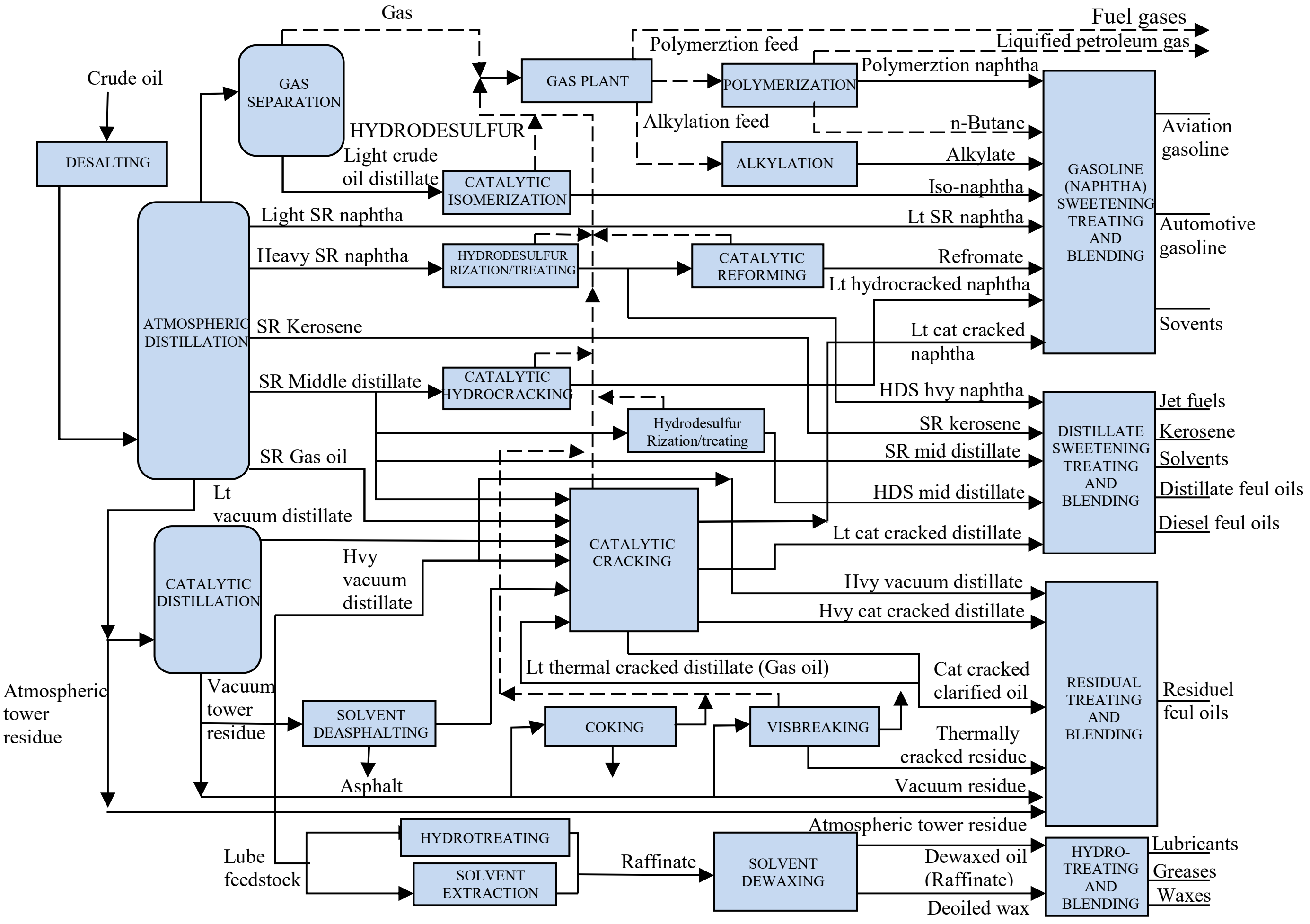


Figure 1.3 : refinery process

It is generally agreed that crude petroleum oil was formed from decaying plants and vegetables and dead animals and converted to oil by the action of high pressure and high temperature under the earth surface, and by the action of the biological activities of micro-organisms. Organic materials of plant or animal origin accumulate in the lowest places, usually in the crevices, low-lying land, sea bed, coral reefs, etc., and are gradually buried under the surface of Earth. Thus, huge amounts of organic matter are trapped layer after layer in the earth crust and rock. Crude oil, liquid petroleum that is found accumulated in various porous rock formations in Earth's crust and is extracted for burning as fuel or for processing into chemical products. Crude oils are customarily characterized by the type of hydrocarbon compound that is most prevalent in them. They are paraffins, naphthenes, and aromatics.

Paraffins are the most common hydrocarbons in crude oil; certain liquid paraffins are the major constituents of gasoline (petrol) and are therefore highly valued. Naphthenes are an important part of all liquid refinery products, but they also form some of the heavy asphalt like residues of refinery processes. Whereas, aromatics generally constitute only a small percentage of most crudes. The most common aromatic in crude oil is benzene, a popular building block in the petrochemical industry. Refinery crude base stocks usually consist of mixtures of two or more different crude oils.

Crude oils are complex mixtures containing many different hydrocarbon compounds that vary in appearance and composition from one oil field to another. Crude oils range in consistency from water to tar-like solids, and in color from clear to black. An average crude oil contains about 84% carbon, 14% hydrogen, 1%-3% sulfur, and less than 1% each of nitrogen, oxygen, metals, and salts. Refining adds value by converting crude oil (which in itself has little end use value) into a range of refined products, including transportation fuels. The primary economic objective in refining is to maximaze the value added in converting crude oil into finished products.

In most refineries, this process is carried out in two stages. The oil is first heated to the maximum temperature allowable for the crude being processed and for the operation being practiced and then fed to a fractionating tower which operates at slightly above atmospheric pressure. It yields several distillate products and a bottoms product. This tower is usually called the atmospheric tower.

Overall properties of crude oils are dependent upon their chemical composition and structure. Not all compounds contained in crude oil are hydrocarbons. There are present also as impurities, small quantities of sulfur, nitrogen and metals. The composition of crude oil, on an elemental basis, falls within certain ranges regardless of its origin.

Atmospheric Crude Tower

Crude distillation unit (CDU) is at the front-end of the refinery, also known as topping unit, or atmospheric distillation unit. It receives high flow rates hence its size and operating cost are some of the largest in the refinery. Many crude distillation units are designed to handle a variety of crude oil types.

In most refineries, this process is carried out in two stages. The oil is first heated to the maximum temperature allowable for the crude being processed and for the operation being practiced and then fed to a fractionating tower which operates at slightly above atmospheric pressure. It yields several distillate products and a bottoms product. This tower is usually called the atmospheric tower.

In fact, industrial distillation columns do not provide perfectly sharp separations. There are several causal factors such as, initial calculations using crude oil assays assume that all materials at a certain boiling point goes to one product or another, imperfect separations result in light ends & heavy ends “tails” in adjacent products and presence of tails complicate the definition of “cut point”.

The key to understanding crude columns is to understand that the atmospheric crude tower is a type of main fractionator. The important characteristics that distinguish main fractionators from other types of towers include all the heat available for the distillation enters the tower with the feed. Feed heat usually comes from a fired heater or a preheat train. The tower has multiple heat removal zones using either pump arounds or pump downs. Multiple side draw products leave the towers. All these characteristics make main fractionators different from classical distillation towers. Main fractionators have intimately linked heat and material balances. Understanding their operation requires tracking how heat and material balances affect each other.

There are many available guidelines developed to aid engineers in selecting and sizing the refinery atmospheric crude tower, but mostly these guidelines are developed by certain companies and might only be suitable for the application of the refinery atmospheric crude tower provided by their own companies. Hence, it is important to obtain a general understanding of refinery atmospheric crude tower sizing and selection and whenever changes are needed in a process system, this basic knowledge is still applicable. This handbook is made to provide that fundamental knowledge and a step by step guideline; which is applicable to properly select and size refinery atmospheric crude tower in an independent manner.

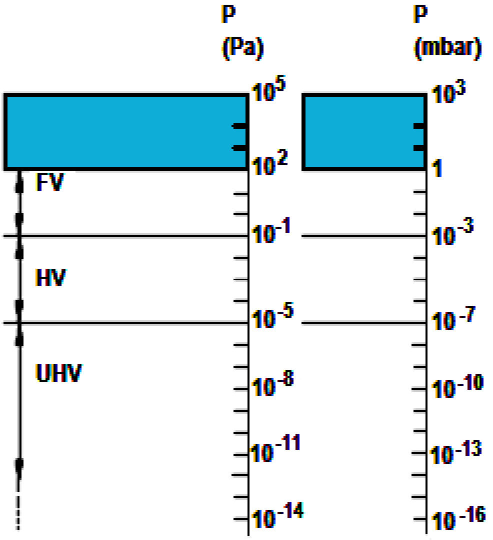
Selection of refinery atmospheric crude tower is based on the method used for heat removal. The processes are typically composed of series of flash drums, type U, type A and type R. Whereas, in sizing the tower, there are several aspects that should be considered.

Vacuum Tower

A vacuum is a space entirely devoid of matter “absolute vacuum”, when the air pressure in a space lies below atmospheric pressure. In physics, a vacuum is defined as “a state of emptiness that can be achieved by experiment” – in other words, nothing. This definition refers to the state of a space entirely devoid of matter (sometimes also referred to as an “absolute vacuum”). In practice, however, this state cannot be achieved. Therefore, talk instead about a vacuum when the air pressure in a space is lower than the atmospheric pressure or when the density of air molecules is reduced.

The vacuum plays a vital role in research in the fields of chemistry, biology and physics. It is also indispensable in many industrial processes. Noteworthy examples include semiconductor manufacture or mass spectroscopy. Vacuum technology has also plays a part in the development and implementation of new ideas in handling technology, i.e. lifting, holding, rotating and transporting all kinds of parts.

The vacuum ranges below are classified per physical attributes and technical requirements.



GV = Rough vacuum
FV = Medium vacuum
HV = High vacuum
UHV = Ultra-high vacuum

Figure 1.4: Vacuum ranges

Table 1.3: Vacuum range and its application

Vacuum range	Pressure range (absolute	Applications
Rough vacuum	Atmospheric pressure 1 mbar	Applications in industrial handling technology. In practice, the vacuum level is often specified as a percentage, i.e. the vacuum is defined in proportion to its ambient pressure. The material and the surface finish of workpieces play a major role in vacuum applications.
Medium vacuum	10^{-3} … 1mbar	Steel degassing, light bulb production, drying of plastics, freeze drying of foodstuffs, etc.
High vacuum	10^{-3} … 10^{-8} mbar	Smelting or annealing of metals, electron tube manufacture.
Ultra-high vacuum	10^{-8} … 10^{-11} mbar	Spraying of metals, vacuum metallizing (coating of metals) as well as electron beam melting.

The production of vacuum (subatmospheric pressure) is required for many chemical engineering processes, for example, vacuum distillation, drying, and filtration. The type of vacuum pump needed will depend on the degree of vacuum required, the capacity of the system, and the rate of air in-leakage. Reciprocating and rotary positive displacement pumps are commonly used where moderately low vacuum is required, about 10mmHg (0.013 bar), at moderate to high flow rates, such as in vacuum filtration. Steam-jet ejectors are versatile and economic vacuum pumps and are frequently used, particularly in vacuum distillation. They can handle high vapor flow rates and, when several ejectors are used in series, can produce low pressures, down to about 0.1mmHg (0.13 mbar).

Vacuum towers are one of the simpler refinery units since they are not a conversion unit like a hydro-cracker or FCCU. However, vacuum units are important because, along with crude units, they process a major portion of a refiney's incoming crude. Crude and vacuum unit performance affects all downstream operations.

Vacuum units have improved over the years. Originally, many vacuum units had trays for mass transfer. In fuels type vacuum towers where low pressures improve heavy vacuum gas oil (HVGO) recovery and profitability, trays gradually were replaced with random packing. The packing had lower pressure drops than trays, reducing flash zone pressures and overall column pressure drop, but had fouling issues. In the '70s end '80s, structured packings were successfully installed in many units. Structured packing has an even higher capacity than random packing and is now the dominant contacting device in vacuum service with less fouling than random packing.

Desalter Unit

Oil produced in most oil fields is accompanied by water in the form of an emulsion that must be treated. In addition, this water normally contains dissolved salts, principally chlorides of sodium, calcium, and magnesium. If crude oil is left untreated, when it is processed in a refinery the salt can cause various operating and maintenance problems.

Salt occurs naturally in all crudes but can vary significantly in concentration and makeup between crudes. The salt content of crude oil is highly variable and results principally from production practices used in the field. Salt may be derived from reservoir, aboard tankers, ballast water of varying salinity, formation waters or from other waters used in secondary recovery operations.

The salt content of crude oil almost always consists of salt dissolved in small droplets of water that are dispersed in the crude. Sometimes the produced oil contains crystalline salt, which forms because of pressure and temperature changes and because of stripping of water vapor as the fluid flows up the wellbore and through the production equipment.The bulk of the salt present will be dissolved in coexisting water and can be removed in Desalter, but small amounts of salt may be dissolved in the crude oil itself.

The salts that are most frequently found present in crude oil feedstocks are sodium, calcium and magnesium chlorides ($NaCl$, $CaCl_2$ and $MgCl_2$) although other forms of salt can be present in smaller quantities. If these compounds are not removed from the oil several problems arise in the refining process.

Metals from salts can also cause catalyst deactivation and sintering which result in lower catalyst activity. Sodium has been found to be the most harmful metal for catalysts. This decrease in activity implies that used catalyst must be replaced more often to maintain a given activity level.

The amount of salt going into the charge furnace must be controlled to minimize corrosion in the downstream equipment. Since facilities are designed for a specific corrosion allowance it is critical that salt and corrosion to be controlled and to stay at or below the design limits.

The purpose of desalting is to remove contaminants from crude oil before it enters the processing units. By removing the contaminants at the onset it is possible to minimize corrosion and fouling in downstream units.

Refiners usually desalt the entering crude to less than 1 PTB (lb salt/1000 bbl) or the salt content on crude. Desalting in the field reduces corrosion downstream while the crude is transported either in pipelines or tankers. In addition the desalted water can, after suitable treatment, be re-injected back into the reservoir. This solves any environmental problems.

Although not widely used in production facilities, desalting of crude oil in the field is required where produced water has a significant salt content. Refineries perform this function, but they are having increasing problem disposing the salt in environmentally stringent locations. Salt should be reduced below 10 to 30 pound per 1000 barrels (PTB) to prevent corrosion and/or heat exchanger fouling.

Desalting which follows the initial dehydration or emulsion breaking, consist of:

1. Adding dilution (or less saline) water to the crude
2. Mixing this dilution water with the crude to dilute the sediment and water (S&W)droplets in the crude
3. Dehydration (emulsion treating) to separate the crude oil and diluted brine (S&W) phases.

The result is to dilute the original S&W droplets and so reduce the salt content (PTB) for comparable levels of crude dehydration (remnant vol % S&W). Desalting can be performed in a single stage or in two stages, depending on the requirements of the refinery. Dehydration efficiency of a Desalter is usually 95% in a single stage and up to 99% in two stages.

The desalting process is similar to the dehydration stage in electrostatic coalescer. The difference is the injection of less saline diluent water and the use of a mixing valve for crude / diluent water contact. Desalting is a process whereby fresh water is mixed with the crude oil. The fresh or low salinity water dissolves crystalline salt in the oil or dilutes the entrained produced salt water. When the oil is dehydrated, any entrained water left in the oil will be less salty, thus reducing the crude oil's salt content (PTB) to specification. This is the basic approach used by all field desalting system.

The efficiency of the development of desalting systems has always been evaluated in terms ofquantities of salt and water being removed. In this respect, heating crude oil streams has been acrucial part of various desalting/dehydrationor refining processeswhere water may be driven offas steam at the end. Salts present in the water, however, do not leave with the steam. They crystallize and may either remain suspendedin oil or causes scale forming within heat-exchangerequipment. Those entrained salt crystals may deactivate catalyst beds and plug processingequipment.

When designing a Desalter, its type and size are all dependent on a number of operational factors such as required pressure, temperature, viscosity and flow rate, as well as user specification relating to maximum salt amount (PTB) allowed in the product oil stream.

Installing a Desalter in crude oil production is to minimize the occurrence of water in oil emulsions which the main objectives are (Bartley, 1982):

1. Maintaining production rate in a field,
2. Decreasing the flow of salt content to refinery distillation feedstocks,
3. Reducing corrosion caused by inorganic salts and
4. Minimizing energy required for pumping and transportation

The desalting process involves six major steps:

1. Separation by gravity settling,
2. Chemical injection,
3. Heating,
4. Addition of less salty water (dilution),
5. Mixing and
6. Electrical coalescing.

Hydrotreaters

Oil and natural gas are the most important raw materials for the organic chemical industry. Oil is a complex mixture, its composition depends on the location where it is produced. The most important components are:

1. Hydrocarbons (alkanes, alkenes, cycloalkanes, aromatics)
2. Sulphur compounds
3. Nitrogen compounds
4. Oxygenates.

There are many methods that may be employed to remove acidic components (primarily H_2S and CO_2) and other impurities from hydrocarbon streams. The available methods may be broadly categorized as those depending on chemical reaction, absorption, adsorption or permeation.

Hydrotreaters are the most common process units in modern petroleum refineries. hydrotreating catalysts represent 10% of the annual sales of the total market of catalysts. In hydrotreating units, reactions that convert organic sulfur and nitrogen into H_2S and NH_3 also produce light hydrocarbons.

In hydrotreating catalytic hydrogenation takes place in which double bonds are hydrogenated and S, N, O and metals, are removed from molecules and aromatic molecules are hydrogenated using hydrogen as a reactant. These processes use catalysts based on transition metal sulfides.

The common objectives and applications of hydrotreating are listed below:

1. Naphtha (catalytic reformer feed pretreatment) : to remove sulfur, nitrogen, and metals that otherwise would poison downstream noble metal reforming catalysts
2. Kerosene and diesel : to remove sulfur and to saturate olefins and some of the aromatics, resulting in improved properties of the streams (kerosene smoke point, diesel cetane number or diesel index) as well as storage stability
3. Lube oil : to improve the viscosity index, color, and stability as well as storage stability
4. FCC feed : to improve FCC yields, reduce catalyst usage and stack emissions
5. Resids : to provide low sulfur fuel oils to effect conversion and/or pretreatment for further conversion downstream.

Table 1.4: Feeds and product objectives for different kinds of hydrotreaters

Feed	Products from Hydrotreating
Naphtha	Catalytic reformer feed
Straight-run light gas oil	Kerosene, jet fuel
Straight-run heavy gas oil	Diesel fuel
Atmospheric residue	Lube base stock, low-sulfur fuel oil, RFCC* feed
Vacuum gas oil	FCC feed, lube base stock
Vacuum residue	RFCC* feed
FCC light cycle oil	Blend stocks for diesel, fuel oil
FCC heavy cycle oil	Blend stocks for diesel, fuel oil
Visbreaker gas oil	Blend stocks for diesel, fuel oil
Coker gas oil	FCC feed
Deasphalted oil	Lube base stock, FCC feed

*RFCC = “residue FCC unit” or “reduced crude FCC unit,” which are specially designed to process feeds that contain high concentrations carbon-forming compounds.

The following chemical steps and/or reactions occur during the hydrotreating process (depending on the impurities present):

1. Sulfur removal, also referred to as desulfurization or hydro-desulfurization (HDS) in which the organic sulfur compounds are converted to hydrogen sulfide
2. Nitrogen removal, also referred to as denitrogenation or hydro-denitrogenation (HDN) in which the organic nitrogen compounds are converted to ammonia
3. (Organo-metallic) metals removal, also referred to as hydro-demetallation or hydrodemetallization, in which the organo-metals are converted to the respective metal sulfides
4. Oxygen removal, in which the organic oxygen compounds are converted to water
5. Olefin saturation, in which organic compounds containing double bonds are converted to their saturated homologues

6. Aromatic saturation, also referred to as hydro-dearomatization, in which some of the aromatic compounds are converted to naphthenes
7. Halides removal, in which the organic halides are converted to hydrogen halides

Refinery Furnace

Fired heaters and boilers are essential components of most refineries, chemical plants and power generation facilities. Process heaters are widely used in petroleum refineries, where they are called refinery heaters. Process heaters are used to transfer heat generated by the combustion of fuels to a fluid other than water contained in tubes. This fluid may either be process fluid or a heat transfer fluid.

They are used for pre-heating crude oil and other feed stocks for many refinery processes where the use of steam from boilers may not be practical. Process heaters are useful where a temperature higher than that easily obtainable with steam is necessary. Process heaters bum a variety of fuels, including natural gas, refinery and process gas and distillate and residual oils. Process heaters are widely used in petroleum refineries, where they are called refinery heaters. Applications include

- preheating crude oil and other feeds for distillation,
- hydrotreating,
- reforming and
- coking.

In some operations, such as thermal cracking, chemical reactions occur in the process heater tubes. Total annual process heater energy consumption in refineries is approximately 2.3 quadrillion Btu, equivalent to a mean of 260,000 MMBtu/hr (on a three-shift, 365-day basis).

Typical process heaters can be summarized as follows:

- Start-Up Heater — Starts-up a process unit where it is required to heat up a fluidized bed of catalyst before adding the charge.
- Fired Reboiler — Provides heat input to a distillation column by heating the column bottoms and vaporizing a portion of it. Used where heat requirement is greater than can be obtained from steam.

- Cracking Furnace — Converts larger molecules into smaller molecules, usually with a catalyst (pyrolysis furnace).
- Process Heater — Brings feed to the required temperature for the next reaction stage.
- Process Heater Vaporizer — Used to heat and partially vaporize a charge prior to distillation.
- Crude Oil Heater — Heats crude oil prior to distillation.
- Reformer Furnace — Chemical conversion by adding steam and feed with catalyst.

One of the problems encountered in refinery fired heater is an imbalance in the heat flux in the individual heater passes. This imbalance may cause high coke formation rates and high tube metal temperatures, which reduce a unit’s capacity and can cause premature failures. Coke formation on the inside of heater tubes reduces the heat transfer through the tubes, which leads to the reduced capacity.

The choice of refinery heater style and design is crucial for the best performance of furnace. Factors affecting the performance of refinery heater are influenced by the maximum amount of the heat absorbed, the capacity of burners, process requirements, economics and safety.

Catalytic Reforming

The problem of low octane ratings of naphtha is solved by increasing the contents of isomers and aromatics in its composition. In the catalytic reforming unit of a refinery, the objective is to convert lower octane value naphtha into higher octane reformate that can be used for gasoline blending. The function of the reformer is to efficiently convert paraffins and naphthenes to aromatics with as little ring opening or cracking as possible. Catalytic reforming is a process whereby light petroleum distillates (naphtha) are contacted with a platinum-containing catalyst at elevated temperatures and hydrogen.

Reforming involves some reactions such as Isomerization, Dehydrogenation, and Dehydrocyclization which convert the low octane number components in naphtha into very high octane number components, consequently enhancing the antiknock quality of gasoline. The principal reforming reactions are the cracking of paraffins, paraffins isomerisation, dehydrocyclisation of paraffins to naphthenes and the dehydrogenation of naphthenes. The cyclisation and dehydrogenation reactions produce valuable aromatics.

In BTX production, the objective is to transform paraffins and naphthenes into benzene, toluene, and xylenes with minimal cracking to light gases. The yield of desired product is the percentage of feed converted to these aromatics. In motor fuel applications, octane values of the feed may be raised via aromatization or through isomerization of the paraffins into higher octane branched species without sacrificing yield. Yield is typically defined as liquid product with five or more carbons.

Catalytic reforming is a major conversion process in petroleum refinery and petrochemical industries. Catalytic reforming is a process whereby light petroleum distillates (naphtha) are contacted with a platinum-containing catalyst at elevated temperatures and hydrogen pressures ranging from 345 to 3,450 kPa (50–500 psig) for the purpose of raising the octane number of the hydrocarbon feed stream. The low octane, paraffin-rich naphtha feed is converted to a high-octane liquid product that is rich in aromatic compounds. catalytic reforming produces reformate with octane numbers of the order of 90 to 95. Hydrogen and other light hydrocarbons are also produced as reaction by-products. In addition to the use of reformate as a blending component of motor fuels, it is also a primary source of aromatics used in the petrochemical industry.

Catalytic reforming processes are commonly classified into three types based on the regeneration systems of the catalyst, namely (i) semi-regenerative catalytic reformer process, (ii) cyclic regenerative catalytic reformer process and (iii) continuous catalytic regeneration reformer process. The mechanism for the regeneration steps could be classified into fixed-bed catalyst system; fixed-bed catalyst combined a swing reactor and a moving bed catalyst with special regenerator.

BTX

Benzene, Toluene, and Xylene are become the lowest molecular weight of the aromatic class. They are very beneficial for petrochemical feedstocks. They are considered as one group because in real application, benzene, toluene and xylene are produce in the same process. The familiar name is “BTX”.

Originately produced from commercial pyrolysis of coal, BTX production shifted to gasoline production. These aromatic compounds have such high value octane number that made them good components to be mixed with gasoline products to alter its octane number as market requirements

Benzene, Toluene and Xylene combined produce one of the largest aromatic volumes that is used in the petrochemical industry. Toluene could be converted to Benzene to fulfilled market demand by hydroalkylation process. Products separation is required to split each into pure components. Thus, separation process could be consisted of: Extraction, Distillation, Crystallization or combination of all of those processes.

Catalytic Cracking

The fluid catalytic cracking process (FCC) is defined as a process for the conversion of feedstock like straight-run atmospheric gas oils, vacuum gas oils, and heavy stocks into high-octane gasoline, light fuel oils, and olefin-rich light gases. In the late 1950’s, catalytic cracking was more than 60 per cent from all refingin cracking capacity. The features of FCC process are reliable operations and the ability to adjust the products.

Catalytic cracking process is typically applied on distilled gas-oil charge stocks with average yields about 40 – 45 % of gasoline. The process widey applied due to the minimal product yields of residual fuel oil compare to other process such as thermal cracking. Large volumes of olefinic production could be produced with good gas recovery, purification systems and further conversion to salable products like gasoline derivatives.

The goal of this refinery fluidize catalytic cracking gudieleine is to review the technical aspects of how a fluid catalytic cracking unt is designed and operates. Starting whih the history of fluid catalytic cracking technology, and how it has been improved for decades, what are the factors which influenced the process and how it corresponded to economical considerations.

DEFINITIONS

Absolute viscosity – A measurement of fluid for its resistance to internal deformation or shear.

Absorption: A separation process involving the transfer of a substance from a gaseous phase to a liquid phase through the phase boundary.

AC – Alternating electrical current

Acid Gases: Impurities in a gas stream usually consisting of CO_2, H_2S, COS, RSH, and SO2. Most common in natural gas are CO_2, H2S and COS.

Adsorption: The process by which gaseous components adhere to solids because of their molecular attraction to the solid surface.

Air Preheater - Heat exchanger device that uses some of the heat in the flue gases to raise the temperature of the air supply to the burners.

Alkanolamine: An organic nitrogen bearing compound related to ammonia having at least one, if not two or three of its hydrogen atoms substituted with at least one, if not two or three linear or branched alkanol groups where only one or two could also be substituted with a linear or branched alkyl group (i.e. methyldiethanolamine MDEA). The number of hydrogen atoms substituted by alkanol or alkyl groups at the amino site determine whether the alkanolamine is primary, secondary or tertiary.

Alkylation - the process in which isobutane reacts with olefins such as butylene to produce a gasoline range alkylate.

Aniline point - the minimum temperature for complete miscibility of equal volumes of aniline and a test sample. This test is an indication of paraffinicity and the ignition quality of diesel.

Antifoam: A substance, usually a silicone or a long-chain alcohol, added to the treating system to reduce the tendency to foam.

API gravity - an arbitrary scale expressing the density of petroleum products.

Aromatic molecules - Any of a large class of organic compounds whose molecular structure includes one or more planar rings of atoms, usually but not always six carbon atoms. The ring's carbon-carbon bonds (bonding) are neither single nor double but a type characteristic of these compounds, in which electrons are shared equally with all the atoms around the ring in an electron cloud.

ASTM distillation - standardized laboratory batch distillation for naphtha and middle distillate at atmospheric pressure.

ASTM gap - the difference between the ASTM 5% boiling point of the heavier product and the 95% point of the lighter product.

Atmospheric tower - distillation unit operated at atmospheric pressure.

Benzene – An aromatic compound with single ring and composed of six carbon atoms and six hydrogen atoms (C_6H_6).

Breeching - The hood that collects the flue gas at the convection section exit.

Bridge-wall Temperature - The temperature of the flue gas leaving the radiant section

Bulk Temperature - The average temperature of the process fluid at any tube cross section.

Carbon rejection – A process in order to reduce the number of carbon elements within

Catalysis – A process in which to rearrange and manipulate compounds to become different structure without changing the number of carbon and hydrogen elements.

Catalyst - A substance, usually used in small amounts relative to the reactants, that modifies and increases the rate of a reaction without being consumed in the process.

Catalytic - Causing a chemical reaction to happen more quickly

Catalytic cracking - the process of breaking up heavier hydrocarbon molecules into lighter hydrocarbon fractions by use of heat and catalysts.

Catalytic reforming - a process for improving the octane quality of straight-run naphtha and of mixed naphtha containing cracked naphtha

Center Wall - A refractory wall in the radiant section, which divides it into two separate cells.

Cetane number - The performance rating of a diesel fuel, corresponding to the percentage of cetane in a cetane-methylnaphthalene mixture with the same ignition performance. Related to ignition quality and defined as the time period between the start of injection and start of combustion (ignition) of the fuel.A higher cetane number indicates greater fuel efficiency. Also called cetane rating.

Characterization factor - a systematic way of classifying a crude oil according to is paraffinic, naphthenic, intermediate or aromatic nature.

Chelate: An organic molecule in which a central metallic ion is held in a coordination compound.

Claus Process: The process in which one third of the H_2S is burned to SO_2 which is then reacted with the remaining H_2S to produce elemental sulfur.

Cloud point - temperature at which a haze appears in a sample which is attributed to the formation of wax crystals.

Coil - A series of straight tube lengths connected by 180° return bends, forming a continuous path through which the process fluid passes and is heated.

Coke - formed in the processes to convert the residuum fuels to the more desirable distillate products of naphtha and lighter through to the middle distillates

Convection Section - The portion of a heater, consisting of a bank of tubes, which receives heat from the hot flue gases, mainly by convection.

Corbelling - Narrow ledges extending from the convection section side walls to prevent flue gas from flowing preferentially up the side of the convection section, between the wall and the nearest tubes.

Crackability – An easiness feedstock to be converted in fluid catalytic cracking unit.

Crossover - Piping which transfers the process fluid either externally or internally from one section of the heater to another.

Crude assay - a procedure for determining the general distillation and quality characteristics of crude oil.

Crude oil - a mixture of hydrocarbon compounds. These compounds range in boiling points and molecular weights from methane as the lightest compound to those whose molecular weight will be in excess of 500.

Cut point - temperature on the whole crude TBP curve that represents the limits (upper and lower) of a fraction to be produced (yield of a fraction).

Damper - A device to regulate flow of gas through a stack or duct and to control draft in a heater.

Deasphalting - The process of removing asphalt from petroleum fractions.

De-butanizers - A fractionator designed to separate butane (and more volatile components if present) from a hydrocarbon mixture De-butanizers are used in refineries to remove butanes and lighter compounds from product streams

Degradation Products: Impurities in a treating solution that are formed from both reversible and irreversible side reactions.

Dehydration – Removing water droplets or S&W or BS&W from crude oil (sometimes called treating)

Demulsifier – or demulsifying chemicals are a mixture of chemicals used to break the emulsion by destroying a weakening the stabilizing film around the dispersed droplets.

Denitrogenation - Removal of nitrogen dissolved in the bloodstream and body tissues by breathing 100% oxygen for an extended period.

Dependent variables – A parameters in which has been fixed and dependable to other operating process.

Desalination - Process of removing salts from water sources

Desalting – Reducing the salt content of a crude oil by diluting the entrained/emulsified water and then dehydrating.

Desulfurization - The process of removing sulfur from a substance, such as flue gas or crude.

Distillate - the products of distillation formed by condensing vapors.

Downstream process – A part of crude oil processing after petroleum reached earth's surface in order to chemically modified and making them daily products.

Draft - The negative pressure (vacuum) at a given point inside the heater, usually expressed in inches of water.

Electrodes or grid – plates or rods used to establish the electric field in electrostatic treaters.

Electrostatic treater -treater using electric fields in the oil coalescing area.

Emulsifier - in addition to oil and water, a third substance called an emulsifier or emulsifying agent must be present for a stable emulsion to be produced. The emulsifiers usually exist as a film on the surface of the dispersed droplets.

Emulsion – a combination of two immiscible liquids. One liquid is broken into droplets and is known as the discontinuous, dispersed, or internal phase. The liquid that surrounds the drops is continuous or external phase.

End points - the actual terminal temperatures of a fraction produced commercially.

Excess Air - The percentage of air in the heater in excess of the stoichiometric amount required for combustion

Exothermic - A process or reaction that release heat, i.e. a process or reaction for which the change in enthalpy, ΔH, isnegative at constant pressure and temperature

Extended Surface - Surface added to the outside of bare tubes in the convection section to provide more heat transfer area.

Extraction - A process for separating components dissolved in a liquid feed by contact with a second liquid phase.

F-Factor - the ratio of the hot gallons per hour (GPH) of the lightest product from draw off tray to the total vapor product (cold GPH) leaving the lightest product draw off tray.

Film - A thin fluid layer adjacent to a pipe wall that remains in laminar flow, even when the bulk flow is turbulent.

Film Temperature - The maximum temperature in the film, at the tube wall.

Finishing - the purification of various product streams by processes such as desulfurization or acid treatment of petroleum fractions to remove impurities from the product or to stabilize it.

Fire Box - A term used to describe the structure which surrounds the radiant coils and into which the burners protrude.

Fired Heater Efficiency - The ratio of heat absorbed to heat fired, on a lower heating value basis.

Fixed-Bed – A kind of an first catalytic cracking process which employed a series of chambers

Flash point - the temperature at which the vapor above the oil will momentarily flash or explode.

Flue Gas - A mixture of gaseous products resulting from combustion of the fuel.

Fluid catalytic cracking (FCC) - the main player for the production of gasoline. The catalyst in this case is a zeolite base for the cracking function.

Fluidized-Bed – A last technology of catalytic cracking which most efficient and effective to be implied.

Forced Draft - Use of a fan to supply combustion air to the burners and to overcome the pressure drop through the burners.

Fouling – The reduction in performance of process equipment (heat transfer tubing, membranes, etc.) that occurs as a result of scale buildup, biological growth, or the deposition of colloidal material.

Fractionating tower - process unit that separates various fractions of petroleum by simple distillation, with the column tapped at various levels to separate and remove fractions according to their boiling ranges.

Fractionation criteria - a correlation between Reflux Ratio, N, G and ΔT50% TBP between the adjacent cuts.

Fractionator - A mixture substance composed from hydrocarbon-rich gases.

Freezing point - temperature at which the hydrocarbon liquid solidifies at atmospheric pressure.

Furans - One of a group of colorless, volatile, heterocyclic organic compounds containing a ring of four carbon atoms and one oxygen atom, obtained from wood oils and used in the synthesis of furfural and other organic compounds.

Gas concentration unit – A unit in which unstable gasoline are separated into fuel gas and C_3 – C_4.

Grain: A unit of mass where one pound is equivalent to 7,000 grains and a specification of 0.25 grain of H2S per 100 SCF is equivalent to an H2S concentration of 4.0 ppmv.

Gravity separation - refers to the primary free settling of water and is related to the residence time that takes place in both settling tanks and desalting vessels.

Header Box - The compartment at the end of the convection section where the headers are located.

Heat Available - The heat absorbed from the products of combustion (flue gas) as they are cooled from the flame temperature to a given flue gas temperature.

Heat Density - The rate of heat transfer per unit area to a tube, usually based on total outside surface area.

Heat Duty - The total heat absorbed by the process fluid, usually expressed in MBtu/hr

hydrocarbon compounds.

Hydrogen addition – A process in which to extend the number of hydrogen elements within hydrocarbon molecules.

Hydrotreating - Oil refinery catalytic process in which hydrogen is contacted with petroleum intermediate or product streams to remove impurities, such as oxygen, sulfur, nitrogen, or unsaturated hydrocarbons.

Independent variables – A variables that not correlated and dependable to other operating process.

Induced Draft - Use of a fan to provide the additional draft required over that supplied by the stack, to draw the flue gas through the convection section, and any downstream heat recovery equipment.

Inorganics – A space in which composed not only hydrocarbon elements but also inorganic elemets like sulphur (S) and nitrogen (N).

Interface – the contact surface between the boundaries of the two immiscible liquids (e.g., the surface area between water droplets and the surrounding oil or the surface between separated crude and water in a vessel.

Isomerization of light naphtha - the process in which low octane number hydrocarbons (C4, C5, C6) are transformed to a branched product with the same carbon number.

LHSV (Liquid hourly space velocity) - Usually feed flow rate divided by catalyst mass or volume in heterogeneous catalysis

Liquid Oil – A mixture substance composed by liquid phase petroleum (crude oil).

Loading Capacity – A term refers to a maximum content of solute within the extract before it separate. Loading capacity could be determined by the point in which all the extractant in solution is completely occupied by solute.

Lower Heating Value (LHV) - The theoretical heat of combustion of a fuel, when no credit is taken for the heat of condensation of water in the flue gas.

Lubricant - any material interposed between two surfaces that reduces the friction or wear between them.

Maldistribution - Non-uniform liquid/gas flow leads to poor catalyst utilization, resulting in lower than expected activity and cycle length.

Mass Velocity - The mass flow rate per unit of flow area through the coil. Typical units are lb/s-sq. ft.

Membrane – In desalting, used to describe a semipermeable film. Membranes used in electrodialysis are permeable to ions of either positive or negative charge. Reverse osmosis and nanofiltration membranes ideally allow the passage of pure water and block the passage of salts

Mercaptans - A group of sulfur-containing organic chemical substances. They smell like rotting cabbage, and are, for the most part, what make pulp mills smell like pulp mills. If mercaptans are in the air, even at low concentrations, they are very noticeable.

Mid boiling point components - typically useful in compiling the assay narrow boiling fractions are distilled from the crude, and are analyzed to determine their properties by plotting against the mid boiling point of these fractions

Moving-Bed – A kind of next generation catalytic cracking process that consisted of Thermofor and Houdry air-lift process.

Naphtha - Normally refers to a number of flammable liquid mixtures of hydrocarbons, i.e., a component of natural gas condensate or a distillation product from petroleum, coal tar or peat boiling in a certain range and containing certain hydrocarbons.

Naphthenes - saturated hydrocarbon groupings with the general formula C_nH_{2n}, arranged in the form of closed rings (cyclic).

Natural Draft - System in which the draft required to move combustion air into the heater and flue gas through the heater and out the stack is provided by stack effect alone.

Natural Gas - A mixture substance composed from hydrocarbon-rich gases.

Net Fuel - The fuel that would be required in the heater if there were no radiation losses.

NMP – N-methyl 1-2-pyrrolidinone, refer to the one a kind of extractive distillation process in which main solvent is N-methyl 1-2-pyrrolidinone.

Octane numbers - a measure of a gasoline' s resistance to knock or detonation in a cylinder of a gasoline engine. The higher this resistance is the higher will be the efficiency of the fuel to produce work.

Oil-in-water (o/w) emulsion – an emulsion consisting of oil drops disperse in a continuous water phase. This do-called reverse emulsion often occurs on waste waters and produced brines. The water content is generally greater than 85 volume percent.

Olefin - Any of a class of unsaturated open-chain hydrocarbons such as ethylene, having the general formula CnH2n; an alkene with only one carbon-carbon double bond.

Once-through process – A kind of process which only applied on pilot plant scale.

One-Side Fired Tubes - Radiant section tubes located adjacent to a heater wall have only one side directly exposed to a burner flame. Radiation to the back side of the tubes is by reflection/ re-radiation from the refractory wall.

Overflash - to provide additional heat (over and above that set by the product vaporization required) required by the process to generate the internal reflux required by the process.

Partial pressure - the contribution of one component of a system to the total pressure of its vapor at a specified temperature and gross composition.

Partition Ratio – A proportion that show a minimum amount of solvent that allowed for extraction process.

Pass - A coil that transports the process fluid from fired heater inlet to outlet.

Petrochemical process – A process in which purposes of further modification of first derivative petroleum products to intermediate chemical compounds or daily basis products.

Physical Solvent: A liquid capable of absorbing selected gas components by solubility alone without associated chemical reactions.

Polythionic acid - an oxoacid which has a straight chain of sulfur atoms and has the chemical formula $H_2S_nO_6$

Pour point - the temperature at which the oil ceases to flow.

ppmv: A volume concentration of a species in a bulk fluid measured in parts per million.

Precipitate – A substance separated from a solution by chemical or physical change as an insoluble amorphous or crystalline solid.

Pressure drops - the difference in pressure between two points of a fluid carrying network. Pressure drop occurs when frictional forces, caused by the resistance to flow

Production – A branch of crude oil petroleum processing in which bringing crude oils to earth’s surface.

Radiant Section - The section of the fired heater in which heat is transferred to the heater tubes primarily by radiation from high-temperature flue gas.

Reactor – A vessel where main catalytic cracking reaction achieved.

Reboiler - an auxiliary unit of a fractionating tower designed to supply additional heat to the lower portion of the tower.

Refinery process – A process which aiming the recovery of usable fraction from crude oil either using physical and chemical modification to get the first derivatives petroleum products.

Reflux - the portion of the distillate returned to the fractionating column to assist in attaining better separation into desired fractions

Regenerator - A unit including reboiler, still column and other related facilities to regenerate (or re-concentrate)

Reid vapour pressure (RVP) - the vapour pressure determined in a volume of air four times the liquid volume at 37.8 ^{o}C (100 ^{o}F)

Residence Time - The time period for which a fluid will be contained within a specified volume.

S&W content – Oil, as produces from the well and production equipment, may contain considerable amounts of brine, as well as solid materials. The water solids content is refferes to as sediment and water (S&W) or basic sediment and water (BS&W).

Saline water – Water with dissolved solids exceeding the limits of potability. Saline water may include sea water, brackish water, mineralized ground and surface water, and irrigation return flows.

Salt diffusion – The movement of ions or molecules under influence of a concentration difference.

Saturated-chain hydrocarbon – A kind of hydrocarbon that aim to paraffinic and cycloparaffinic compounds.

Selective Treating: Preferential removal of one acid gas component, leaving at least some of the other acid gas components in the treated stream.

Separation - a physical process where compounds are separated by different techniques.

Service Factor – A measure of the continuity of operation, generally expressed as the ratio of total running days for a given time period to the total calendar days in the period.

Shield Section - The first two tube rows of the convection section.

Smoke point - an indication of the smoking tendency of fuel. It is used for evaluating the ability of kerosene to burn without producing smoke.

Solubility – A measure of the maximum amount of a certain substance that can dissolve in a given amount of water, or other solvent, at a given temperature.

Sootblower - A steam lance (usually movable) in the convection section for blowing soot and ash from the tubes using high-pressure steam.

Sour Gas: Gas containing undesirable quantities of hydrogen sulfide, mercaptans and/or carbon dioxide.

Space velocity - The relationship between feed rate and reactor volume in a flow process; defined as the volume or weight of feed (measured at standard conditions) per unit time per unit volume of reactor (or per unit weight of catalyst).

Specific conductance (conductivity) – Quantitative expression for the capability of a particular solution to conduct electricity. It is defined as the conductance of a cube of that particular water that is 1 cm long and has a cross sectional area of 1 cm^2. Conductivity is usually expressed in micromohos per centimeter.

Stack - A cylindrical steel, concrete or brick shell which carries flue gas to the atmosphere and provides necessary draft.

Stack Effect - The difference between the weight of a column of high-temperature gases inside the heater and/or stack and the weight of an equivalent column of external air, usually expressed in inches of water per foot of height.

Stack Temperature - The temperature of the flue gas as it leaves the convection section, or air preheater directly upstream of the stack.

Stage – A unit of desalting equipment capable of purification and separation of the feed water into product and concentrate. If separation is insufficient, more than one stage can be arranged in series

Stripping - the removal (by steam-induced vaporization or flash evaporation) of the more volatile components from a cut or fraction.

Sulfur content - a measure of “sourness” & “sweetness” of crude passed onto products as much as regulations or market accepts.

Tar and Bitumen – A mixture substance formed mostly from high-molecular weight solids.

TEG – Tetraethylene Glycol, refer to the one a kind of extractive distillation process in which main solvent is tetraethylene glycol.

The material balance - the process represented by the process flow diagram is either shown in table form on the bottom of the flow sheet or on an attached but separate table

Threshold Limit Value: The amount of a contaminant to which a person can have repeated exposure for an eight hour day without adverse effects.

Toluene – Another name of “methylbenzene” composed by seven carbon atoms and eight hydrogen atoms (C_7H_8)

Turbidity – Opaqueness or cloudiness caused by the presence of suspended particles in water, usually stirred-up sediments. The turbidity of a water is measured by its capacity for absorbing or scattering light.

Two-Side Fired Tubes - Radiant section tubes which are exposed on both sides to direct radiation from the burners.

Unsaturated-chain hydrocarbon – A kind of hydrocarbon which could be produced by fluid catalytic cracking units, steam cracking and low polymerization of low molecular weight components.

Upstream process – A process to bringing up crude petroleum oils flew out from earth's subsruface to above the soil.

Visbreaking - a mild thermal cracking process used to break the high viscosity and pour points of vacuum residue to the level which can be used in further downstream processes.

Viscosity - resistance to flow, usually measured at 100 ^{o}F.

Water-in-oil (w/o) emulsion – Crude oil emulsions nearly always consist of water drops dispersed in a continuous oil phase. This type is also called a regular or normal emulsion

Wetting – refers to the adhesion or sticking of a liquid to a solid surface. If the solid surface (grain of reservoir rock, fines, etc) is covered preferentially by oil, the surface is called oil wetted. Conversely, if water is preferentially attracted, the surface is water wetted.

Xylene – An aromatic compound with single ring and composed by eight carbon atoms and ten hydrogen atoms (C_8H_{10}).