PETROLEUM
Refining Technology

Dr. Ram Prasad

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PETROLEUM REFINING TECHNOLOGY

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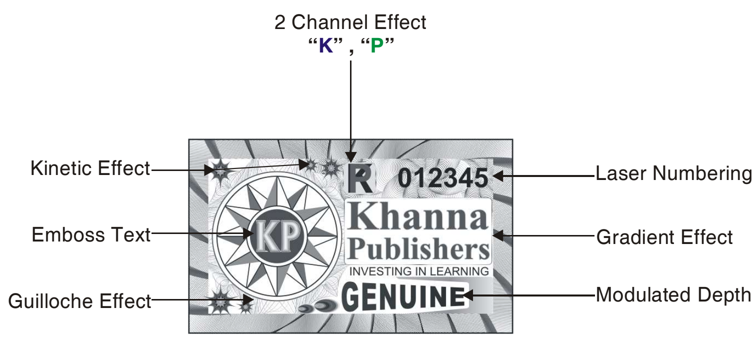

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PREFACE

It gives me a great pleasure in presenting the book on "Petroleum Refining Technology". The relevant topics for working Chemical/Petroleum Engineers in Petroleum Refineries have been covered.

The first chapter gives an account of theories of oil and gas formation, methods for exploration and drilling for oil and gas. It highlights the development of petroleum refining industry in India.

The knowledge of chemistry and composition of crude oil is essential in the selection of the refining processes. The characteristics, constituents and classification of crude oils have been discussed in Chapter 2.

Indian cruides such as Bombay High, Assam are waxy in nature. These require special method for transportation. The problem related to the handling of waxy crude oils and their feasible solutions have been discussed in Chapter 3.

Quality control of petroleum products is a necessary if the products are to give satisfactory performance to the customers. Bureau of Indian Standard, New Delhi standardizes procedures and issues specifications for each petroleum products. Definition, method and significance of the various laboratory tests have been given in Chapter 4.

Chapter 5 discusses manufacture, properties and uses of petroleum products. This chapter covers LPG, naphtha, gasoline, kerosin, ATF, diesel fuel, fuel oil, hydrocarbon solvents, lubricating oils, petroleum waxes, bitumen and petroleum coke.

Petroleum refining processes have been discussed in six chapters (6–11). Crude oil distillation is the first unit in the refinery and carried out in two stages-atmospheric and vacuum. Before discussing these processes the removal of impurities by electrical desalting process has been discussed. The influence of the process variables on the operation of a fractionating column and the scope for improvement have been discussed in Chapter 6.

Crude oil distillation produces reside which is to be upgraded. Thermal conversion processes for this purpose include visbreaking and coking. These processes have been discussed in Chapter 7.

Catalytic conversion processes use catalyst and either change carbon number or carbon/hydrogen ratio. The most important processes include fluid catalytic cracking, catalytic reforming, hydrocracking, catalytic alkylation, isomerization and polymerization. Catalytic isomerization neither changes carbon number nor carbon/hydrogen ratio. These processes have been discussed in Chapter 8.

Finishing processes are necessary to make the petroleum products suitable for use with respect to performance, corrosivity, suitability on storage, odour etc. Various finishing processes such as hydrogen sulphide removal processes, sulphur recovery processes, sweetening processes, solvent extraction processes and hydrotreating processes have been discussed in Chapter 8.

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Lubricating oils should possess and maintain proper viscosity, flow as liquid at the handling and operating temperature and have good thermal and oxidation stability. Lubricating oils of various grades are manufactured by mixing of the selected lubricating oils base stock and additives. A modern lube oil complex consists of vacuum distillation unit, solvent deasphalting unit, solved extraction unit, solvent dewaxing unit and hydrofinishing unit. These processes have been discussed in Chapter 10. The detail on the manufacture of petroleum waxes have also been presented in this chapter.

Chapter 11 discusses the manufacture of bitumen from crude oil.

Generation of processes engineers have accepted corrosion as a fact of life, an incurable virus whose progress may be slowed but never stopped. Corrosion can reduce the life of refinery units. Chapter 12 discusses types and forms of corrosion and their control in crude oil distillation, thermal cracking, fluid catalytic cracking, amine gas processing, and steam and condensate lines.

Air, water and soil are vital of life on this planet. These resources are to be protected and used wisely. Chapter 13 discusses air pollutions, water pollution and sludge treatment and disposal.

Chapter 14, highlights, designs and operation of petroleum processing equipments.

It is hoped that this book in its present form will be useful for the students of chemical engineering.

I will be highly grateful, if short comings of this edition inform of contents, errors are highlighted to me.

—Ram Prasad
Kanpur

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"PETROLEUM, EXPLORATION, PRODUCTION AND REFINING

1.1 INTRODUCTION

Energy is known to play a vital and important role in the industrial and economic development of any country. Petroleum provides a relatively cheap and convenient source of energy as compared to other fuels such as coal and electricity. India is the 4th largest consumer of petroleum products in the Asia-Pacific region and 15th largest consumer in the world. However, in crude oil production, India ranks 22nd in the world. The consumption is growing annually at 6-7 percent while production of crude oil is stagnating. This mismatch between domestic production of crude oil and consumption of petroleum products has increased the dependency on imports to 47 percent of crude oil and 15 percent of petroleum product requirements, which amounts to 25 percent of India's exports.

Petroleum is the foundation of the industrial civilization. It has shaped civilization since the ancient times. Many interesting references connected with the early use of petroleum, especially oil and bitumen, exist in ancient history. The 'eternal fires of Baku' were the result of the ignition of oil and natural gas from a seepage. The basket in which the baby Moses was hidden was made water-proof with bitumen. The Tower of Babel was constructed using bitumen as mortar. In the Far East oil was used for lighting. It was rubbed into the coats of camels to cure them of mange. The North American Indians used petroleum as a medicine. The Mexican Indians valued bitumen as chewing-gum. Christopher Columbus used bitumen to make his ship seaworthy. Marco Polo observed that mineral oil burned well to give both light and heat. It is said that when Alexander the Great visited Persia, the inhabitants sprinkled the street with oil and set it alight.

The occurrence of crude oil without gas is rare. On the contrary, large deposits of gas occur without oil, such as at Sind (Pakistan), Po (Italy) and Siberia (Russia). Oil is usually associated with gas in varying proportions known as gas/oil ratio depending upon its chemical nature and physical conditions of its occurrence like trap (natural barriers that prevent further flow of oil), depth, and temperature. Presence of gas in oil makes oil mobile and easily recoverable. The downstream products of crude oil on distillation and processing are varied and numerous. Some of the well known ones are fuel gas, petrol, domestic gas (LPG), naphtha, kerosine, diesel, fuel oil, lubricants, waxes and petroleum coke. Without oil, ships, trains, aeroplanes and industries will come to a halt.

1.2 FORMATION OF OIL AND GAS

There are two theories of the genesis of petroleum: the organic theory and non-organic theory. The former holds that petroleum is of an organic origin and is the currently favoured proposal. It predicts limited reserves worldwide; moreover Indian reserves are predicted as minimal. The latter maintains that it is of non-organic genesis, supposedly of primordial origin. On the basis of this theory, oil reserves would be much larger than those predicted by the organic theory. India, oil-poor in the organic theory, is predicted to be oil-rich in the non-organic one.

The non-organic theory that was much prevalent earlier suggests that oil is formed by the action of water on metallic carbides or by atmospheric radioactivity or by cosmic radiation. The rare occurrence of oil in meteorites, igneous dykes and in petrozoic rocks weighs in favour of the non-organic theory.

The organic theory which is the most prevalent today, suggests that the petroleum was formed from remains of plants and animals that died millions of years ago and accumulated on ocean floors. Tiny, minute marine animals and plants comprising mainly algae, fungi, diatoms and foraminifera used to float on the surface of the sea and were abundant during the Mesozoic (about 225 million years back) and Cainozoic (about 65 million years back) period. On the other hand, rock surface and land are continuously getting eroded. Broken pieces of material like sand, clay, lime are carried away by rain and subsequently deposited on beds of oceans. In millions of years the sediments pile up to a great height (several thousands of metres) and subsequently, pressure and temperature continue to rise in those rocks. Shells and skeletons of dead planktons, sponges and jelly fish sublime on sea bed and subsequently get buried under the piling sediments. Aerobic bacteria present in the ocean floor and sediments act as scavengers and attack the organic matter. Some complex chemical transformation takes place that is facilitated by the enormous overburden pressure, rising temperature and the absence of oxidizing agent. The process continues through various complicated stages and chemical reactions forming fats, amino acids, lipids and finally into oil and gas. Oil is produced within the temperature range of 100–200^{o}C. Source rock when subjected to greater overburden pressure and temperature beyond 160^{o}C for a long period does not generate liquid oil but gas.

Amongst the different sedimentary rocks like sandstones, shales, clays and limestones, the clays are more suitable for formation of oil and serve as 'source rocks'. With the piling up of sediments, lower sediments get progressively compressed and the fluids in them are squeezed out. Oil formed in the clay rises up or sideways and if the rock above is like a sandstone with pore spaces, fissures and fractures, the oil tends to get accumulated in such a reservoir, provided this upward and sideways migration is prevented by the intervention of an impervious layer of rock known as cap rock from moving further. This layer traps the oil. In a normal oil pool gas remains at the top, oil below it and water further below. These pools remain intact till disturbed by earth.

1.3 OIL AND GAS EXPLORATION

Oil exploration is a complex process. It begins with prognostication and involves an entire gamut of activities. The hunt for the hydrocarbons is focused at the favourable or promising areas based on geological considerations. Geological survey aims at selection and mapping of such areas which satisfy the criteria of being sedimentary rocks preferably of marine origin with the presence of anticline structures of Mesozoic (50 percent of oil produced belongs to this era), Cainozic (40 percent of oil produced belongs to this era) and Paleozic (10 percent of oil produced belongs to this era) periods.

Owing to the presence of fault planes and fissures, a seepage of oil to the surface may take place. The analysis of surface samples of soil, water and oil or gas, in such cases, for detection of oil and gas is known as geochemical prospecting.

Magnetic surveys are then done. Magnetometer survey is carried out either on the ground or from the air by air-borne magnetometer. It is based on the principle that the magnetic attraction on the surface depends on the magnetic intensities of the rocks and their distance from the surface. It helps to delineate the nature and possible dip angle of the subsurface rocks. Dip is the angle that a geological stratum makes with a horizontal plane (the horizon): the inclination downward or upward of a stratum or bed. The same principle can be applied to the measurement of the gravitational attraction at the surface by a gravimeter. These two methods together help in demarcating areas having thicker pile of sediments with better chances of oil.

The seismic method of oil and gas exploration involves generation of a series of shock waves in the subsurface and picking up the reflected waves by sensitive geophones which are laid along a line on the surface. The time taken for the return signifies the velocities through the subsurface rocks and these can be interpreted to assess the nature of rocks and their angle of dip.

The field studies are supported by an equally elaborate testing of samples in the laboratory. Sophisticated modern equipment like Electron Microscope, Mass Spectrograph, X-rays Chromatograph, Nuclear Magnetic Resonance (NMR), Spectroscopy, Infra-red, Ultra-violet and Differential Thermal Analysis (DTA) are indispensable aids. On the basis of all these studies, the most suitable places where oil is likely to be found is selected for drilling.

1.4 DRILLING FOR OIL AND GAS

The drilling equipment (shown in Fig. 1.1) consists of a tall huge tower called 'derrick' anchored to the ground, engines, mud pumps, water tanks, draw-works and many other modules. The travelling block is suspended from the crown block (a large pulley at the top of the derrick). The swivel, attached by a large hook to the travelling block, can rotate freely, and the kelly is fitted onto this. Rotary table at the centre of the derrick floor holds the kelly (which has a square or hexagonal cross-section) and can be rotated at a desired speed by the engine. To begin drilling, the kelly is hauled up the derrick, its bottom is fitted with a drill bit and lowered through the rotary table until that bit is resting on the earth. With the starting of the engine, the rotary table rotates the kelly and the drill bit which is pressed hard against the earth by the weight of the drill string above, cuts and penetrates the rock at the bottom.

Much of the success of drilling depends on the quality of mud which is a specially prepared slurry of water, various chemicals and adhesives like barytes, bentonites, xanthanite. It is pumped through the drill column to carry out several important functions such as removing cuttings to the surface, cooling the bit (heat generated is due to friction), lubricating the bit, providing buoyancy to the drill string to reduce the hook load, retaining the side wall of the well from caving in, allowing to examine the hole by lowering a variety of instruments and balancing the formation pressure that prevents the formation fluids from running into the well. With the increase in depth of the open hole, the side walls of the well tend to collapse. To avoid this, a casing pipe is introduced into the hole. The annular portion between the hole and the casing pipe is cemented. Further drilling is carried out with smaller diameter bit, and at a certain depth a smaller diameter casing is introduced and cemented in the same manner.

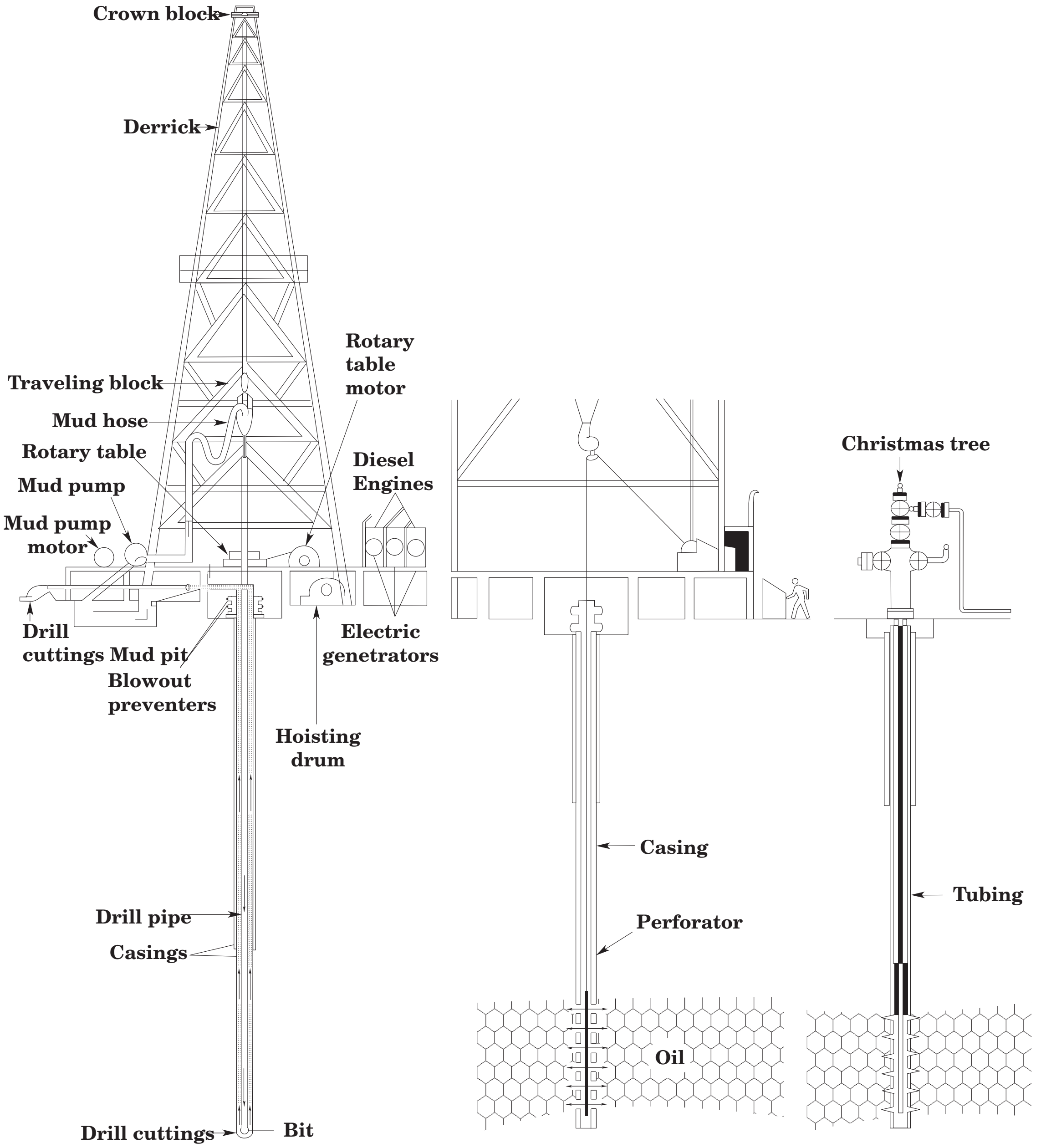

Fig. 1.1. (a) Drilling equipment (derrick) (b) Perforations in casing pipes to test formation fluid

Coring is done to get a factual sample of the drilled rock to know its composition, its physical properties like the grain size, porosity, packing of grains, permeability, its angle of dip, the fluids such as water and gas or oil, if present, and the evidence of life at the time the rock was deposited. Coring may be of different types, namely, conventional core, side wall core, rubber-sleeve core, diamond core and wire-line core.

While drilling, the geologists continuously collect, wash and examine the rock cuttings that come up to the surface with mud and ascertain the nature of the rock and its fossil content.

Based on the principle that different rocks have different physical and electrical properties, several vital characteristics of the sub-surface rocks are studied.

In addition, a sample of the fluids in the well can also be brought up to the surface by special devices called drill-stem test (DST). During drilling one often encounters various complications. The drill bit may get stuck up, side of the well may cave in or tools may be lost in the well. Recovery of objects dropped in the hole is called 'fishing'.

All the data obtained are recorded and processed by computers and subsequently interpreted by geologists, geophysicists, chemists and reservoir engineers jointly. They decide on the most likely areas that could be dug up for oil. At this stage, the well is taken over to test the presence of hydrocarbons and if found in enough quantity measures are taken for its subsequent exploitation.

In order to test the formation fluid, it is allowed to come into the well by perforating the casing pipes at the desired places with the help of a perforating gun. The mud is gradually replaced by water. Thus the hydrolytic pressure is progressively reduced against the formation pressure. When the formation pressure exceeds the hydrolytic pressure of the well, the formation fluid begins to enter into the well. The well is then under production and the fluid is allowed to flow under controlled conditions through a choke or a bean. If it produces oil, the well is called an oil well and if it produces gas escape it is called a gas well. The oil and gas escape through a pressure vessel called separator which separates oil, gas and water at reduced pressure. If no oil or gas is encountered, the well is abandoned dry.

At the initial stage oil and gas rise to the surface under their own formation pressure. With continued production, formation pressure decreases and the viscous oil and gas cease to be self-flowing. As a result, artificial lifting such as sucker rod pump, water or gas injection or polymer injection is employed for maintenance of pressure.

1.5 PRODUCTION OF CRUDE OIL AND NATURAL GAS

Crude petroleum is found in the void spaces of porous rock along with gas and water. It is trapped under pressure beneath impermeable rock formations. When the trapped formation is pierced, fluid flows out of the trap into the well bore. The fluid in the well-bore is lifted out either naturally by the release of gas that lowers the head or with a mechanical pump to maintain the influx into the well-bore. However, the withdrawl of the fluid from the reservoir lowers the pressure therein and in turn the influx rate into the well-bore decreases. This rate eventually decreases to a value insufficient to pay for the cost of lifting the fluids to the surface. The recovered oil accounts to only 15-20 percent of original oil in place. In some oil reservoirs which have a continuous aquifer the reservoir oil is replaced almost volume to volume by water and pressure decline is very gradual. This increases its recovery efficiency to the range of 40-60 percent of original oil in place.

The enhanced oil recovery (EOR) is practiced in two stages: (*a*) Secondary recovery (*b*) Tertiary recovery. The most popular conventional type of secondary recovery duplicates the natural water drive reservoir. Water is injected into a series of wells in order to displace the oil to adjoining producing wells. Water, because of its higher density, relatively efficient displacement characteristics and its nearly incompressible nature, can raise the reservoir pressure quickly. Depletion drive reservoirs will usually be more susceptible to successful recovery operations than reservoirs operating under driving forces, particularly gas cap drive reservoirs present a problem since the moving oil and/or the displacing fluid may pass into the depleted gas cap. Water, however, has two major problems that impede its efficiency. It does not flush all of the oil from the pore spaces as it moves through the reservoir rock. About 30-70 percent of the oil is left behind in the form of small droplets held within the larger pores. Second limitation is that the advancing water front bypasses significant portions of the reservoir due to difficult well placements and unexpected geological configurations. This lack of a perfect sweep efficiency is responsible for leaving behind crude oil in areas not reached by water flood.

A number of methods/techniques are employed to recover the remaining oil. The different techniques may be broadly classified into three categories:

(*a*) Miscible/immiscible displacement process
* Miscible hydrocarbon displacement (LPG enriched gas & lean gas)
* Carbon dioxide injection
* Inert gas injection (Nitrogen, air, etc.)

(*b*) Thermal recovery processes
* Steam stimulation
* Steam flooding (including hot water)
* In-situ combustion

(*c*) Chemical flooding processes
* Surfactant/polymer injection
* Polymer injection
* Alkaline flooding

Selection of a suitable EOR method requires a careful analysis of reservoir configuration and the oil properties. Trapping and release of fluids from porous media is a complex phenomena. For a specific system, trapping behaviour is controlled by (*i*) the pore geometry of rock matrix, (*ii*) fluid-rock properties, in particular, wettability and (*iii*) fluid-fluid interactions including viscosity, rock density difference, interfacial tension and partition coefficient. The general properties of pore system, its shape, size and distribution in the rock plays an important role in trapping of oil. It is established that (1) Trapping of fluids occurs in unique and reproducible patterns which are controlled by capillary forces, (2) Nearly complete networks of interconnected equal size pores exist throughout the pore size distribution, (3) individual pores have good accessibility with adjacent pores, thereby allowing alternate paths of flow around isolated immobile phases, (4) Fluids can be trapped at pore constrictions for all degrees of wetting. Non-wetting phases are trapped in discontinuous masses whose lengths are largely determined by interfacial tension and potential gradient. For selection of suitable EOR methods laboratory investigation under simulated conditions of reservoir are necessary. Mathematical models (3 phase, 3 dimension) are used to analyze the reservoir geometry. The past performance of the reservoir is matched to predict the performance of reservoir under different operating conditions. Based on these modelling studies, the most suitable EOR method is selected for maximum production of the oil in place.

In India, the increase in crude oil production is not significant during the last 4-5 years. No new oil fields with substantial reserve is discovered. The percentage of primary recovery in the total oil production is gradually decreasing. Rate of production from Bombay High is reported to have already shown the declining trend. Some of the old oil fields of Assam and Gujarat under prevailing price structure have already reached their economic limit. On economic terms, both ONGC and OIL may prefer to plug the well, pull the pipe and abandon the field. It is better to use EOR methods after primary recovery. It is imperative that proper assessment of EOR potential in the country is required for making recovery plans. The successful application of any EOR process depends on its viability. The price of oil is the most important factor for how much will be produced and when. Gas injection may not find wide application in India. It is true that natural gas or associated gas, propane, enriched gas and lean gas are available in India. But the pressure required to liquefy the gas is high and it may not suit the shallow Indian reservoirs. So is the case with air and nitrogen gas injection. But in some reservoirs carbon dioxide could be injected. Again it depends on the availability of low cost carbon dioxide in plenty. It is estimated that at about 4-6 million cubic feet of CO_2 is required to recover a barrel of crude oil. Although thermal methods predominate as most successful EOR processes, they may not be applicable on a large scale in India. Depth of the Indian reservoir and API values 28 - 45 restrict the injection of steam or hot water for additional recovery because of apparently unattractive cost benefit ratio. Of course in Western sector it may be successful in some reservoirs. In-situ combustion is the most difficult method to predict properly. Moreover, it is economical and successful in heavy oil recovery only. It appears that the chemical flooding viz. polymer flooding or surfactant-polymer flooding may prove successful in India. For alkaline flooding, acid number of the crude must be high which is not so with Indian crudes. Polymer flooding method may become more popular in India not only for its easy handling but also for the economic returns. Surfactant/polymer flooding is required to be assessed properly, particularly the non-compatible nature of surfactant to various monovalent and bivalent metal ions and in Indian reservoirs these metals are plenty.

The production of crude oil in India is given in Table 1.1. From a meagre 0.5 million tonnes of oil produced from one of the oldest oilfields in the world-Digboi in Assam, the indigenous crude production is expected to go up to 44.45 MMTPA (million metric tonnes per annum) by the turn of the century. Till 1947, India used to produce around 0.5 to 1.0 MMTPA of crude oil from Digboi and Naharkatia fields of Assam. After independence in 1947, two public sector companies were formed by Government of India, namely Oil & Natural Gas Commission (ONGC) and Oil India Limited (OIL) to explore and produce oil and natural gas in India from both onshore and offshore fields. Up to 1960, India was practically depending on imported crude oil.

ONGC first struck oil in Cambay in 1958-59 and in Ankaleshwar fields (Gujarat) in 1960, followed by oil finds in other parts of Gujarat such as Nawagam, Ahmedabad, Mehsana, Gandhar, Kalol, Tapti basin, etc. Biggest oil field struck by ONGC was Bombay High offshore fields in Arabian sea in 1974. In 1976, ONGC found a large sour gas reservoir at South Bassein, south of Bombay High offshore fields. Also, gas/oil was found in smaller quantities at Heera, Panna, Ratna and Neelam offshore fields in Arabian sea.

Crude production in the country has been going through fluctuating fortunes. From a high of 34.09 million tonnes in 1989-90, it dipped to 26.95 million tonnes in 1992-93 and stayed at that level in the following year also. But in the past couple of years there has been a recovery and the curde production was 33.865 million tonnes in 1997-98. The offshore reserves account for about 63 percent of total oil produced in the country. This reveals how poor the country is in on shore oil reserves and how much it is dependent on Bombay High. The production of natural gas in the country is currently about 74 million standard cubic metres per day and the total gas availability for sale about 61 million standard cubic metres per day.

Table 1.1 Production of Crude Oil in India

Year	*Million tonnes Crude oil production,*
1960-61	0.45
1965-66	3.48
1970-71	6.81
1975-76	8.45
1980-81	10.50
1985-86	30.16
1989-90	34.09
1990-91	33.00
1991-92	30.35
1992-93	26.95
1993-94	27.02
1994-95	32.24
1995-96	35.19
1997-98	33.865

1.6 PETROLEUM REFINING, OPERATION AND OPTIMIZATION

Crude oil in its raw form has got very limited use. By adopting various refining processes in the refineries, crude oils are separated into a number of fractions which are suitable for various uses. Crude oils received from oil fields are stored in refinery storage tanks. From these takes crude oil is fed to the atmospheric distillation unit. All the crude oils are basically mixture of hydrocarbons which can be physically separated in groups of different boiling range by the conventional process of distillation. The fractionation of crude oil yields the following streams in the order of rising boiling ranges :

* Methane, Ethane and Propane mixture
* Liquefied Petroleum Gas (LPG)
* Naphthas/Gasoline fractions
* Kerosine/Aviation Turbine Fuel (ATF)
* High Speed Diesel Oil (HSD) and Light Diesel Oil (LDO)
* Reduced crude oil (RCO)

Depending upon the crude oils properties and impurities present in them, the above products are further treated to meet the required specification. Reduced Crude Oil is further distilled under vacuum to recover some more lighter fractions. This process produces light vacuum gas oil (LVGO), heavy vacuum gas oil (HVGO) and vacuum residue (VR). In order to meet the viscosity specification of fuel oil, heavy residues such as HVGO, RCO and VR are processed in visbreaking unit to reduce their viscosity. To produce bitumen, the vaccum residue is air-blown in Bitumen Blowing Unit. To maximize the production of middle distillates, heavy residues such as HVGO are processed in fluid catalytic cracking (FCC) unit, hydrocracking unit and coking unit. Straight-run naphtha of low Octane Number is processed in catalytic reforming unit to enhance its Octane Number. Reformate rich in benzene/toluene is used as feedstock for Udex unit to produce benzene and toluene. Kerosine fractions from certain crudes such as Assam crude do not meet specification on smoke point due to higher aromatic content. To improve smoke point of these fractions, Edeleanu process is usually employed.

1.6.1 Selection of Processes for Optimization

Optimization is the process of determining the best possible way of selecting the processes scheme and fixing the unit capacities etc. The selection of process/processing scheme is to be optimized considering all the objective functions. The following factors would influence the decision making in the selection of processes and process scheme for a given refinery :

* Type of crude
* Product slate
* Product specification
* Investment and operating costs
* Merits/demerits of alternative processes.

Type of crude. The type of crude to be processed in a refinery will have a bearing on the process scheme. For example, crudes containing high sulphur require the installation of desulphurisation processes/sweetening processes for streams. Kerosine from Aghajari crude has a peculiar problem of colour deterioration on storage which cannot be corrected by treating in an Merox unit and hence desulphurisation unit would be required. Some crudes are not suitable for making lubricating oils, and some are not suitable for making bitumen. In some cases the products do not require any treatment like some of the indigenous crudes etc. Therefore, each and every stream from the crude distillation unit has to be evaluated for making a suitable scheme of treatments/secondary processing facilities.

Product slate. The capacity of the refinery, the type (lube or non-lube) and size of the secondary processing units is largely governed by the product slate which in turn is decided by the demand of petroleum products. The process scheme is selected so as to match with the product slate. In India, generally the maximization of middle distillates is the main criteria. In U.S.A., the production of light distillates particularly, motor spirit is maximized in FCC unit by keeping high severity operations. If the objective is to maximize HSD in a refinery processing high sulphur crudes, it would be advantageous to provide an FCC unit with a desulphurisation unit either for straight-run gas oil or cycle oils so as to upgrade the heavier ends to the maximum possible extent as limited by sulphur specifications. For extreme maximization of middle distillates, a hydrocracker can also be considered which upgrades the heavy ends to the middle distillates (ATF/kerosine/HSD) better than any other known process. Yield of kerosine/HSD from a hydrocracker is of the order of 80 to 85 percent as compared to about 50 percent from FCC unit.

Product specifications. Generally the treatment processes are governed by the specifications of the products. Depending on the type of crude processed and the quality of streams, a judicious selection of treating processes has to be made from a simple caustic wash, Merox sweetening units to a hydro-desulphurisation unit. The flash point of the middle distillates are often relaxed, with a view to maximize these products. Therefore, to take advantage of such relaxed specifications, it would be desirable to provide a naphtha splitter column in the process scheme, so that heavy naphtha can be injected into kerosine/diesel cuts.

Investment and operating costs. This is a very important point to be kept in view while fixing the refinery capacity, selecting the processes and sizing the unit capacities. However, the selection of process technology at times may entirely be governed by the products demand rather than by investment cost limitations. Investment costs are function of refinery size and its complexity. Economy of scale, for the same complexity, results as the capacity increases. Investments per unit of processing capacity progressively go down. In some cases, a particular plant size may become economical and in some other cases it may not be economical. For example, some oil companies do not consider it economical to provide FCC Unit of less than 0.6 MMTPA capacity. Similarly, the latest trends are to provide single crude distillation unit of 8 to 10 MTPA capacity.

Some of the plants are consuming high amount of fuel and utilities. This aspect has to be kept in view, while selecting a process. For example, in case of hydrocracker, the total energy consumption is about 1.6 times than that of Fluid catalytic cracker. Further, a substantial quantity of naphtha is consumed to meet the hydrogen requirement of hydrocracking. The total energy consumption in a fuel refinery would be of the order of 10 to 11 percent.

One has to be cautious in the selection of new process technology keeping in view the situation, location and availability of local expertise. Some of the technologies for upgradation of the heavy residues may not be straight way made applicable to Indian conditions. Developments like continuous catalyst regeneration may not be very attractive to refineries which upgrade naphtha for the production of motor spirit of moderate octane number. Desulphurisation of fuel oil which is now being practiced elsewhere with the objective of reducing pollution in concentrated industrial areas may not be applicable in some other situations, where pollution hazards are low. Hydrocracking though a very vital process for maximizing middle distillates has a sophisticated metallurgy and requires special operational and maintenance care. Processes now adopted for direct hydrocracking of residues would call for sufficient high investments and high operating costs because of the hydrogen requirements, particularly for high sulphur crudes. Reduced crude oils from indigenous crudes because of their low sulphur and metal contents would be better suited to this type of technology.

Merits/demerits of alternative processes. There may be more than one process to do the same type of operation. For example, there are various types of sweetening process for naphthas and ultimately a choice has to be made on the merits and demerits of the individual processes, operating costs and quality of the product etc. For extraction of aromatics from kerosine, apart from conventional Edeleanu process one could possibly choose sulfolane process or mild hydrogenation in order to improve the smoke point. For the extraction of aromatics from the lube oil distillates either furfural or phenol extraction could be adopted.

1.6.2 Optimization in a Running Refinery

Optimization of the operation of a running refinery is subjected to the influence of various factors. There are some factors which are beyond refinery's control. These include :

(*a*) Crude mixture
(*b*) Type of processing units
(*c*) Demand pattern
(*d*) Movement constraints
(*e*) Product specifications
(*f*) External streams
(*g*) Industrial relations.

Those factors which are within refinery's control are given below.

(*a*) To investigate the possibilities of improving over processing capacities not only for crude oil but also for secondary processing units.
(*b*) To adopt various effective measur of controlling the erosion/corrosion in processing units to improve their service factors.

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Refining Technology

This book provides a sound and comprehensive introduction to the various aspects of the Petroleum Refining Industry, such as transportation of waxy crude oils, chemistry of crude oil, petroleum products, refining processes, corrosion and pollution problems, and design of petroleum processing equipments. This book will be valuable to undergraduate as well as postgraduate Chemical Engineering students. This book will also be a useful reference to practicing engineers who wish to expand their knowledge.

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