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Origin, Formation and Composition of Petroleum

1.1 ORIGIN AND FORMATION OF PETROLEUM

Today, most of the countries in the world are importers of energy. The fossil fuels, accumulated over aeons of geological activity are irreversibly consumed at a rate more than million times faster than they were formed. This has left us in a precarious position especially for petroleum and its products. The hike in price of petroleum and its products, both in national and international scenes is frequent for two simple reasons; the mounting demands and fast depletion of reserves. The importance of petroleum in present day civilization is ever increasing due to its unmatched contribution for our energy requirements, in lubrication and in petrochemical field. Thus its competence to serve mankind is unquestionable and unique too. Sixty percent of the energy needs of the world are met by petroleum. The advent of I.C. and Jet engines have revolutionalised the techniques of motive power, a fact, without which the rumbling civilisation would have to contend with a snails-pace. Such a premium stock of limited resources is fast depleting, perhaps due to indiscriminate and wanton consumption. The important question today is how long can the reserves meet the demand even with sky high prices? The high degree of conservation and restrictions in consumption may draw out the global reserves to another century at the consumption rate of today. Then, what?

According to Mayer and Hocott "There is no dearth of petroleum and natural gas resources remaining in the earth. As a matter of fact, there is no foreseen shortage of available supplies by present technology until well into the next century".[1]

Of course, every effort is made to locate new prospective fields, and innovation in search of secondary recovery techniques to lift the oils from existing sources, and what are presently uneconomical fields, is in progress. The controversies may be subdued by understanding the formation of petroleum, at least to some extent. Perhaps resources may not be the problem, but availability may be.

1.1.1 Occurrence of Petroleum

Petroleum occurs in the earth's crust, in all possible states and varies in colour from light brown to dark brown or black, exhibiting luminescence in some cases. It is a mixture of various hydrocarbons, of homologous series namely paraffins, naphthenes and aromatics. Thus the main elements are C (84-86%) and H_2 (11-14%) and other elements O_2, N_2, S rarely constitute about 8%, including different metals in traces. Petroleum is more homogeneous than coal and occurs mostly in sedimentary rocks.

1.1.2 Origin and Formation

Scientists till now are entangled with the problem of explaining successfully the origin and formation of huge hydrocarbon deposits and notably a sound theory has yet to be evolved. Mendeleeff and Berthelot, were caught up with the idea of explaining reasons for such deposits. Their explanation was based upon the inorganic reactions, mainly on the activity of acetylene series. Some carbides produce hydrocarbons when reacted with water, such as

$$CaC_2 + 2\ H_2O \rightarrow C_2H_2 + Ca(OH)_2$$
$$Al_4C_3 + 12\ H_2O \rightarrow 3\ CH_4 + 4\ Al(OH)_3$$

Assuming the availability of such carbides in earth's crest, they arrived at this axiom; in fact, the deposits of such magnitudes could never be balanced with these ideas.

The cosmic hypothesis of V.D. Sokolov depicts that the hydrocarbon vapours were already in cosmic clouds. Favourable conditions leading to precipitation of these clouds, rained hydrocarbons, which were either adsorbed or entrapped in earth's crest. A doctrine may possibly be explained if ever man comes across such giant deposits in a distant planet, where there happened to be no life at all.

Truly speaking, hydrocarbon vapours are present in certain planets. Hoyle cited the presence of hydrocarbons in the atmosphere of Venus.[2] These hydrocarbons must be distinguished from the earthly deposits, as purely derived from inorganic materials. Different and conflicting theories appeared in large number to explain the formation of petroleum deposits. The inorganic basis of petroleum formation had to be given up in favour of organic theory due to the following observations and facts as enumerated by J.D. Haun[3]:

(a) The homologous series present in petroleum are found only in organic matters.
(b) Nitrogen compounds in petroleum, especially plant derived porphyrins, comprise a very small amount but their significance is immense in the formation of petroleum from life source.
(c) The range of radio isotopes of carbon C^{12}-C^{13} is within the ranges of natural Carbonaceous materials and not from inorganics, as they do not have any chance to absorb radioactivity.
(d) Optical activity, a pre-requisite of natural organics, is exhibited by petroleum.
(e) Petroleum formation is a result of low temperature activity only.
(f) Petroleum is always associated with sedimentary rocks, (even recent formations too) and not with igneous rocks.
(g) Small quantities of petroleum (hydrocarbons) in recent sediments suggest, that the formation of petroleum is normal, continuous and does not require any severe physico-chemical conditions.
(h) Most organisms, like diatoms are found in petroleum.

1.1.3 Organic Theories

Engler (1886) was of the opinion that the large marine animals, which dwelt on the globe in the pre-historic days were the main fat contributors. After the natural extinction of these mammoths, the body fat was slowly converted to hydrocarbons, as per his version. But the laboratory experiments revealed that the conversion of fat by hydrolysis yielded only acids and not hydrocarbon gases. Further, surprisingly no oil well was ever sighted with any fossil remains of such animals. This is how the long flourished hopes of this natural fat theory had to be given up.

There are other schools of thoughts concerning the origin and formation of petroleum; some of which are listed as:

Thomas-Graham (1843) was of the view that natural naphtha must be a product of action upon vegetable matter of high temperature. Chaptal (1845) was of the opinion, that when plants became entirely decomposed into vegetable moulds these contained certain oils which escaped decomposition. J.W. Draper (1846) suggested the action of natural heat of earth on coal. Popoff (1875) showed that methane could be produced by decomposition of cellulose. Hoppe-Seyler in 1886 showed that bacteria could produce methane, as is ever evident in swampy areas. Treibs (1934) discovered some of the plant pigments and biological matter in crudes; micro-scopic organic remains found in crudes actually prompted APl to launch a big project API 43 to investigate thoroughly.[4]

A bright explanation by Mikhailovosky, N. Potering and N.C. Anderson seems to be near the goal. Accordingly, the source of petroleum was not a definite species of flora as initiated by Engler, but the organic matter of sea oozes consisting of remains of plants and animal organisms. The initial decomposition of the vegetable and animal matter was a result of activity of micro-organisms; later the organic matter underwent changes due to pressure and temperature of the crest of the earth. Emphasizing the fact, Arkhagelskey, prophesied that petroleum took birth in argillaceous rocks enriched with organic matter and later migrated and got stored in arenaceous rocks. The extension works of P. Trusk and G. Petrov in USA characterised the composition and content of organic matter in rocks of different ages. Controversies always flare up, one school advocates—temperature—pressure distillation or by tectonic stress. Another school advocates as a biochemical process; yet another sees it purely as a chemical or radioactivity reaction— and so on. However, biochemical[5a] theory has been received with some favour, as it is concerned with low temperature and pressure, and bacteria of versatility. Thus it may be concluded that the formation is via a combination of physical and biological processes rather than individually. Petroleum formation[6a] from organic mass may be expounded by two distinct processes namely physical and biological.

1.1.4 Physical Methods

It conjures all the parameters in an ideal reaction and depends upon the factors like:

1. Heat 2. Pressure 3. Heat and pressure
4. Catalysts 5. Radio activity.

1.1.5 Biological Methods

All the biologic methods are governed by source and environ-ments such as :

1. By preservation of hydrocarbons synthesised by the source sediment organisms.
2. Biological reduction (anerobic or aerobic) sources being:
   (a) Fatty acids,
   (b) Proteins and amino acids,
   (c) Carbohydrates.
3. Biological and physical methods, such as
   (a) By condensation of bacterially produced methane under high pressure and temperature in presence of catalysts.
   (b) By bacterial modification of sediments.

API 43—(A.B.C.) completely relates to the transformation of organic material into petroleum. C.E. Zobell in his report of this project mentioned that conversion is genuinely a micro-biological process.[6b] Bacteria, as described by Zobell can survive in fact in all critical conditions, from 0° to 85°C, under extreme pressures upto 10,000 kg/cm^2 and also at well depths of 10,462 metres.[7]

Laboratory tests confirmed that 'Lipoclastic' anaerobes have the capacity to split long chain hydrocarbons to shorter chains.

Evidence in biogeneicity does not differentiate between vegetable and animal source.[8] Close association of crude oil with marine remains suggests it is from fish molluscs, lamellibranches, diatoms foraminiferae and other sea creatures, known from their fossilised remains to have been present in immense quantities in ancient seas. Preponderance of petroleum known today is derived from ancient biological matter, particularly from lipid rich lower marine plants such as plankton[9]. Terrestrial plants supply terpens, which suggests the phenomenon of atmospheric volatilisation of vegetation. The nature of recent hydrocarbons found, does however support the biogenic origin; the main reason being the presence of odd carbon number. These matters are often referred as kerogens or mother substances for shale.

Kerogen is divided into three classes based on the nature of original organic source material. Hydrogen rich straight chain groups usually are from algae, lipids and planktons. These contribute to Type 1 and Type 11 forms of kerogen while Type 111 kerogen is oxygen rich cyclic carbon structures obtained from higher plants, known as lignins. As organic matter accumulates and is converted to kerogen during diagenesis, it will be mixed with various proportions of inorganics *i.e.* sedimentary soils. The sedimentary deposit is classified both in terms of proportion of kerogen and amounts of Type 1 and Type 11. If the kerogen % is less than 1 the bearing sedimentary rock becomes oil source rock and above 1 and upto 50 the rock is classified as Oil shale, above 50 it is known as Humic kerogen as it is found to contain higher plant materials Kerogen to coal, oil, gas is driven by exposure to temperature, pressure, geological environments. The formation of fuels from kerogen is therefore called as geochemical stage or catagenesis.

According to Kenneth Kobe, petroleum results from a series of biochemical and chemical reactions which start with organic remains of dead micro-organisms.[10] Bacteria are involved in first transformation of the constituents of decaying micro-organisms into hydrocarbons.

Anerobic conditions keep porphyrins to remain in crude; if oxygen had been there these would have been decomposed.[11] Bacteria can also decompose organic matter to CO_2, H_2S, etc. Further, it is discovered that no bacteria can produce more than C_2-compounds, thus C_{11} to C_{14} compounds must have been formed from marine life as is evident from certain Gambian crudes.[12] Most organisms are found to generate petroleum in their metabolic processes too (Meyer and Hocott).

Crude oils found in the younger sedimentary deposits do in fact contain appreciable amounts of oxygen and nitrogen. This shows organic material as the source. McNab *et al.*, divided crudes into three types depending upon the time of deposit[13]

Tertiary crudes (Eocene oil)	:	$11 \times 10^6 - 74 \times 10^6$ years of age (asphaltic crudes)
Mesozoicera oil	:	75×10^6 - 200×10^6 years of age
Paleozoic crudes	:	200×10^6 - 500×10^6 years of age (paraffinic crudes)

Brooks and Frost concluded that the organic matter can be decomposed easily under the action of natural catalyst as well as bacteria.[14] The evidence of bacteria in sedimentary rocks is positive and the organics are initially decomposed to acids and gases (CH_4), till the activity of bacteria ceases due to frankensteinism. I.M. Gubkin demonstrated that the formation of petroleum and gas from organics, scattered in argillaceous rocks was a local process and started really with accumulation of organic matter in sea oozes, it may be the fat or carbohydrate. Apart from this, some scientists regard that the hydrogenation of carbon oxides results in -CH_2-chains, which may be congenially taking place under the catalytic activity of earth's crest due to favourable conditions of temperature and pressure. But this is only a derived literature thrusted to explain and can never match with the quantum of oil. Thus every new thought merely resulted in more sterile addendum. The overall explanation hitherto may be summed up in two steps: firstly the action of bacteria in contributing the lighter fractions, secondly continuous catalytic action of earth at depths of 1-2 Km to yield heavier hydrocarbons. It is observed with the depth of mine and time of formation and storage, the API gravity of crude and paraffincicity increase because of severity of reaction, which is in full agreement with the above picture.[9b]

Age of the oil is indicated by CPI (Carbon Preference Index). Hydrocarbons of recent origin show 4 to 5, while ancient bitumen show about 1. The odd carbon number is dominant in recent formations, as the oil ripens the oddity decreases, hence young-deep oil formations CPI is less than young-shallow oils. Age-depth oils do have less CPI than young-shallow deposits.

These are all possible natural reactions occurring over the ages, and petroleum hydrocarbons might have been formed by many processes and each contributing its own share, may be small.

In conclusion, regarding the biologic origin of petroleum there need not be any doubt, because of the oil association with sediments containing a relatively large amount of organic matter, the presence of optically active compounds and complex substances of obvious biological origin. Oil is also absent from formations having adequate traps and porous strata, but without any organic material. The formation is at low temperature, usually less than 200°C or even 100°C. The thermophilic bacteria (bacteria that can survive at high temperature) plays the major role in conversion of this organic mass into liquid hydrocarbons.

1.2 RESERVES AND DEPOSITS OF WORLD

There are very few parts of the world which are self-sufficient in energy. Russia and Eastern Europe are largely self-sufficient in energy and they never look for outside supplies of oil. Middle East, Africa, the major oil producers are exporters of huge energy, while Japan is a leading importer of energy. USA is also energy producing country, but its commitments have grown to such an extent, that it is now a major importer of energy.

Petroleum deposits mainly occur in some elevated sections of porous sandy strata.[1b] Sedimentary rocks accumulate in sea bed at a very slow rate. These layers over millions of years stratify under pressure and temperature and are transformed into metamorphic rocks, sand stones, marbles, etc. These are the basic reservoirs of gas and oil. Whenever fissures and dislocations in zones of earth occur, oil and gas reach surface and get burnt continuously by accidental fires like lightning, etc. and sometimes oil drains to nearby streams too. A false understanding prevails that volcanic eruptions are followed by huge quantities of hydrocarbons.

It is seen coal is more uniformly distributed throughout the world rather than oil; oil is scattered randomly and 80% of oil found to date occurs in what has been called oil-axis-pole.[5b] Gulf Caribbean, Mesopotamian and Persian Gulf are such areas confined to depressions on earth's crest. Initial migration of oil takes place during compaction of dense shales.[15] Although the migration mechanism is not fully understood, evidently it is not effective, with the result, much oil is left in the formations. At present oil from such source is not economically recoverable.

Bacteria in marine sediments may also contribute to the liberation of oil from oil bearing materials in various ways. According to Stone and Zobell obvious import is the bacterial decomposition of organic complex in which oil is trapped.[16] Secondary by dissolving carbonates or sulfates on which oil is absorbed by action of bacterial acids. Thirdly bacterial gases reduce the viscosity of oil.

In erstwhile Soviet Union, the South Caspian Basin, Ural-Volga Basin, and Western Siberian Basins are famous for hydrocarbon deposits which rank next only to Iran-Arabian Basin, the richest in the world.

Once the richest basin, Aspheron-Peninsula has been exploited since last hundred years. It is found through approximate records that oil extracted throughout the world till 1975 was about 43,000 MMT, a considerable amount of which was produced during 70's only.

Kuwait, a small country with 18% of world reserves held its 4th position for a long time in the production of oil after USA, Russia and Venezuela, but now Iran and Saudi Arabia have surpassed Kuwait. Saudi Arabia is about 100 times bigger than Kuwait and is ranking next to Iran with 10 MMbbls. per day. Kuwait is producing approximately 1.25 MMbbls. per day.

US crudes are relatively less sulfur ones and make up about 7% of world reserves.[17] Venezuela and African crudes of relatively low sulfur content constitute about 10% world oil reserves. African countries like Libya, Algeria and Nigeria account to about 300 million tones per annum. A characteristic feature of the oil wells near Middle East is high yields per well. Iraq and Iran are famous for such types of wells, which can produce even 10,000-20,000 tons per day per well. Thus near and Middle East countries with highest proven reserves of 70% of world's petroleum stock; holds the control in the energy export.

At present the trade is governed by OPEC*; fortythree percent of world crude produced in 1972 was shared among the group members, which is very much true today also.

1.2.1 World Reserves

Several estimates of world hydrocarbon reserves were made by almost all leading institutions and companies. As furnished by Weeks the estimates of proven reserves are $1,900 \times 10^9$ bbls of oil against the estimates of Warman (British Petroleum Company) 1,200 to 2,000 x 10^9 bbls. There is no congruency of expression in these reserves; one can judge by the following ultimate reserves as presented by Richard G. Sieidl[n], how the estimates once cited regularly change with better methods of surveys and techniques.

1965	Hendricks	$2,480 \times 10^9$ bbls
1968	Shell Company	$1,800 \times 10^9$ bbls
1970	Moody	$1,800 \times 10^9$ bbls
1971	US National Petroleum Council	$2,670 \times 10^9$ bbls
1972	Weeks (8th WPC, Proceedings 2, p. 99–106)	$3,650 \times 10^9$ bbls

*OPEC: Organisation of Petroleum Exporting Countries A 13 members body consists of: (1) Algeria, (2) Iran, (3) Iraq, (4) Saudi Arabia, (5) Gabon, (6) Kuwait, (7) Ecquador, (8) Libya, (9) Indonesia, (10) Nigeria, (11) Qatar, (12) United Arab Emirats, (13) Venezula.

1975	Whiting (recoverable)	556.2	$\times 10^9$ bbls and
		80	$\times 10^{12}$ Cu.M. gas.
1977	Harry Warmen[18] (recoverable oil reserves)	270	$\times 10^9$ tons of oil
	Gas equivalent to	55	$\times 10^9$ ton of oil

Total proven reserves as per Whiting goes upto 2,200 $\times 10^9$ bbls of oil and 250 $\times 10^{12}$ Cu.M. of gas; of which 30% will be a Off-Shore product and rest onshore. Cumulative oil production of world till January 1974, was put around 270 $\times 10^9$ bbl oil and 20 $\times 10^{12}$ Cu.M. of gas.[19]

Next to coal, natural gas reserves of 60 billion tons oil equivalent are highest in the world; with a proven to potential capacity of 30% for gas and 60% for oil, the chance of finding more amount of gas is always bright.[20]

John J. McKetta[21] *et al.*, have presented the following data on the available energy of today (1980) and estimates of reserves of energy sources:

Available energy	(1980)
Fossil Fuels	
Oil	570 $\times 10^9$ bbls
Natural gas	2,500 Exajoules
Coal	637 $\times 10^9$ tons
Shale	30 Gigatons
Tar sands	15.30 Gigatons
Nuclear source	MW
Renewable energy	
Geothermal	132 MW
Hydroelectric	5.7 Exajoules
Solar	negligible
World oil estimates	240-260 Gigatons
Natural gas	10,500 Exajoules
Of which undiscovered	8,150 Exajoules
Coal	10,125 Billion tons
Of which known reserves	637 Billion tons
Nuclear	
Uranium	3 Million tons
Thorium	630 Thousand tons
Additional undiscovered Uranium	80–280 Million tons

Exajoule = 160 Million barrels
Gigaton = Billion barrels

At present the production of oil in the world is about 3300 MMta and gas over one trillion cubic meters.

Fears of impending oil shortage have raised hopes of finding huge deposits of oil even under deep oceans. The activity now-a-days is more confined to such areas.

According to Klemme there are 334 giant fields in 66 basins that contains 70-75% of oil. Indian subcontinent is placed in Type 4 basin (India and Assam) and the coastal belt in pulled apart basins.

Estimated sedimentary rocks of the world, by D. Ion and Hendricks is about 62×10^{17} tons, which contain an organic matter of 3.5×10^{15} tons, which in turn can yield a hydrocarbon content of 7.7×10^{13} tons.[22]

World oil reserves estimates 2004 : 1188.6 billion barrels (Department of Energy USA)

Of which OPEC 890 and ME 733.8 MMT

NG consumption world 2420 MILLIONTOE 3.3% over 2003 consumption (N. America 705.9)

Reserves of NG World 179.3 Trillion Cubic meters

Reserves of N. America. 7.32 America Central 7.01 ME 72.83 Asia Pacific 14.06

Nuclear energy (World) 382 Gw_e, India capacity (14 plants) 4013 MW_e By the end of X1 Plan 9935 Mwe capacity

Uranium Deposit India (Recoverable at 130 $/kg) 52.7 Thousand tons Probability of going upto 80 thousand tons

Uranium production decreased from 36,700 tons in 1996 to 3,281 tons thousand tons in 2000

Coal reserves (Sub bituminous + Bituminous + lignite + anthracite) World 985 Billion tons (Recoverable 2000)

India Recoverable (Sub bituminous + Bituminous + Lignite) 84.453 Billion tons,

World production 4.342 Billion tons, India 323 MMT

Hydel — India potential capacity 150000 MWe only 20% of which is tapped against this World Hydel energy 692,420 with an additional of 110,183 MWe

Geothermal is enormous World feasible presently 14,400TWH/year; Technically exploitable 40,704 TWh/year

Direct use installed world 18,000 MWe (USA 5366, India 80).

1.2.1.2 The Difference Between Oil Shale and Shale Oil

There is a huge difference between oil shale and oil produced from shale reservoirs, often called shale oil. The former remains a promising, yet expensive-to-produce, also a resource that may eventually require more development. The latter generates significant, real production growth for a host of independent North American E&P firms; with crude around $70 to $80 a barrel, many shale oil projects are generating an after-tax return on investment of as much as 100%.

1.2.1.3 Oil Shale Today

Oil shale is an inorganic rock that contains a solid organic compound known as kerogen. The term "oil shale" is a misnomer because kerogen isn't crude oil, and the rock holding the kerogen often isn't even shale. Conventional liquid crude oil is organic material-plant and animal remains-exposed to heat and pressure in the absence of oxygen over millions of years within the earth. Kerogen is among the first stages in the process of petroleum generation from organic matter; bitumen-the hydrocarbon targeted in oil sands projects-is formed from kerogen and represents a later stage in the process. Kerogen to oil is done by retorting. To generate liquid oil synthetically from oil shale, the kerogen-rich rock is heated to 500 degrees Celsius in the absence of oxygen, a process known as retorting. Shale can be heated under-ground known as in situ retorting or can be mined like coal and retorted on the surface.

There are several competing technologies for producing oil shale. Exxon has developed a process for creating underground fractures in oil shale, filling it with a material that conducts electricity and then supplying power through the shale to heat it . Because of heat the kerogen, gradually converts into recoverable oil. Shell uses electric heaters that it buries underground to heat the kerogen slowly. Although estimates of the cost to produce oil shale vary widely, it's more expensive and energy-intensive and is economical if oil price goes higher than $100 a barrel and feasible for production

There are a handful of projects in the works, but none are likely to produce significant quantities of oil for well over a decade. Brazil's national oil company (NOC) Petrobras (PBR), Shell, Exxon and Japan's Mitsui (MITSY) are among the companies involved in US various oil-shale projects. Clearly, none of these companies represent pure plays. The potential size of the resource is huge. Oil shale naturally occurs in more than 20 countries around the world, and Brazil, Estonia and China all have small commercial projects producing a total of 14,000 barrels of oil per day. However, by far the world's largest oil shale resource is located in the Green River formation of Colorado, Wyoming and Utah. Colorado {1980, Exxon Mobil (XOM) acquired Atlantic Richfield's 60% interest in the Colony} Oil Shale contains the richest shale. Total recoverable resources could be as high as 1 trillion barrels, roughly four times Saudi Arabia's total proved reserves. If crude prices remain elevated for a prolonged period, prompting an increase in oil shale development, it's possible that production will hit 150,000 barrels per day by the late 2020s. The Energy Information Administration (EIA) projects that US oil shale will produce 144,000 barrels per day by 2030.

1.2.1.4 Shale oil

Shale oil plays such as the Bakken have far more in common with shale gas plays like the Marcellus Shale of Appalachia and Haynesville Shale of Louisiana than they do with oil shale of Colorado. Shale oil plays are known as unconventional fields. Truly, natural gas and oil do not exist underground in some giant caverns like oil lakes. Rather, hydrocarbons are found trapped in the pores and cracks of a reservoir rock. A typical conventional reservoir rock is sandstone; which is very pores and capable of holding hydrocarbons. Typically, those pores are also well connected like pipelines (channels) so that oil and gas can easily travel through sandstone reservoir rock because of having a high permeability. geologic pressures help in pushing these hydrocarbons However, Shale fields and other unconventional fields aren't particularly permeable (no channels). This prevents free travel of oil and gas even though there is plenty of oil and/or gas in the rock.. Thus even in shale fields under high geologic pressure, the hydrocarbons are essentially locked up in place.. To free that oil and gas puncturing/fracturing these rocks is done. This is known as "fracking". Producers presently have developed and refined two major technologies to unlock shale: Horizontal drilling and fracturing.: Horizontal wells are drilled down and sideways to expose more of the well to productive reservoir layers.

Fracturing is a process that describes water (with chemicals) is pumped into a shale reservoir under such tremendous pressure that it cracks the reservoir rock. . The chemicals help in increasing pore cavity, reduction of viscosity of oil and increase the permeability of the bed This creates channels through which hydrocarbons can travel. This process is called fracking Fracturing and horizontal drilling are now common in the US and producers have perfected their use on gas shale plays Shale oil, unlike oil shale, does not have to be heated over a period of months to flow into a well. And the oil produced from these plays is; in fact crude oil not differing in any manner from conventional crudes, many producers say that it's even better quality on average than West Texas Intermediate (WTI), the US standard crude The Bakken Shale is an unconventional oil play located in North Dakota, Montana and across the Canadian border in Saskatchewan. The US side of the play offers thicker deposits of oil; however, the Bakken looks like a commercial play in Saskatchewan as well. Fracking has become a World wide tendency which is showing that world can meet energy needs through gas and oil demands through 250 years! Exxon estimates that it would process about 66,000 tons of raw shale per day to produce around 47,000 barrels per day of shale oil (2009). And while Exxon was the largest company to invest in oil shale, it wasn't the only player in the industry. Unocal, Royal Dutch Shell (RDS.A), Amoco and Ashland Oil, among others, all had projects in the region. But almost two years later Exxon abruptly pulled out of the Colony Shale project, writing off more than $1 billion of its investment.

1.3 PETRO GLIMPSES AND PETROLEUM INDUSTRY IN INDIA

Many economists believe that economic rate is directly linked to the consumption of oil. It is seen that the World economy growth rate declining to 3.1% from 4.1% in the previous year 2004 while China's economy is kept at 8.1%. Indian Economic Survey says India's economic growth rate is expected around 6-8% as per the GOI, but in reality it may not be even more than 5% during 2005. Many Planners believe that oil consumption is directly related growth rate, though marginally varies.

The world oil demand during 2005 is expected to be about 90 MMBPD (the major growth in consumption will be from China and India) *i.e* equivalent to 4.5 billion tons of oil. At this rate of consumption the world reserves are expected to last another 40 years. Oil consumption by USA alone is nearly around .900 million tons per annum. While the margins in refining in many countries are coming down as low as 3 $ per barrel (Europe 2.37$) in India it is very high more than world average, about 4.05 $. Due to low marginals many US refineries of smaller sizes less than 3 MMTPA were closed *i.e.* More than 50% refineries about 250 refineries were closed our of 650 refineries operating at peak time. By 2010 the demand of oil in India will be about 140 MMTPA of which 100 MMT will have to be imported.

Petronet the first importer of LNG into the country is making arrangements to bring 5 MMT PA of LNG. Petronet commissioned its terminal at Dahej in Gujarat and successfully marketed 2.5 MT. From Qatar 20 MMT LNG is to be imported. After liberalisation the Multi Nationals have entered the oil field and are giving good competition in all petroleum products to native companies. Royal Dutch Shell returned to India and setting up retail outlets to market the products. Specially in marketing LPG Petronet is a competitor for ONGC and GAIL as they are entering market along with IOC, HPCL, BPCL and IBP.

RIL will step up its production from KG basin to 40 MMCMPD from 2007 with an investment of 10,757 crores (Dhurubhai 1 and 3) RIL has till date made 12 gas finds in deep sea block KGDWN. The estimates show about 8.3 trillion cft in the fields. The discoveries in D6 block has estimates of 14 trillion cft gas. The growth in consumption of petroleum products, mainly in fuels, is surpassing 6%, which is very difficult to be managed by Indian industries hence foreign companies are invited again correcting the fault of nationalization of oil companies.

A second LNG terminal is being setup at Hazira by Shell to sell 2.5 MMT of LNG from 2005. Hazira is being designed to handle 5 million ton LNG and the capacity will be expanded to 10 milion ton. IOC is setting up its terminal on the East coast near Chennai to handle the gas from Iran. This will boost the total sales of IOC to 4.5 MMTPA of gas. In addition Cairn Energy India operates with 5 licences Ravva, KG-OS/6, KG- DWN - 98/2 all in KG basin and CB/OS-2 and RJ-ON-90/1 in West Coast. Again from Qatar 20 million ton LNG is to be imported in the next few years.

IOC's Sri Lanka subsidiary, GAIL's, OVL entry into Egypt and Iran and ONGC's Videsh Nigam acquisitions in Sudan and Libya are some of the ventures Indian companies are doing. OVL's first fruits of investment by producing 3.3 MMT in Sudan. The consumption of petroleum by the whole World is higher than 4200 million tons, OPEC presently produces 27 MMBPD. The demand is much more from China, India and Korea. In addition to the demand often, hurricanes and storms disrupted US oil fields and refining. This marked the abrupt increase in crude price to 60 $ per barrel in 2005. Indian scene in production of oil is same as it was a decade ago, OIL produces around 3 MMTPA while small private players produced 2.5 MMTPA. Only consolation is OVL and ONGC are having reserves of 199 and 1128 MMT. By inviting private parties and multinationals the pricing of petroleum products may change, although Government will exercise its share of opinion, hence there may not be any benefit for consumer except perhaps more availability.

The challenges before the oil companies will be to manage the product prices and keep the products of high quality as per Euro 11 norms. In fact though pollution may be regarded as the highest priority there is no need to go for different high grades of petrol like 91 octane, high speed, Xtra-premium, Xtra-mile. In the name of these brands consumer can be easily cheated as there is no strict method of testing as is followed in Western countries. Further the conditions of the roads, the waiting time at signal points over rule the quality of speed and quality oils thus the Euro 11 normas will have no meaning. Even in USA different grades of gas are sold, the major consumption is of regular quality *i.e* the cheapest one as is in India

Indian situation is clear in having poor resources in oil and gas. Hence the alternative fuels and blending play vital role. In this direction the hope is in alcohol, vegetable oils. Any vegetable oil is suitable for running Diesel engines, however in our country where there is huge shortage of edible oils, and with limited land the program of cultivation of oil seeds will face tremendous difficulties. In other countries, in Malaysia palm oil is plenty, in USA soya bean oil largely available, sunflower or rape seed oil is available in Europe. Some studies in US have shown that these bio and ethanol fuels burn more energy than they produce. Researches at Cornell and California University contend 29% more fossil energy is required to turn corn into ethanol. Also the various forms of grass/wood require 45% more energy and soybeans/sunflowers require more than double the energy than the bio diesels. However the arguments and counter arguments are many and have to be studied carefully. Further the cost difference between Diesel and Petrol in those countries is zero or marginal and the edible oil is not very costly when compared to fuels oils, hence the bio diesels is a working proposition, similarly blending gasoline with alcohol not only to reduce the consumption of hydrocarbon but to reduce pollution is a necessity as it is available in plenty including India.

Strategic considerations are not given much importance in India unlike many western and European countries. USA produces only 45% of oil of its needs. Earlier in 1970-80 there were more than 600 refineries in USA, presently this has been reduced to less than 300. The reasons for shutting the refineries may be more, conspicuously environmental concerns, quality enhancement of motor fuels are on the top of the list. Thus the refining activity is shifting towards Africa and Asia. This obviously requires strategic oil reserves, which the president of USA operates whenever the supply is shrinking due to various reasons. The merger of various national oil companies in to two integrated outfit, *i.e* ONGC, Bharat Petroleum and HP to form an integrated company with exploration, production to down-stream refining and marketing, while the second merger is OIL and IOC. This consolidation is to reduce the operating and overhead costs, which is very high in India. The recent understanding agreement between Iran and India to Supply 7.5 MMT of LNG from 2009 is a significant thrust in the direction of procurement of petroleum. By the end of the decade India may have to import 120 MMTPA assuming a yearly 5.5% growth in consumption of petroleum fuels. This is mainly due to growth in automobile and aviation industries. The present production of gas is about 29 billion cubic meters. Though the earlier predictions of gas deposits were to a limited extent giving an active life of 25 years, the recent discoveries by RIL and ONGC have raised the hopes that gas demands can be met to substantially large extent. Thus the gas accounting to 6% of commercial energy of the country can go up to 7-8% in two/three years. Presently the primary energy demand increased from 1716 MMTOE (million ton oil equivalent) in 1992 to 2421 MTOE in 2001 *i.e.* commercial energy increased from 199 to 225 during that period. The gas consumption in fertilizer industry and power units is more than 80% thus leaving only small % for petrochemical and domestic needs The total current requirement is around 67 MMSCMD of gas.

The World's petroleum industry dates back to 1855 when Samul Kier started the first refinery of 5 bbl capacity at Pittsburg, incidentally first oil well was dug by Colonel Drake in August 1859 at Titusville. Indian oil industry was not lagging at its inception as the first oil well was dug in Captain Goodenhow in 1866 and the first refinery was started in 1893 by Assam Railways and Burma Oil company. Later on in the name of Assam Oil Company the refinery was shifted to Digboi and named as Assam Oil Company and it was the only Refinery in India till 1954. People were under the firm impression that there was no possibility of finding oil resources in

India. International Oil companies as a group written off India as barren land where there was no possibility of finding oil except in some parts of Assam. The Government of India started the refineries on sea coasts to easily procure oil from international market. Providence helped India to invite the Russian experts; accordingly in 1955 a team of top petroleum geologists arrived. Discreet surveys made by the team shoed promising areas. The discovery of Cambay oil field (1958) followed by Ankaleswar, strengthened the hopes of India and the collaboration between Russia and India started.

The real foundation of oil industry took place during 2nd Five–Year–Plan (1956-61) when the Government of India launched a planned program of exploration, production, refining and distribution of oil and products. Accordingly ONGC took birth in August 1956 with assigned duties of exploration and production of oil on On-Shore and Off-Shore. Next to come in this field is Oil India Limited, a joint venture of GOI and Burmah Oil Company (1956), which was given lease to explore and produce oil in Eastern Region. Indian Oil Corporation was floated in 1958 with objectives of procuring, processing, and distribution of oil. It has been divide into two wings, Refinery wing and Marketing wing. Refinery wing procures crude for the refineries, establishment of new refineries and new techniques and developments in quality specifications etc. Marketing division takes care of distribution and transportation imports and exports etc.,

The birth of ONGC, the discovery of new oil fields in Eastern and Western parts of the country had laid the major path for the country's progress on the oil front. Since 1949 to 1960 Standard Vacuum Oil Company alone explored the West Bengal basin and later jointly with Government of India. Since many decades the major oil producing organizations are ONGC, OIL, Assam Oil Company (Now amalgamated with Indian Oil) additional since last 8-9 years Reliance Petroleum, the Government's nationlisation and denationalisation processes to some extent destabilized the industry initially although now open market competition had vitalized the industry.

1.3.1 Oil and Gas Scene

The sedimentary basins of India, onland and Off-Shore up to the 200m isobath, have an areal extent of about 1.79 million sq. km. So far, 26 basins have been recognized and they have been divided into four categories based on their degree of prospectivity as presently known. In the deep waters beyond the 200m isobath, the sedimentary area has been estimated to be about 1.35 millon sq. km. The total thus works out to 3.14 million sq. km. of which about 30% is unexplored. Although this appears to be a sizeable proportion, it is a marked improvement over the corresponding figure of 50% in 1995-96. Also, exploration has been initiated in about 33% of unexplored areas 1995-96. Thus, across eight years, there have been significant forward steps in exploring the hydrocarbon potential of the sedimentary basins of India. (Director General of Hydrocarbons).

Total hydrocarbon resources, inclusive of deep waters, are estimated at around 28 billion tonnes oil and oil-equivalent of gas (O+OEG). As on 01.04.2004, initial in-place oil of 7.89 billion tonnes and ultimate reserves of 2.94 billion tonnes have been established. The resources estimated by DGH for its 'internal use', for the country, are 32 billion tonnes (O+OEG). India's sedimentary area (up to economic zone 200 miles) is 3.14 million square kilometers, of which 0.42 million sq. km area is Off-Shore area, spread over 6000 km coastal line and 0.4 million sq. km area is available in the form of continental slope, while the remaining area is land based[23]. India's Off-Shore basins are divided into 8 regions out of total 26 basins, as shown in Figure l.lb. The hydrocarbon potentiality of the entire region is 23 billion tons. The biggest Off-Shore activity started with discovery of Bombay High in 1973. Oil and oil equivalent (OEG) gas available in the country as per survey's of April 2004 is 1650 MMT. According to estimates the reserves of gas are 763 billion cu. Meters while the production has not gone up beyond 90 MMSCD falling short of demand.

7 Gas hydrate structures with free gas accumulation have been mapped in Andaman Off-Shore areas. Perhaps the recent tsunami effects may lead to migration of oil from Indonesian coast to coastal Andamans. The gas reserves are about 763 billion cu. meters while the oil proven reserves are put at 732 million tons.

Some countries and the reserves are listed here:

Iran	130.8 Billion barrels
Iraq	112.5 ......
UAE	87.8 ......
Kuwait	96.5 ......
Venezuela	78.0 ......
Saudi Arabia	262 ......
USA	22.5
Mexico	18 ......
Brazil	14 ......
Russia	69 ......
UK	25.4 ......
Norway	9.8 ......

Canada is having 178 billion barrels, however most of the reserves are oil-sand deposits which is difficult to extract. Usually oil-sand deposits are mined and oil is extracted by steam heating or extraction methods.

1.3.2 HBJ Gas-Grid (Figure 1.1*a*)

Associated gas comes out along with oil. The quantity of gas dissolved depends upon the saturated pressure of the reservoir. Commonly about 500 SCf dissolves in a barrel of oil under a pressure of 2500 psi. when the production of oil has to be stepped up naturally the associated gas quantum also increases. During the intial stages of Bombay High development there were no infrastructure facilities to consume the gas hence it was flared. During 80-90 the quantum of gas flared was enormous.

About two decades back gas was ranked second to oil, but today the thinking has changed. Right from a boiler fuel to petrochemical feed stock and a clean fuel for automobiles the utility and serviceability of gas has brought increase its creditability to No. 1 fuel. Today GAS Refinery is a reality. The enhanced gas consumption during last decade and ever increasing demand is a real meter to show how it is being regarded as most important material in daily life. GOI has started looking for Hydrocarbon deposits through out the country. The results of which were significant. Rajasthan, Gujarat, Tripura, Palk straits etc. are some of the examples. KG basin discovery in the late 80s brought significant change in the hydrocarbon activity in this region.

To successfully utilise the enaromous amount of associated gas from Bombay High, at Hazira a gas processing plant was commisioned and this sweetned gas is transported through a pipe line known as Hazira-Bijapur-Jagdishpur Pipe line (HBJ). The length of this pipe line initially was 1700 km, (presently it is 2300 km long) and in the second phase was able to transport 20 MMCMD gas. The gas is supplied to six fertiliser plants, and power house for generation of 400 MW besides to a gas cracker plant at Gandhar and IPCL. With branch line drawn up to Kanpur, Faridabad and Salimpur Petrochemical complex (originally planned). In full capacity the line can transport 33 MMMD of gas.

KG basin is the next biggest Off-Shore activity in India, approximate reserves are 7 trillion CM. With the entrance of Reliance Industries with the partnership of Niko Resources of Canada into this basin remarkable achievements were attained. With the success in Gas discovery in M-1 and H-1 wells it has plans to produce 45

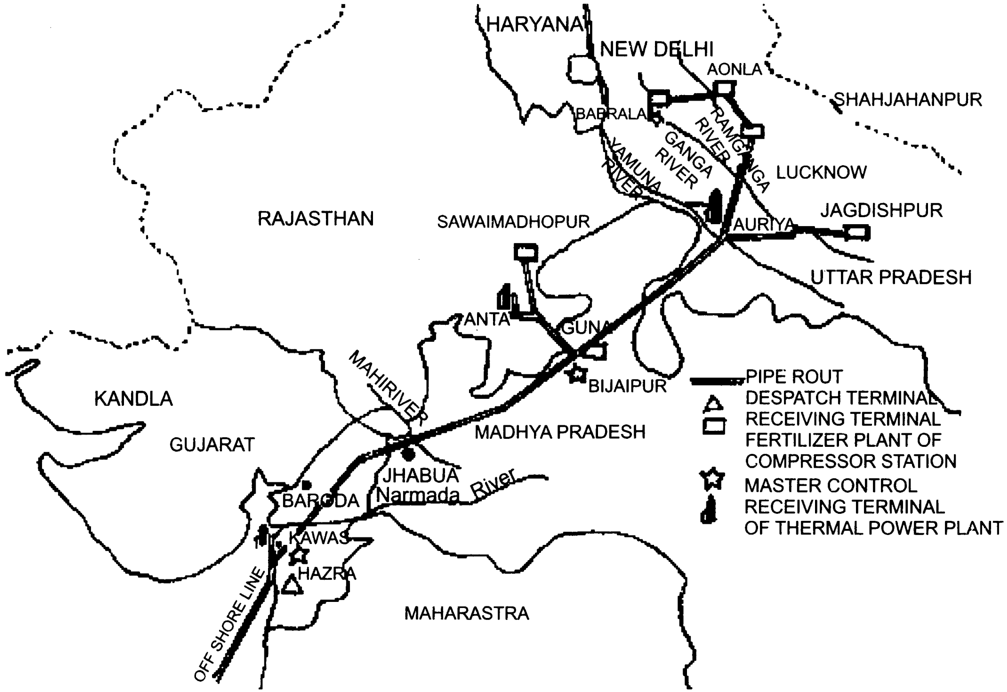


Figure 1.1*a* **GAIL, HBJ Gas Pipe Line.**

MMCMD of gas from its structure D6 (The reserves of which are 1.45 trillion cubic meters gas). Presently 60,000 to one lakh cu. meters of gas is being supplied to Power house in Kovvur 80 Km away from KG basin and other gas consumers. The future of gas is secure in KG basin and will provide gas to Nagarjuna Fertilisers and other gas based power houses when the production reaches one million cu. meters.

In addition to native resources LNG terminals at Dahej, Kochi by Petronet and at Hazira by Shell are in operation. LNG is more expensive because of transportational problems. Natural gas is cooled in cryogenic conditions to liquefy where by the volume of the gas in liquid condition occupies less than 600^{th} of gas volume and then transported. At the consumption point again it is gasified. So the infrastructure and operation adds to the cost of the gas.

1.3.3 Activities in Five–Year–Plans

Of all the quinequennium Plans the Sixth Plan Proved to be the fruitful one [25]. The oil production trebled from 10 to 30 MMTPA, gas production increased many times (2385 to 9774 Cubic meters per day). This was made possible by the relentless efforts of ONGC. Oil India Ltd. from its fields in Assam could produce marginally, however many small prospective fields were added. LPG production increased to million tons from 6.91 lakh tons. The refining picture was also encouraging Mathura Refinery commenced production and with the expansion of existing refineries the refining capacity touched 45 M^2TPA from 26. The discovery of Krishna – Godavari (KG) basin is most promising than it was anticipated, was another milestone in Indian Petroleum Industry. Against this background actual performance of 7^{th} Plan is distressing. Only ten wells were discovered, 3 On–Shore and 7 Off Shore. Even the discovered KG basin could not be vigorously exploited. In the terminal year of the Plan with great difficulty the crude production could touch 34 MMT. Bombay High is stagnating at 21 MMTA. An addition of 1 to 1.5 may be possible from KG and Cauvery basins. Oil and ONGC in Eastern Region can give no more than 5.6 MMT while ONGC and OIL in western Region may add 6-7 MMT. This picture clearly shows the possibility of importing 20 MMT of crude in terminal year of the Plan and addition 3 MMT of products.

In 8th Plan, in KG basin a mini refinery was established. The biggest Refinery at Jamnagar by Reliance of 27 MMTPA was also commenced. The refining capacity was gradually raised to more than 90 MMTPA. The 3 MMTPA refining capacity expansion and modernisation of Chennai Petroleum Corporation Ltd. (CPCL) has resulted in improving the distillate yield and produce cleaner fuels to meet Euro 111. It is also unique in handling Hydrocracker bottoms in Fluid Catalytic Cracker (FCC). Thus the yield of LPG has gone up to 4 lakh ton from 1.8 tons, further the expansion increased the yield of gasoline to 7 lakh tons. Thus the overall capacity of the refinery gone up to 9.5 million tons. Many changes have been brought in refinery administration. Nagarjuna Oil Corporation Ltd. is going to start a refinery at Cuddalore in Tamilnadu (6 MMTPA) 1976 nationalisation was the talk in 1997 deregulation of all the oil refineries and private participation was again allowed. Complete deregulation was allowed since 2002. Similarly APM (Administered price mechanism) has been dismantled since 2001-2002 in favour of market driven price mechanism (MPM).

During 2001-2002 IOC commissioned the following projects:

- FCC and Vacuum distillation unit at Haldia Refinery
- Production of unleaded petrol at Guwahati Refinery
- Gas turbine at Panipat Refinery
- Bulk storage terminals and depots at eight localities
- LPG bottling plants at six locations

The seven IOC refineries achieved crude throughput of 33.76 million tons, with Chennai and Bongaigon Refineries combined, the total handling of crude gone up to 42 million tons. The LPG bottling capacity had also gone up to 3.24 million tons. It could handle 47 million tons of petroleum products including low sulfur diesel (0.05% S). In Ninth–Five–Year–Plan, the small refinery at Thatipaka, KG Basin is able to supply about ten thousand tons of high speed diesel just by flashing the crude as the crude is highly paraffinic. Nagarjuna Oil Corporation Ltd. is going to start a refinery at Cuddalore in Tamilnadu (6 MMTPA). There is no rational out look in this regard as the automobile industry is allowed to expand freely. Even the surveys show that the Diesel consumption and petrochemicals consumption is down by 1 to 1.5%. Similarly naphtha consumption has come down due to alternate fuels.

Total demand for the petroleum products in the year 2005-06 is estimated to be 111.063 MMT registering a negative growth of 0.5% over 2004-05. Depleted growth was mainly due to less demand for products such as Naphtha (9.4%), LDO (34.8%) and HSD (0.2%). However, demand for other major products *viz.*, LPG, MS, ATF, SKO and Lubes are likely to go up by 1.7%, 4.6%, 14.6%, 1.8% and 11.3% respectively during the year 2005-06 over 2004-05.

Indigenous crude production including condensate for the year 2005-06 is estimated at 32.427 MMT. The crude intake of Indian refineries during the year is 127.334 MMT. Crude imports for refineries were estimated at 98.471 MMT. (67.605 MMT for PSU refineries 30.866 MMT for private refinery).

Against the gas demands, the production of 75 MMCMPD is almost half. The Tenth–Plan shows a short fall of 94 MMCMPD of gas. If the power sector expansion by 25000 MWs really takes place in coming Five–Year–Plan then the gas demand alone for the plants would be 150 MMCMPD. Thus relatively, even if better availability of gas is envisaged, presently even 50% of the demand could not be met due to lack of infrastructure and the Pipe Line project is under the authority of GAIL. However private producers are allowed to develop their own net work to serve consumers within 100 km from the point of production. Coal Bed Methane (CBM) is also being considered. The Reliance has plans to produce CBM from Sohagpur mine showing about 3.65 GBM.

The total current requirement of gas is around 67 MMSCMD. The present allocation is 30.5 MMSCMD from domestic sources against which supply is 23 MMSCMD. In addition to 23 MMSCMD, there is an additional requirement of 44.50 MMSCMD for conversion of naphtha and FO/LSHS units, expansion units, de-bottlenecking projects and revamping of closed units. Of the 23 MMSCMD being supplied to the fertilizer sector, 17.3 MMSCMD is APM gas and 5.8 MMSCMD is RLNG. An additional 6 MMSCMD of gas is expected from Panna-Mukta-Tapti (PMT) in next two years.

Similarly the lubes demand is increasing, just in three years time 1997-2000 the increase in imports shows 25-66 thousand tons. With strict laws enforced by environmentalists the production of lubes has become more complicated. There are many varieties of additives for specific purposes and the purpose and uses are many. The disposal of wastes is the biggest problem. The quality of the crude is first important for the production of lubes. The present capacity of Indian refineries is about 8.4 lakh ton of base stock against a demand of 1.2 million tons, hence the imports are increasing.

1.3.4.1 Growth of World Oil Industry

150 years ago the first petroleum refinery of 5bbl capacity was started by Samuel Kiers in Pittsberg in 1855-56. The first oil well (79 ft deep)

was dug by Col. Edwin L Drake in Titusville, Pennsylvania in August 1859. These incidents were the characteristic landmarks of American Petroleum Industry as well as to some extent the world's petroleum industry. George Bissell (1821 - 1884) is often considered the father of the American oil industry Against this the world's first oil refinery opened at PloiestL Romania in 1856. Later Several other refineries were built at that location with the investment from the US companies which were occupied by Nazi Germany during World War II.. Till the middle of 19th century there was no growth of petroleum industry and the products were waxes and burning oil. The advent of IC engines changed the industrialisation like electric motor. With the invention of automobile and airplane transportation and other industrial and defense needs changed displacing all other industries to second place and petroleum refining became the order of the day. These engines sought better quality and quantity of fuel hence a new wave of design and practice of refinery operations were pouring in from the European and western countries. I.

1.3.4.2 Russian Oil Industry

Oil extraction on the Aspheron Peninsula where Baku is located , dates back to 7th and 8th centuries. In the tenth century Arabian traveler. Marudee, reported that both white and black oil were extracted from Baku . And the area shot into fame as "oil Belt Of Baku" known by the name Black city and also became the 'Black Gold Capital'. Reports say that First oil well was dug in 1847 itself in Baku at BibiEyat oil field by Russian Engineer F.N. Semyonov

1.3.4.3 Indian Oil Industry

Indian petroleum Industry cannot be treated in isolation, as API and Indian petroleum industry are closely accompanying in the historic voyage of 150 years. IPI is just seven years to API at its inception. Infact this is the second oldest industry next to Sugar/Gur/Textile industry in India. In March 1867 the first oil well in the Asian continent was dug using mechanical means in the Makum Namdang area in Upper Assam.

India's oil industry is discernible into three distinct phases

(a) Pre independence
(b) Post independence
(c) Private Sector (economic Liberlisation era)

1.3.4.4 Pre Independence Oil Industry:

The history of Assam since 19th century is closely linked with the discovery of oil and its subsequent and continuing exploitation firstly, by the British, and later in the post-Independence period by different organizations of India Even though the sub surface oil explorations started in Assam in 1860, the beginning of Indian petroleum industry was registered with digging of an oil well (102 ft) by Cap. Goodenough of McKillop, Stewart & Co., Calcutta in November 1866, at Nahorpung about 30 miles south east of Digboi, just seven years after the world's first commercial oil well operated in USA . After finding no oil , the mission was given up. In March 1867 the first oil well in the Asian continent was dug using mechanical means in the Makum Namdang area in Upper Assam. The hit of oil at 118 feet and over a tone of crude oil production was the real foundation of Oil industry in India In 1889 the Assam Railway & Trading Company began massive oil exploration and production in Digboi. 1893 saw the formation of Assam Oil Syndicate to handle oil production in Assam and a complex sprung up in north of Digboi (1889). In 1901 with the establishing of the Assam Oil Company that started producing 500 barrels of crude oil per day and established a refinery to refine this crude in Digboi itself.

And the first oil refinery was started in 1893 at Margherita (3000 bbl capacity), which was later shifted to then commissioned Digboi refinery in 1901. by AOC. This followed by the second well at Makum near Margherita, about 8 miles from Digboi. In 1911 the Burma Oil Company came to Assam with the intention of oil exploration and production and soon they discovered massive oil reserves in the so called Burma Valley.

1.3.4.5 Post independence

Waman Bapuji Metre, (1906–1970), admiringly referred Metre in the Indian oil industry circles, was the doyen of Indian petroleum geologists. W. B. Metre joined Assam Oil Company Ltd. (AOC), a wholly owned subsidiary of Burmah Oil Company Ltd. (BOC), at Digboi in upper Assam as a geologist in 1930 It was under his leadership in 1953, that Assam Oil Company made the discovery of the first new oil field in post free- India, striking oil at No. 1 Nahorkatiya exploration well, at a location based on a pre-war seismic survey The Independent India's Oil industry was begun with

Second Five Year Plan.(1956-61) Cambay oil field discovered by Russian Experts is the start of indigenous industry .Born were the organizations for surveys & exploration and development of oil fields and erection of refineries and the sustainable programs were drawn up. This resulted in the birth of ONGC,OIL,IOC initially and many off-shoot organisations like GAIL,OVL,DGH etc

1.3.4.6 Oil And Natural Gas Commission (Corporation) ONGC: (August 1956)

With its head quarters at Dehra Dun, it was the premier institution for surveys and production and transportation of crude. Until IOC was born it was even taking care of refining activity. In fact it is the kick starter of refining and petrochemical activity in India. Established aromatic complex that became Koyali refinery olefin complex became prodigious IPCL in IPCL. It is the major crude producing organization in India. The biggest discovery of Bombay High later KG Basin were the triumphs of this institution. It has over sea organization (OVL) for all exploration works and extended its presence from Russia to Iran, Nigeria and Vietnam. Import of gas through Bangladesh from Burma and Gas from Iran are main ventures pending. Flagship explorer ONGC has discovered four new oil fields in Assam.

The new fields discovered in 2006-07 include Mekeypore, Kalyanpur,Panidihing and the latest, Disangmukh. At present, ONGC's Assam Asset has a recoverable reserve base of 72.8 million metric tonnes (MMT) of oil.

Under its cap are Ankaleswar oil filed, Jaisalmeer gas fields Kalolo.Balol fields of heavy crudes, Bombay High, KG, Kaveri Basins, Andmans, Some parts in Eastern region.

The gas cracker plants MGCC, GANDHAR, PATA are real gems in its crown. It has over seas venture in the form ONGC (OVL) The Assam Asset has a production target of 1.55 MMT for the year 2007-08. However, with a sustained annual increase in production, the asset now plans to achieve a target of 1.95 MMT in the year 2011-12 in Assam ONGC has single-handedly scripted India's hydrocarbon saga by: Establishing 6.42 billion tonnes of In-place hydrocarbon reserves with more than 300 discoveries of oil and gas; in fact, 6 out of the 7 producing basins have been discovered by ONGC: out of these In-place hydrocarbons in domestic acreages, Recoverable Reserves are 2.29 (BMT) of Oil Plus Oil Equivalent Gas. Cumulative production of

762.3 Million Metric Tonnes (MMT) of crude and 440.7 Billion Cubic Meters (BCM) of Natural Gas, from 115 fields. ONGC produces about 22 MMTPA through Off-Shore fields. The KG basin has been a potential zone for extraction of oil and gas for a long time. The ONGC started exploration for oil and gas in the KG Basin in April 1977, and drilled its first well near Narasapuram in 1978, and discovered gas. As part of exploration for oil and gas, the ONGC has drilled 622 wells, including 483 on land, and 136 offshore. At present 55 oil wells including 34 on land, 21 offshore and 176 gas wells, including 151 on land, and 25 offshore are in operation in the KG basin.

ts onshore oil production witnessed a gradual change over the period, from 0.207 MMT in 2005-06, to 0.284 million metric tonnes in 2008-09. ONGC has set up a mini-refinery at Tatipaka to distill crude oil into naphtha, high-speed diesel, superior kerosene oil and low sulphur high stock. It has rigs at Penikilpadu, South Mahadevapatnam, Kalla, Kesudaspalem, Malapuram and at Vadali. Currently, the ONGC produces 840 tonnes of oil and 44 lakh cubic metres of gas daily.

1.3.4.7 Oil India Limited (February 18, 1959,)

Established with its Head quarters at Duliajan,Oil India Private Limited was incorporated to to look after the prospects of oil industry in Eastern sector and expand - develop the newly discovered oil fields of Naharkatiya and Moran in the Indian North East. In 1961, it became a joint venture company between the Indian Government and Burmah Oil Company Limited, UK. In 1981, OIL became a wholly-owned Government of India enterprise.

Its discoveries Gelki oil fields and Tripura gas fields are note worthy. The organization had developed indigenous technology to transport waxy crudes and established an LPG plant based on Turbo Expansion Technology,(50,000tpa) first in Asia.(1982) It is also a partner in Brahmputra gas cracker . The Company produces around 2.7MMMSCM (06-07) Natural gas and has a dedicated pipeline network for collection/supply of gas as fuel and feedstock to many nearby industries such as Refinery, Fertilizer & Petrochemical Plant, Power generation Plant and 200 Tea Gardens. Additionally, OIL's exploration activities are sprea l over onshore areas of Ganga Valley and Mahanadi. OIL also has participating interest in NELP exploration blocks in Mahanadi Offshore, Mumbai Deepwater, Krishna Godavari Deepwater, etc. as well as various overseas projects in Libya, Gabon, Iran, Nigeria and Sudan. OIL, operates 1,432 km of cross-country crude oil pipelines. Commissioned in 1962, OIL's crude oil pipeline traverses 79 river crossings,. The state-of-the-art pipeline can transport over 8.0 MTPA of crude oil, feeding 4 Public Sector Refineries in North-east India. It produces 2264.57 MMSCUM natural gas and oil 5MMTPA during 2006-2007.

1.3.4.8 Indian Oil Corporation Ltd. :(1959)

Beginning in 1959 as Indian Oil Company Ltd., Indian Oil Corporation Ltd. was formed in 1964 with the merger of Indian Refineries Ltd. (Estd. 1958) Head Quarters at Delhi, Indian Oil Group of companies owns and operates 10 of India's 23 refineries with a combined refining capacity of 70 million tonnes per annum - the largest share among refining companies in India Two refineries of subsidiary Chennai Petroleum Corporation Ltd. (CPCL) and one of Bongaigaon Refinery and Petrochemicals Limited (BRPL) amalgamated in to IOC. The Corporation's cross-country crude oil and product pipeline network spanning about 9,300 km meets the vital energy needs of the country.

IOC achievements include

Largest and the widest network of petrol & diesel stations in the country, numbering about 21,000. Including Auto LPG Dispensing Stations. It supplies Indane cooking gas to over 66.8 million. In addition an R&D center at Faridabad supports, develops and provides the necessary technology solutions to the operating divisions of the corporation. They are backed for supplies by 170 bulk storage terminals and depots, 101 aviation fuel stations and 89 Indane LPG bottling plants. Indian refining major IOC had listed out its areas of interest in twelve different African countries -- namely Algeria, Angola, Congo Brazzaville, Egypt, Equatorial Guinea, Gabon, Libya, Mauritius, Nigeria, South Africa, Sudan and Tunisia.

Take over of Bongaigaon Refinery & Petrochemicals Ltd. INDMAX technology for the 4 MMTPA Fluidised Catalytic Cracking (FCC) unit at the Corporation's upcoming 15 MMTPA refinery-cum-petrochemicals complex at Paradip in Orissa, as well as for the FCC unit coming up at BRPL and HPCL: The Corporation's cross-country crude oil and product pipeline network spanning about 9,300 km meets the vital energy needs of the country.

1.3.4.9 DGH

To promote hydrocarbon activity in the country t, DGH has carried out several surveys to upgrade information covering a total area of 2 million sq kms of which, 84% is in offshore and 16% in on land. It has done pioneering work for initiating gas hydrate exploration in the country. East Coast and Andaman Deepwater areas is found to be promising areas for Gas Hydrates.. The total prognosticated gas resource from the gas hydrates in the country is placed at 1894 TCM.

Area Opened Up for CBM Exploration	13600 Sq Km
Blocks Awarded	26 Nos.
CBM Resources in Awarded Blocks	1374 BCM
Production Potential in Awarded Blocks	38 MMSCMD

1.3.4.10 GAIL(Gas Authority of India Est. 1984 Aug, New Delhi

It is India's flagship Natural Gas company, integrating all aspects of the Natural Gas value chain (including Exploration & Production, Processing, Transmission, Distribution and Marketing) and its related services. In a rapidly changing scenario, It is spearheading the move to a new era of clean fuel industrialisation, creating a quadrilateral of green energy corridors that connect major consumption centres in India

GAIL's Business Portfolio includes

6,700 km of Natural Gas high pressure trunk pipeline with a capacity to carry 130 MMSCMD of natural gas across the country

7 LPG Gas Processing Units to produce 1.2 MMTPA of LPG and other liquid hydrocarbons

1,922 km of LPG Transmission pipeline network with a capacity to transport 3.8 MMTPA of LPG, 30 oil and gas Exploration blocks and 3 Coal Bed Methane Blocks ,13,000 km of OFC network offering highly dependable band - width for telecom service providers (TELECOM), Joint venture companies in Delhi, Mumbai, Hyderabad, Kanpur, Agra, Lucknow, Bhopal, Agartala and Pune, for supplying Piped Natural Gas (PNG) to households and commercial users, and Compressed Natural Gas (CNG) to the transport sector 6,700 km of Natural Gas high pressure trunk pipeline with a capacity to carry 130 MMSCMD of natural gas across the country . GAIL began its city gas distribution in Delhi in 1997 by setting up nine CNG stations, catering to the city's vast public transport fleet. GAIL established North India's only gas based integrated petrochemical complex in Pata using natural gas as the feedstock and has a capacity of 4,40,000 TPA of Ethylene and 3,10,000 TPA of Polymers (HDPE 1,00,000 TPA & LLDPE). In 2001, GAIL commissioned world's longest and India's first Cross Country LPG Transmission Pipeline from Jamnagar to Loni. The Brahmaputra Cracker and Polymer Limited (BCPL) is a joint venture promoted by GAIL (India), and Oil India Limited (OIL),

The company has also extended its presence in Power, Liquefied Natural Gas re-gasification, A Rs 5,640 crore, 2,80,000 TPA Petrochemical Complex in Assam, A 6,200 crore, 4,00,000 TPA gas cracker complex plant in Kochi, Kerala - the feedstock for this plant, will be imported LNG, which will be regassified at the terminal of Petronet LNG Ltd. at Kochi.

GAIL has signed a Production Development Agreement with the National Petrochemicals Company, Iran, for jointly developing a polyolefin plant with a capacity of 1 MMTPA ethylene. Present day gas supply position shows:

Sector wise supply and demand for NG MMSCMD

	2007–08	2009–10
Power	79.7	102. 7
Fertilizers	41.0	55.9
City gas	12.1	13,8
Petrochemicals	25.4	29.1
Sponge iron	6.0	6.9
Total demand	179.2	225.5
Supply	80.5	120.0

GAIL's LPG plants Capacity (MTA)(from NG)

(a) Bijaipur (2 Nos), Madhya Pradesh 4,06,000

(b) Auraiya Pata, UP2,58,250

(c) Gandhar (2.2 lack tons) & Vaghodia, Hazira in Gujarat. 2,07,000 & 73,000

(d) Ussar, Maharastra 1,39,500

(e) Lakwa, Assam 85,000

(f) Duliajan assam 50,000

(g) Nagapattanm 50000

Domestic Gas Supply Outlook(MMSCMD)

Sources	07–08	08–09	09–10	10–11	11–12
ONGC	47.28	48.42	45.69	44.67	41.08
Pvt./JV	23.26	61.56	60.28	58.42	57.22
Anticipated D6 (RIL)	20.00	30.00	40.00		
GSPC	54	54	54		
Total	70.54	109.98	179.97	187.09	192.30

1.3.4.11 GSPC Gujarat State Petroleum corporation: (1979)

One of the leading oil and gas exploration, development and production companies in India. KG BASIN OFF-SHORE BASIN, primary asset is the Deen Dayal field in the Krishna-Godavari basin (the "KG basin"), which has significant gas reserves, part of which, Deen Dayal West ("DDW"), It t operates of the offshore KG-OSN-2001/3 block (the "KG block"), which includes the Deen Dayal field, and hold an 80.0% Working Interest in the block. Gujarat State Petronet Limited (GSPL) was set up to complement the efforts of GSPC. While GSPC harnesses and procures natural gas, GSPL is building the infrastructure that transmits the gas across the state of Gujarat and ultimately allows last-mile linkage to the end-user. This holds Working Interests in 15 producing fields in the Cambay basin further working Interests in 64 onshore and offshore exploration and production blocks. 53 of these blocks are located in India and 11 are located in Australia, Egypt, Indonesia and Yemen.also engaged in other activities in the energy sector as well like wholly owned subsidiary, GSPC LNG Limited "GSPC LNG"), is developing an LNG terminal at Mundra in Gujarat. Associated company Gujarat State Energy Generation Limited ("GSEG"), owns and operates a gas based power plant at Hazira in Gujarat. Another wholly owned subsidiary, GSPC Pipavav Power Company Limited ("GPPC"), is setting up a gas-fired combined cycle power plant at Pipavav in Gujarat. GSPL had also set up a wind farm at Jakhau in Gujarat.The company acquired several discovered oil and gas fields in the first and second rounds of bidding initiated by the Government of India during 1994-95. . State-owned (GSPC) has struck gas in the Krishna Godavari basin, off Andhra Pradesh . The reserves are estimated at 20 trillion cubic feet (tcf). In 1976, ONGC found gas in the Vasai offshore fields (in the Arabian Sea) with an estimated reserve of 24-27 tcf.

KG BASIN GSPC's Deendayal block, Reliance's Dhirubhai blocks, ONGC's G1 deepwater blocks and Cairn Energy's Annapurna, Padmavati and Kanaka Durga blocks may tilt the energy matrix for India as it goes about globe trotting in search of energy security. Total output at 100 mcm per day IT dwarfs the recent gas discoveries in the region by Reliance and ONGC. While Reliance was the first to strike gas off the Andhra coast in November 2002, estimated at 14 tcf, ONGC announced its find in March this year with estimated reserves of 4 tcf.

There are four major offshore platforms in the KG Basin – Oil & Natural Gas Corporation's GS-15 and GS-23, Reliance Group's D-6, one of the biggest offshore platforms in the country, Cairn Energy's Ravva and Gujarat State Petroleum Corporation's platform near S. Yanam. All the four have been placed on high alert. Exploration in deepwaters of Krishna Godavari Basin, off the Andhra cost, has given seven gas discoveries with reserves of 10.5 trillion cubic feet. "Another 10 tcf reserves are estimated in another shallow water block (awarded to GSPC) in the same basin," he said adding the total potential of in KG Basin was 40-50 tcf RIL started its production of crude oil at the KG-D6 block of the KG basin in 2008 with a production of 5,000 barrels a day. They achieved hydrocarbon production of 5,50,000 barrels. The block is located in the Bay of Bengal, 50 km off the Kakinada coast, a ONGC's natural gas reserves increased from 540.7 BCM in 2006-2007 to 550.27 BCM in 2007-2008. However, private companies and joint ventures walked away with all the accolades as they were able to increase their natural gas reserves from 459.4 BCM in 2006-2007 to 613.01 BCM in 2007-2008.t a depth of 8,000

ONGC's natural gas reserves increased from 540.7 BCM in 2006-2007 to 550.27 BCM in 2007-2008. However, private companies and joint ventures walked away with all the accolades as they were able to increase their natural gas reserves from 459.4 BCM in 2006-2007 to 613.01 BCM in 2007-2008.

1.3.4.12 Reliance Era: Jamnagar (1999)

Started with a refinery (the biggest in India 29MMTPA It has spread its wings to all fields of petroleum. With in 6 years it established another refinery of 33 MMTPA at Jamnagar. Its business comprises of Petroleum refining, marketing products and Petrochemicals production. Oil & gas exploration production- transportation and marketing are its activutues. It has producing blocks in KG Basin Supply of D-6 gas to fertilizer industry-: RIL's pipeline 1.5 mmscmd of gas.Reliance produces 550,000BPA, Cairon produces 40,000BPA

Reliance Industries has struck 9.46 tcf gas in D6 block while Cairn Energy of UK has found 1.2 tcf in the adjacent D5 block, he said. While reserves of state-owned companies ONGC and OIL increased marginally by 1.5%, reserves of private companies and joint ventures,led by RIL, increased by a whopping 33.4% in 2007-2008

Manufacturing Facilities: Reliance Industries Limited operates world-class manufacturing facilities across the country at Allahabad, Barabanki, Dahej, Dhenkanal, Hazira, Hoshiarpur, Jamnagar, Kurkumbh, Nagothane, Nagpur, Naroda, Patalganga, Silvassa and Vadodara.

1.3.4.13 Petronet LNG Limited (PLL)

It is government of India 's a joint venture company promoted by the Gas Authority of India Limited (GAIL), Oil and Natural Gas Corporation Limited (ONGC), Indian Oil Corporation Limited (IOC) and Bharat Petroleum Corporation Limited (BPCL) The country's first LNG receiving and regasification terminal at Dahej, Gujarat, and is in the process of building another terminal at Kochi, Kerala. While the Dahej terminal has a nominal capacity of 10 MMTPA [equivalent to 40 MMSCMD of natural gas], the Kochi terminal will have a capacity of 5 MMTPA [equivalent to 20 MMSCMD of natural gas]., a JV promoted by GAIL, IOCL, BPCL and ONGC was formed for import of LNG to meet the growing demand of natural gas. PLL has constructed a 5 MMTPA capacity LNG terminal at Dahej in Gujarat and expanded to 10 MMTPA capacity. is likely to expand this terminal to 10 MMTPA capacity by 2008-09 Shell's 2.5 MMTPA capacity LNG terminal at Hazira has been commissioned. Dabhol LNG terminal (total 5 MMTPA capacity,) is functioning. PLL has been formed for setting up of LNG import and regasification facilities. PLL has a long term LNG supply contract with RasGas, Qatar, for import of 7.5 MMTPA of LNG. PLL has successfully implemented a pilot project for supplying LNG through cryogenic road tankers. PLL is also coming up with a LNG terminal at Kochi, Kerala, with an initial capacity of 2.5 MMTPA, expandable up to 5 MMTPA and it is scheduled to be operational by end of 2011. GAIL has 12.5% equity stake in PLL, along with BPCL, ONGC and IOCL as equal partners.

1.3.4.14 Ratnagiri Gas and Power Pvt. Ltd. (RGPPL)

RGPPL is a joint venture company between GAIL, NTPC, Financial Institutions and MSEB. The capacity of the Ratnagiri Gas & Power

Station is 2,150 MW, which is the largest gas based power generation facility in the country and is currently producing 1,850 MW of power. RGPPL is in the process of commissioning an LNG import terminal of 5 MMTPA capacity. GAIL has 32.88% stake in the Company along with NTPC as equal partner.

1.3.4.15 Tripura Natural Gas Company Limited (TNGCL)

TNGCL is presently supplying gas to around 7,500 domestic, 170 commercial and industrial consumers and has set up one CNG station in Agartala, which is catering to more than 1,400 vehicles. TNGCL has received authorisation from MoPNG for CGD in Agartala. GAIL has 29% stake in the Company. "Dominion is marketing 4.6 million tonnes per annum and Gail has booked 50% of such capacity for 20 years," It has signed a deal with US energy firm Dominion for using capacity at its Cove Point terminal at Lusby in Maryland.

1.3.4.16 Indian Petroleum (At the End of Tenth Plan): Capacity 134.MMT 2012 Refinery through put is 180MMTPA

(IOC Refineries 10 at the End Of 11th Plan)

EXISTING	CAPACITY	EXPANSION (MMTPA)
Koyali	12.5	15-18
Barauni	4.2	6
Guwahati	1.0	
Haldia	3.75	6.5
Mathura	9.0	
Numaligarh	3.0	
AOC	1.065	
Panipat	6.0	12-15
Bongaigon	2.35	
Paradip	15	
[Chennai		
Refineries ltd	6.5	9.5
Manali 3rd phase	3	4
Narimanam Chennai	0.5	
HPCL		
Vizag	7.5	8.33
Mumbai	5.5	
+ Swing Refinery	2.0	
Bhatinda	9.0	

BPCL		
Mumbai	8	12
Kochi	7.5	
PRIVATE		
Vadinar (Essar)	14	20
Reliance	27	33/30
Nagarjuna	6.0	15 (2015)
GAIL		
Bina	9.0	
ONGC		
MRPL complex	9.69	
KG Basin	23000Bbl	
Kakinada ??	30?	
	159	+ 50 by the end of 12th Plan

1.3.5.1 Boost in Refining Refineries (IOC Refineries -10)

1. Guwahati Refinery, IOCL (Assam)

Guwahati Refinery is the country's first Public Sector Refinery as well as Indian Oil's first Refinery since 1962. Built with Romanian assistance the crude processing capacity at the time of commissioning of Refinery was 0.75 MMTPA and the capacity was subsequently enhanced to 1.0 MMTPA. Refinery was designed to process a mix of OIL and ONGC crude. Quality LPG, Motor Spirit, Aviation Turbine Fuel, Superior Kerosene Oil, High Speed Diesel, Light Diesel Oil and Raw Petroleum Coke are the products of this Refinery. It is fitted with a secondary Delayed Coking Unit (DCU).

2. Barauni Refinery, IOCL (Bihar)

Barauni Refinery was built in collaboration with the Soviet Union at a cost of Rs.49.4 crores and went on stream in July, 1964. The initial capacity of 2 MMTPA was expanded to 3 MMTPA by 1969. The present capacity of this refinery is 6.00 MMTPA. A Catalytic Reformer Unit (CRU) was also added to the refinery in 1997. Barauni Refinery was initially designed to process low sulphur crude oil (sweet crude) of Assam. After establishment of other refineries in the Northeast, Assam crude is unavailable for Barauni. Hence, sweet crude is being sourced from African, South East Asian and Middle East countries like Nigeria, Iraq and Malaysia. The refinery receives crude oil by pipeline from Paradip on the east coast via Haldia.

3. Koyali Refinery - IOCL(Gujarat)

This refinery was built with Soviet assistance at a cost of Rs.26 crores and went on stream in October 1965. When commissioned, the refinery had an installed capacity of 2 mmtpa and was designed to process crude from Ankleshwar, Kalol and Nawagam oilfields of ONGC in Gujarat and capable to process indigenous and imported, both low sulphur and high sulphur grades of crude oil. The product slate includes besides fuels, petrochemical products such as Linear Alkyl Benzene (LAB), Polypropylene Feed Stock, Food & Polymer Grade Hexane Its facilities include five atmospheric crude distillation units. The major units include CRU, FCCU and the first Hydrocracking unit of the country, 1.2 MMTPA for conversion of heavier ends of crude oil to high value superior products.. Its mega project worth around Rs.7000 crore to comply with the road map for supplying eco-friendly Bharat Stage-III and IV compliant MS and HSD and to upgrade the bottom of the barrel to improve the gross margin of the Refinery India's first diesel hydrodesulfurisation. By September 1999 ,ts capacity reached 13.7MMTPA. The refinery's facilities include five atmospheric crude distillation units.. company plans to go for the expansion and take the capacity up to 16 MMTPA as part of its long-term plan The refinery was modified to handle imported and Bombay High crude. The refinery also produces a wide range of specialty products such as benzene, toluene, MTO, food grade hexane, solvents and LABFS

4. Mathura Refinery, IOCL(Uttar Pradesh).

The refinery, was built at Rs. 253.92 crores It was commissioned in January, 1982 to processes 6.0MMTPA. The FCCU and Sulphur Recovery Units were commissioned in January, 1983. The refining capacity of this refinery was expanded to 7.5 MMTPA in 1989 with further increase ,the present capacity is 8MMTPA. The refinery processes low sulphur crude from Bombay High, imported low sulphur crude from Nigeria, and high sulphur crude from the Middle East. A DHDS Unit was commissioned in 1989 for production of HSD with low sulphur content of 0.25% wt. (max.). The major secondary processing units provided were Fluidised Catalytic Cracking Unit (FCCU), Vis-breaker Unit (VBU) and Bitumen Blowing Unit (BBU). a

Continuous Catalytic Reforming Unit (CCRU) Through Hydrocracker Unit (from Chevron, USA)

5. Digboi Refinery (Assam)

This is the oldest working Refinery of the World, established in 1901 by Assam Oil Company. Earlier this was at Margheretta processing 3000bpd established in 1893. IOC took over this refinery in 1981(October.14th) A new delayed cracking unit of 1,70KTPA was commissioned in 1999,A new solvent dewaxing Plant for maximum production of micro crystalline wax was commissioned in 2003.Also a hydrotreater for diesel installed. The capacity is almost same around 0.7MMTPA , having most of the units in this oldest refinery still working..

6. Haldia Refinery (IOCL)(West Bengal)

This Refinery was commissioned in January 1975 , to process Middle East crude, capable of producing lube oils. The fuel sector was built with Frcnch collaboration while Rumanian collaboration launched lube stocks. Presently it is capable of refining MM. 7.5 MMTPA Products include Jute Batching Oil. Diesel Hydro Desulphurisation (DHDS) Unit (1999,) for production of low Sulphur content (0.25% wt) High Speed Diesel (HSD). for producing BS-II and Euro-III equivalent HSD. Residue Fluidised Catalytic Cracking Unit (RFCCU) was commissioned in 2001 in order to increase the distillate yield of the refinery as well as to meet the growing demand of LPG, MS and HSD. Refinery also produces eco friendly Bitumen emulsion and Microcrystalline Wax. A Catalytic Dewaxing Unit (CIDWU) was installed and commissioned in the year 2003 for production of high quality Lube Oil Base Stocks (LOBS

7. Panipat Refinery, IOCL, (Haryana)

This refinery was set up in the IOC chain in 1988 costing Rs 3868 crores Installed to process 7MMTPA expanded to 13MMTPA. A Naphtha Cracker at Panipat, built at a cost of Rs 14,400 crore, is the largest operating cracker in India. It was expanded to process 15MMTPA in 2006. The major secondary processing units of the Refinery include Catalytic Reforming Unit, Once Through Hydrocracker unit, Residue Fluidised Catalytic Cracking unit, Visbreaker unit, Bitumen blowing unit, Sulphur block and associated Auxiliary facilities. In order to improve diesel quality, a Diesel Hydro

Desulphurisation Unit (DHDS) was subsequently commissioned in 1999. Referred as one of India's most modern refineries, Panipat Refinery was built using global technologies from IFP France; Haldor-Topsoe, Denmark; UNOCAL/UOP, USA; and Stone &Webster, USA The feed for the unit is sourced internally from Indian Oil's Koyali, Panipat and Mathura refineries. Panipat Refinery has also developed new products like 96 RON petrol, and sub-Zero diesel for the Indian army The Naphtha Cracker produces - Polypropylene (capacity: 600,000 tonnes), High Density Polyethylene (HDPE) (capacity: 300,000 tonnes) and Linear Low Density Poly Ethylene (LLDPE) (350,000 tonnes Swing unit with HDPE), Mono Ethylene glycol unit.Another technologically advanced plant is manufacturing Paraxylene (PX) from captive Naphtha and thereafter, converting it into Purified Terephthalic . It receives crude from Vadinar through the 1370 km long Salaya-Mathura Pipeline which also supplies crude to Koyali and Mathura Refineries of IndianOil. Panipat refinery with an expected consumption of 15430 TMT of crude worth Rs.64,517 crore will be the single biggest crude consuming refinery

Consumption of crude at eight IOC operated refineries is expected to be 54,750 TMT, worth about Rs.231,996 crore.

Panipat refinery with an expected consumption of 15430 TMT of crude worth Rs.64,517 crore will be the single biggest crude consuming refinery

8. Paradip (IOCL) (Odisha)

After delays Paradip refinery took the shape when Indian Oil Corporation Limited announced in March, 2006 that it is going to set up a refinery and petrochemical complex in the state of Odisha. Initially the production capacity was stated to be 9 MMTPA which was augmented to 15 MMTPA in due course. A 300,000bpd crude and vacuum distillation unit, a 104,000bpd vacuum gas oil hydrotreater, and 80,000bpd delayed coker unit, a 78,000bpd fluidised catalytic cracker (FCC) and a 53,000bpd crude catalytic reformer are established .Chemicals like paraxylene (24,000 bpd), polypropylene and styrene (10,000 bpd alkylation unit),are to be produced. It also commissions a pipeline from refinery to Ranchi. The refinery will produce 5.97 million tonnes of diesel, 3.4 million tonnes of petrol, 1.45 million tonnes of kerosene/ATF, 536,000 tons of LPG, 124,000 tons of naphtha and 335,000 tonnes of sulphur. The fluidised catalytic cracker will use the Indmax process developed by IOC. The process will convert heavy distillate and residue into LPG and light distillate products.Consumption of crude at eight IOC operated refineries is expected to be 54,750 TMT, worth about Rs. 231,996 crore

Consumption of crude at eight IOC operated refineries is expected to be 54,750 TMT, worth about Rs.231,996 crore. Panipat refinery with an expected consumption of 15430 TMT of crude worth Rs.64,517 crore will be the single biggest crude consuming refinery the first indigenous grass root Refinery in the country integrated with a Petrochemical complex at one location.

9. Chennai Refinery, (CPCL) (earlier MRL) Manali (Tamil Nadu)

Under the name of Chennai Petroleum Corporation Ltd was established in joint sector with GOI and AMOCO- National Iranian Oil Company in 1965 to process 2.5 MMTPA and now its capacity 9.5. CPCL became a group company of Indian Oil Corporation Limited (IOCL). After AMOCO and NIOC withdrew from the company. CPCL has two refineries with a combined refining capacity of 11.5 Million Tonnes Per Annum (MMTPA). The Manali Refinery is one of the most complex refineries in India with Fuel, Lube,Wax and Petrochemical feed stocks production facilities. CPCL's second refinery is located at Cauvery Basin at Nagapattinam. This unit was set up in Nagapattinam with a capacity of 0.5 MMTPA in 1993 and later enhanced to 1.0 MMTPA. The main products of the company are LPG, Motor Spirit, Superior Kerosene, Aviation Turbine Fuel, High Speed Diesel, Naphtha, Bitumen, Lube Base Stocks, Paraffin Wax, Fuel Oil, Hexane and Petrochemical feed stocks. Propylene Plant with a capacity of 17,000 tonnes per annum was commissioned in 1988 to supply petrochemical feedstock to neighbouring downstream industries. The unit was revamped to enhance the propylene production capacity to 30,000 tonnes per annum in 2004. CPCL also supplies LABFS to a downstream unit for manufacture of Liner Alkyl Benzene. The crude throughput for the year 2011-12 was 10.557 million metric tonnes (MMT) Delayed Coker Unit produces 50,000 bpd. A hydrocracker revamp, and sulfur recovery unit are also installed.

10. Bongaigon Refinery(BRPL) (Assam){subsidiary of IOCL)

The one million ton Bongaigaon Refinery & Petrochemicals Ltd. was incorporated on the 20th of February in 1974 under public sector of the government of India. BRPL became a subsidiary company of the Indian Oil Corporation Ltd., which is a Union Government undertaking because of its 76% equity. This was established under political considerations as there was no sufficient crude to run this refinery. The refinery presently processes crude oil produced in the Assam oil fields, as well as, Ravva oil fields in Andhra Coast through Pardip-Haldia- Bongaigon. The best crude of KG basin is lost to Assam while HPCL at Vizag has to import crude from outside (high sulfur) The production facilities of the company consists of a refinery with a crude processing capacity of 2.35 million tones per year While commercial production of the refinery started in 1979, the petrochemicals complex is designed to have a Xylene plant, dimethyle terephthalate (DMT) plant and a polyester staple fibre (PSF) plant which were commissioned in stages, The major products from the refinery are LPG, MS, Naptha, ATF, SKO, HSD, LDO, LSHS, LVFO, RPC & CPC. DMT and PSF, which are the most important products of the Petrochemicals sector. While the petroleum products (except RPC & CPC) are marketed by the Indian Oil Corporation Ltd., (Marketing Division), the Petrochemical products and RPC & CPC are marketed by BRPL itself through its own marketing network. Two Crude Distillation Units (CDU), two Delayed Coker Units (DCU) and a Coke Calcination Unit (CCU) with a processing capacity of 2.35 MMTPA of crude oil.. An LPG Bottling Plant with a capacity of 44,000 MTPA was also commissioned in the year 2003... BRPL has the unique distinction of being the first integrated refinery of India.

HPCL-2Refineries

11. Mumbai Refinery (HPCL), (Maharastra- Thane)

The refinery was established in Independent India by ESSO in 1954 with a capacity of 3MMTPA increased to 6.5 MMTPA. After Nationalisation under the nameof Hindustan Petroleum Corporation Ltd. (1974/7/04) existing. Plans to expand the capcity is 7.9 MMTPA (2012). The Lubricating Oils Refinery set up at Mumbai is largest lube refinery in India(3.35 lakh tons). Crude through put from two refineries is 16.19MMT in 2012 (Vizag 8.68 MMT) The refinery is installing a new FCCU of 1.4 MMTPA capacity, which will increase the FCCU processing capacity from the existing level of 1 MMTPA to 2.4 MMTPA. It has adopted cogeneration principle of steam FCCU CO boiler at Mumbai refinery HPCL is going to set up a Guru Gobind Refinery in Punjab.

12. Visakh Refinery (HPCL) (Andhra Pradesh)

Established as Caltex Refinery in1957,with a capacity1.0 MMTPA was amalgamated into HPCL in May 1978. The capacity was changing periodically presently standing at 7.5 MMTPA(1999) and likely to 8.33 MMTPA. effective since April 2010. Diesel Hydro desulphurization (DHDS) project was commissioned in the year 2000 to meet BS-I/II specification of diesel. The facilities were further augmented in 2005 by addition of 2nd Reactor in DHDS unit for supplying BS-III grade diesel. Visakh Refinery is executing the Mounded storage system for LPG and Propylene in place of existing LPG /Propylene Horton sphere

BPCL - 2Refineries + Joint Ventures: 2

13. Mumbai (BPCL) (Mahaul)

Established by Burma-Shell in 1955 to process imported crude at a rate of 5.25 MMTPA, expanded to 6.9 MMTPA. Further, it was expanded to 12 MMTPA in a Refinery Modernization Project undertaken by the company. The project added CDU/VDU, HCU, LOBS, HGU units After nationalization it was christened as Bharat Petroleum Corporation Ltd(1976). The crude throughput at BPCL's Mumbai Refinery, during, 2011-12 was 13,355.4 KT, which included 4,359.8 TMT of indigenous crude and 8,995.6 TMT of imported crude. High sulphur crude made up 47.5% of the throughput. During the period, 3,568.9 TMT of light distillates were processed by the refinery against a target of 3,224.5 TMT. 7,057.9 TMT of middle distillates were processed against a target of 6,175.4 TMT and 2,099.6 TMT of heavy distillates were processed against the target of 2,298.4 TMT. BPCL's bitumen and LPG business during April-November, 2011-12, grew at 30.17% and 8.87% as against the industry's growth of 6.33% and 7.51%. The total amount of high sulphur imported crude processed at the Mumbai refinery during June 2012, stood at 540,338 MT. This comprised of 139,716 MT of Kuwait export crude, 108,423 MT of Arab extra light, 85,775 MT of lower zakum crude, In addition, the refinery also processed 140,223 MT of .mported low sulphur crude during June. This was made up of 91,332 MT of Mellitah crude, 34,579 MT of Miri light crude, 9,952 MT of AKPO and 4,360 MT of EL Sahara? Refinery currently processes about 12 Million Metric Tons of crude oil per annum. BPMR has processed 61 different types of crude in five decades of its operations, making it one of the most flexible Refineries in the country. Bharat Petroleum Corporation Limited only PSU Oil Company in top category of "BRICS Carbon Ranking" amongst BRICS nations comprising of companies from Brazil, Russia, India, China & South Africa.

14 Kochi Refinery, Cochin, Kerala

Kochi Refinery, a unit of Bharat Petroleum Corporation Limited (BPCL), embarked on its journey in 1966 with a capacity of 50,000 barrels per day. Formerly known as Cochin Refineries Limited and now named as Kochi Refineries Limited It was originally established as a joint venture in collaboration with Phillips Petroleum Corporation, USA. It is one of the two Refineries of BPCL that has refining capacity of 9.5 MMTPA. Its fuels wing produces Liquefied Petroleum Gas, Naphtha, Motor Spirit, Kerosene, Aviation Turbine Fuel, High Speed Diesel, Fuel Oils and Asphalt. Specialty products include Benzene, Toluene, Propylene, Special Boiling Point Spirit, Poly Iso Butene and Sulphur. High sulphur crude made up 49.7% of the crude throughput at the refinery during the period with 10.5 MMTPA (2012) capacity, The Kochi refinery's delayed coking unit will have the capacity to process 3.84 tpd of vacuum resid and FCC products based on Lummus Technology. The refinery is under expansion from the present capacity of 9.5 MMTPA to 15.5 MMTPA and LPG production is expected to go up from 0.519 MMTPA to 1.26 MMTPA. 0.5MMTPA shall be consumed at Kochi whereas the balance approximately 0.76 MMTPA will be required to be exported Upgrading Refinery to produce clean automotive fuels; Installation and commissioning of Hydrocracker unit under Refinery Modernization Project (RMP) for production of Euro lll Grade Auto Fuel product (High Speed Diesel): Installation of Diesel Hydro-desulphurization facility for production of Euro lll Grade Auto Fuel product (High Speed Diesel): Revamp of catalytic Reformer Unit for production of Euro III Grade Motor spirit. Installation Methyl Tertiary Butyl Ether (MTBE) Unit to replace Tetra Ethyl Lead (TEL) from motor spirit. BPCL is upgrading their refinery units for producing Euro-III/IV quality auto fuels from 2010. Production of High Quality Group II + Lube Oil Base Stock (LOBS) for manufacturing environment friendly (ultra low sulphur, long life) lube oils.

15. Numaligarh Refinery,(1985) Numaligarh, Assam

Popularly known as Assam Accord Refinery BPCL has major shares followed by OIL, has been commissioned in 1999 having a capacity of 3MMTPA. and a VDU 1.3 MMTPA. It has Delayed coker 0.3 MMTPA, with coke calcination plant, hydrocracker 1.1 MMTPA and sulfur recovery unit. It produces MS.LPG and naphtha of 313 k tons and middle distllates ATF132, SKO270, HSD 1856 k tons respectively.

16. The Bharat Oman Refineries Limited (BORL) (Bina MP)

Conceived in the early 1990s as the Central India refinery, Bina Refinery, located at Bina, was built as a joint venture between India's Bharat Petroleum Corporation (BPCL) and Oman's Oman Oil Company, and the 6 MTPA refinery was commissioned in May 2011During the next two-three years, capacity of the refinery will be expanded from six to nine million tonnes with the ultimate objective being 15 MMTPA by 2015-16.

The project faced significant delays on account of environmental clearances and poor infrastructure and suffered high escalation of a budgeted ₹6,300 crore to ₹9,100 crore. The refinery also consists of a 1 MTPA naphtha hydrotreater, a 0.5 MTPA catalytic reformer to produce gasoline, a 1.95-million-tonne hydrocracker, a 1.63-million-tonne diesel hydrotreater and a 1.36-million-tonne delayed coker. Exports of naphtha from the refinery began in 2012. The plant is equipped to produce Euro III and Euro IV petroleum products and is capable of producing Euro V petroleum products with minimal additional investment. The crude is transported through a 935-km long pipeline from Vadinar to Bina. The products of the refinery are then transported through the 257- km Bina-Kota pipeline where it joins the Mumbai-Manmad-Bijwasan pipeline to reach the markets of North India.

Mumbai Refinery: The crude throughput at BPCL's Mumbai Refinery, during April to March, 2011-12 was 13,355.4 KT, which included 4,359.8 TMT of indigenous crude and 8,995.6 TMT of imported crude. High sulphur crude made up 47.5% of the throughput. During the period, 3,568.9 TMT of light distillates were processed by the refinery against a target of 3,224.5 TMT. 7,057.9 TMT of middle distillates were processed against a target of 6,175.4 TMT and 2,099.6 TMT of heavy distillates were processed against the target of 2,298.4 TMT..

BPCL's all-product sales during April to March, 2011-12 stood at 31.2 MMT, registering a growth of 6.6%. .BPCL's bitumen and LPG business during April-November, 2011-12, grew at 30.17% and 8.87% as against the industry's growth of 6.33% and 7.51%.

17. Bhatinda Refinery (2008) Punjab

Known as Gobind Singh Refinery (GGSR) is a refinery owned by Hindustan Mittal Energy Limited (HMEL) a joint venture between HPCL and Mittal Energy Limited he work for refinery started in and the refinery became operational in March 2012. The crude from ME is transported via Kandla - Bhatinda pipe line. Its annual capacity is nine million tons (180,000 barrels per day). It was built at a cost of $4 billion. The refinery will get its crude oil supply from Mundra a coastal town in Gujarat through a 1,014 km pipeline? It is a refineru of highest yields of propylene,. One of the highest Nelson Complexity Indices in the region with the ability to process Heavier and Sour crudes. Also, Petronet India planned a 2,290km cross-country pipeline to cater to north and central India. ExxonMobil believed there was no market and withdrew in February 1999.

Private sector -4

18. Essar Oil Refinery, Vadinar,

Though started in 1996, it could not be completed till 2006. Thegrass roots refinery in Gujarat was refinery has a capacity of 300,000 barrels per day . which started commercial production on May 1, 2008. It is configured to produce Euro II and Euro III grades of petrol and diesel fuel After its expansion it runs at a Nelson complexity index of 12.8. This means it will be able to refine all varieties of crude, producing Euro 5 grade fuels. The refinery recently expanded to a 20 million tons per annum. Essar has a global portfolio of onshore and offshore oil and gas blocks, with about 35,000 sq km available for exploration. It has over 750,000 bpsd of global crude-refining capacity (Vadinar + Stanlow U.K + Kenya refinery 50% stake). Essar's exploration and production business has 2.1 billion barrels of oil equivalent of reserves and resources. It is capable of producing LPG, Naphtha, light diesel oil, Aviation Turbine Fuel (ATF) and kerosene and it is designed to handle sweet to sour and light to heavy crudes. Vadinar Refinery (Essar Oil) is capable of processing over 80% of ultra heavy and heavy crude in its crude mix and produce higher grade products like Euro-

IV and Euro-V compliant petrol and diesel to cater to the domestic and international markets. The capacity of the refinery raised to 20 MMTPA (June 2012).This changed its complexity from 6.1 currently to 11.8 on the Nelson index, making it India's second largest single-location refinery to produce fuels compliant with the latest Euro IV and Euro V emission standards. Essar's exploration and production business has 2.1 billion barrels of oil equivalent of reserves and resources. Of this, approximately 150 million barrels are 2P and 2C resources, 1 billion barrels are prospective resources and 1 billion barrels are unrisked, in-place resources. Essar Oil Refinery will be expanded in two phases to achieve a capacity of 36mmtpa.

19. Nagarjuna Oil Corporation Ltd, (NOCL) Cuddalore, Tamil Nadu ,(2013)

The Refinery is one of the ventures of Hyderabad-based Nagarjuna Group, which was founded in 1973, by KVK Raju In the first phase, the implementation of six million tons a year capacity unit will be completed and operations are expected to commence by April 2014, It will be expanded to 9 million tons per annum and bringing the total crude processing capacity to 15 million tons per annum by 2015-16 The refinery can process some of the world's sour crudes and is said to have Nelson Complexity Factor (NCF) of around 8.74. The Crudes that are processed in the refinery are Bonny Light and Arab Mix crude.25 The Refinery's primary units include Crude Distillation Unit (CDU) and Vacuum Distillation Unit (VDU) which is said to be the mother units, and secondary units include Catalytic Hydrodesulphurization Unit, Methyl Tertiary Butyl Ether Unit, Cold Box Unit, Fluid Catalytic Cracking Unit, Delayed Coker Unit, Diesel Hydrodesulphurization Products include. High Speed Diesel, naphtha and Aviation Turbine Fuel. The refinery is designed for producing feedstock of EURO III and EURO IV standards Apart from regular petroleum fuels that are expected from this expansion, NOCL plans to set up a Xylene production facility, a Purified Terephthalic Acid (PTA) plant and a Propylene Recovery Unit.

20. Tatipaka Refinery(Mini) (2001) Andhra Pradesh

ONGC'S mini refinery at Thatipaka, approximately handles 0.1MMtPA light crude produced in KG basin. It removes lights suitable for farming application.

21. Mangalore Refinery: (April 2012) Mangalore (Karnataka) Phase-III

ONGC, set up in 1993 MRPL oil refinery at Mangalore . The refinery has a versatile design with high flexibility to process crudes of various API gravity and with high degree of automation. MRPL has a design capacity to process 9.69 million metric tonnes per annum and is the only refinery in India to have two hydrocrackers producing premium diesel (high cetane). It is also the only refinery in India to have two CCRs producing unleaded petrol of high octane. Currently, the refinery is processing about 12.5 million tonnes of crude per year. It is setting up a 3 MMTPA CDU/VDU, a 2.2 MMTPA Petrochemical Fluidised Catalytic Cracking Unit (PFCCU), a 3 MMTPA Delayed Coker Unit (DCU), a 3.7 MMTPA Diesel Hydrotreating Unit (DHU), a 0.65 MMTPA Coker Heavy Gas Oil Hydrotreating Unit (CHTU), a 70 KTPA Hydrogen Generation Unit and a 440 TMTPA Poly Propylene Unit,. Before acquisition by ONGC in March 2003, MRPL was a joint venture oil refinery promoted by M/s Hindustan Petroleum Corporation Limited (HPCL), a public sector company MRPL's Refining Capacity is around 8 % of India's total Refining capacity as on 1-04-2012. Also with enhanced capacity of 15 MMTPA with a Refinery complexity of around 9.5, MRPL is well placed globally, to compete with the peers in the Refining Industry.

21 & 22. Reliance Refineries , Jamnagar, Gujarat

The refinery was commissioned on 14 July 1999 with an installed capacity of 668,000 barrels per day (106, 200 m^3/d). It is currently the largest refinery in the world. The Jamnagar Complex is the first manufacturing complex of its kind, having a fully integrated petroleum refinery, petrochemicals complex, The Jamnagar Refinery with a refining capacity of over 33 million tons per year and paraxylene production of 1.5 millions tons per year, Reliance Jamnagar is the world's largest grassroots refinery and aromatics complex. Reliance Petroleum's parent company, Reliance Industries Ltd., is the largest private sector company in India.In 2008, a second refinery was built adjacent to the first, with an investment of over $6bn to double the company's Jamnagar facility's capacity to approximately 1.24 million barrels per day. Construction on the refinery was started in 2005 and took 36 months to complete in 2008.

On 25 December 2008, Reliance Petroleum Limited (RPL) commissioned its refinery into a Special Economic Zone in Jamnagar, Gujarat, from where only exports are permissible The completion of the RPL refinery has enabled Jamnagar to emerge as a 'Refinery Hub', housing the world's largest refining complex with an aggregate refining capacity of 1.24 million barrels oil per day, more than any other single location in the world. It is among the top ten refineries in the world. The second refining unit can process approximately 29 million tons. The combined capacity of the two refineries is 62 million tons, ranking the Reliance's Jamnagar refineries With its commissioning, the country's refining capacity jumped to 178 million tonne per annum (MTPA) compared with its annual demand of 129 MTPA. (2008)

23. Kakinada Refinery and Petrochemicals Ltd (KRPL). Andhra Pradesh

A16 MMTPA refinery is planned in 2006 with investors. ONGC being the major player Still the materialization is not complete. It is marked in the petro corridor of Kakinada- Rajahmundry route.

1. 3.5.2 Reserves and Potential Hydrocarbon locations

The Earth's total original endowment of oil amounts to 2.1 -2.8 trillion bls. As of 1998 we consumed 800billion bls. World energy consumption was growing about 2.3% per year. While in India it is up to 3% World Oil consumption is likely go up to 121 million bbls/day by 2020. It may be around 200 MMTPA in India by 2015. The oil shock of 1973 had unfurled the most intricate avenues of alternate energies. Almost same time the Scientists of MIT forwarded a hypothesis of LIMITS TO GROWTH. (Under club of Rome) And the lamentable Peak Oil Theory by Hubbert had added additional fuel to the burning prices of oil. Today if we look at those theories they are notjhing but Oil industry/ Rich capitalistic countries theories to extract more resources from third countries at far lower rates than prevailing or expected to reach. Since the oil exploitation started there was no smoothsailing for industry, like pollution, environmental disorders, safety, carcinogenic fear all were adversaly affecting still the oil became a sincere slave to humanity.

Proved Reserves of Natural Gas (Trillion Cubic Feet)

	2007	2008	2009	2010	2011
North America	310.229	316.706	343.577	NA	NA
United States	237.726	244.656	272.509	NA	NA
Central & South America	240.745	261.795	266.541	266.803	268.541
Brazil	10.820	12.280	12.890	12.862	12.940
Venezuela	152.380	166.260	170.920	175.970	178.860
India	37.960	37.960	37.960	37.960	37.928
Middle East	2,566.038	2,548.900	2,591.653	2,658.273	2,686.373
Africa	484.433	489.630	494.078	495.250	517.706
Canada	57.946	58.200	57.906	61.950	61.950
Mexico	14.557	13.850	13.162	12.702	11.966
World	6,216.033	6,219.265	6,289.147	NA	NA

See the figure 1.1b3 World oil consumption it is evident no where Peak consumption is shown but continues with increasing consumption.

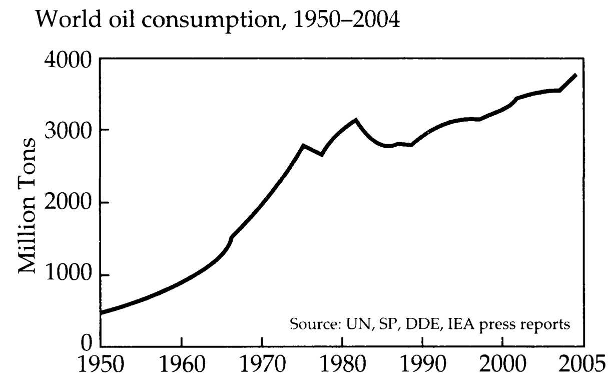


Figure 1.1b2 Oil consumption in the World (UN Source)

2000 USGS survey shows 2,300 billion barrels (370×10^9 m3) reserves proved are available and unconventional other types are many more times. Unconventional sources, such as heavy crude oil, oil sands, and oil shale are not counted as part of oil reserves. In 2009, the USGS updated the Orinoco tar sands (Venezuela) recoverable "mean value" to 513 billion barrels (8.16×10^{10} m3), with a 90% chance of being within the range of 380-652 billion barrels (103.7×10^9 m3), making this area "one of the world's largest recoverable oil accumulations" The Earth's total original endowment of oil amounts to 2.1 -2.8 trillion bls. As of 1998 we consumed 800billion bls. World energy consumption was growing about 2.3% per year. While in India it is up to 3% World Oil consumption is likely go up to 121 million bbls/day by 2020. It may be around 200 MMTPA in India by 2015.

Oil sands &bitumen	30%
Conventional oil	30%
Extra heavy oil	25%
Heavy oil	10%

Present World gas reserves are 300,000 billion CM (higher than shown above) while Russia leads with 55,000, Iran 33,500 billion CM, while India is having just 1,200BCM (Central Intelligence Agency: The World Fact Book). According to current estimates, more than 80% of the world's proven oil reserves are located in OPEC Member Countries, with the bulk of OPEC oil reserves in the Middle East, amounting to 66% of the OPEC total. OPEC Member Countries have made significant additions to their oil reserves in recent years. As a result, OPEC's proven oil reserves currently stand at 1,199.71 billion barrels. The present position NGLs and oil amount to 1.2 trillion bbls, (2010)Shale oil 4.8 trillion Tar sands (Canadian Deposits) 6.trillion bbls known deposits recoverable at the present rate of consumption another century and half is required to exhaust these reserves. According to Daniel Yergen for every bbl consumed during 2007-9 1.6 bbl new reserves were added, (BloombergBusiness week, Feb 5, 2012)

WORLD PEAK conventional crude oil production could plausibly occur anywhere between 2021 at a volume of 48.5 billion barrels per year and 2112 at a volume of 24.6 billion barrels per year product usage" Energy Information Agency (www.eia.doc.gov) Some Great World energy consumption was growing about 2.3% per year. While in India it is up to 3% World Oil consumption is likely go up to 121 million bbls/day by 2020. It may be around 200 MMTPA in India by 2015. World Oil Reserves (2004) 1188.6 billion barrels US Dept of Energy) or 928 billion ton hydrocarbons of which OPEC has 890 billion barrels (32 billion tons probable Indian reserves for internal use by DGH India) 1,161 billion barrels of oil equivalent .(Natural gas 1150 billion cubic meters & gas hydrates 1900 trillion cubic meters. in India) Oil Reserves estimation show 778 Million tons recoverable 2011-12)

1.3.5.3 *Incredible Discoveries:*

In 1976 Offshore discovery Cantarell oil field off Mexico became a minting machine for Petroleos(Pemex) Today it is producing 2.3 mmbd and has a reserve for 25 mmb in deep waters. New technologies are helping to probe more clearly beneath the Earth's surface. These advances allow to maximize the production of existing oil and natural gas fields and to drill deeper than ever before to locate and recover resources that were once considered too difficult to develop and exploit.. The Tahiti Field in the deepwater U.S. Gulf of Mexico demonstrates Chevron's capabilities. Tahiti's deepest producing well is more than 26,700 feet (8,140 m), a record for the Gulf of Mexico. (Production began in May 2009). Yamal peninsula holds the largest gas reserves of the Russian Federation 32.84 BCM. In 2009 alone the Natural gas production was registered at 33.846 million cubic metres.

1.3.5.4 *Future Scenario*

Energy consumption in the developed countries may increase by 3-3.5%a year while developing economies like China, Brazil, India, Turkey may reach unexpected consumption rates. China's strategy of tapping in and around may produces 70% of its oil demands by 2035 while looking for another 150 MMTPA. Brasil with 4 or more million tons of alcohol can go for cleaner energy. Its inorganic oil fields along with one of the biggest discoveries in the world can export about 100MTPA by 2035. India on the other hand is in a deplorable condition.. No Systematic policies to find alternative energy sources have been implemented, Solar panels/solar vehicles should have been the order of the day, but no hope even for another ten years. Stunning growth in automobile sector would drain of continuously exchange reserves, making the country more dependent on oil from other countries. Even nuclear energy is not progressing, facing hurdles due to local resistance hence energy sector's future is dim. Aided by no strict policy on growth of population as followed in China, India's population will grow at much faster rate than any other country adding more perils to energy sector.

Royal Dutch Shell, when major oil resources getting harder to find, and the need for cleaner, reliable alternative energies to share growing needs of population (June 11, Fortune: 2012) Shell's slogan for 250 year supply of NG to the World(www.shell.us/letsgo) is well known, however the effect of it in Market price is not good.

US domestic oil production peaked in 1970. Global production of oil fell from a high point in 2005 at 74 mb/d, but has since rebounded, and 2011 figures show slightly higher levels of production than in 2005. Most of the remaining oil is from unconventional sources. Rough estimates indicate that out of an available 2 trillion barrels of oil, about half has been consumed. Between 1995 and 2005, U.S. consumption grew from 17,700,000 barrels per day (2,810,000 m^3/d) to 20,700,000 barrels per day (3,290,000 m^3/d), a 3,000,000 barrels per day (480,000 m^3/d) increase. China, by comparison, increased consumption from 3,400,000 barrels per day (540,000 m^3/d) to 7,000,000 barrels per day (1,100,000 m^3/d)

The World has witnessed ups and downs in oil consumption after Oil shock of 1973. Oil production per capita has declined from 5.26 barrels per year (0.836 m^3/a)in 1980 to 4.44 barrels per year (0.706 m^3/a) in 1993, but then increased to 4.79 barrels per year (0.762 m^3/a) in 2005 In 2006, the world oil production took a downturn from 84.631 to 84.597 million barrels per day (13.4553×10^6 to 13.4498×10^6 m^3/d) although population has continued to increase. This has caused the oil production per capita to drop again to 4.73 barrels per year. Canada has been looked upon as a favorable supplier given its gigantic reserves of hydrocarbons. The country is also the third largest natural gas producer in the world which makes it a lucrative long term supplier to the needed. 'Its average annual gas production totals 6.4 TCF with reserves over 1.72 TCM. U.S. petroleum consumption reached an estimated 18.87 million barrels per day in 2011, and is expected to increase to 18.96 million barrels per day in 2012. Demand for 2012 is projected to continue to decline to 8.74 million barrels per day.. This equates to an average of 33 miles per vehicle per day. The cost of crude oil accounted for 72% of the cost of a gallon of gasoline in the United State while refining accounted for just 12%. Taxes and distribution/marketing accounted for 11% and 5% respectively.

World non energy refinery products (2009) include: Naphtha & spirits 56% bitumen 21%, asphalt, wax 1% , lubes 9% petroleum coke 23%. Important fuels and refining in the world and India are shown below

Production of energy fuels '000 tons

		Total, oil fuels	Aviation gasoline	Motor	jet fuel	kerosene	Diesel	fuel oil	LPG gas	Refinery gas
World	2006	3230197	1618	889670	228016	92420	1178057	588396	112278	129741
	2009	3224425	1430	913897	221817	83453	1230897	518459	118749	125618
India	2006	107299	–	12539	7805	8491	54268	15697	6315	2184
	2009	144440	–	22554	9304	8545	77605	17535	6515	*2382

1.3.5.6 Indian Hydrocarbon Activity

Indian crude production during April-February 2013, was 34.639 MMT. The targeted production for the cumulative period was 36.517 MMT. Gas production April-February 2012-13 period came to 37.503 MMCM, which was also lower then the planned target of 37,716 MCM. Cumulatively, in the April-February period, Indian refineries processed 165.637MMT of crude, which was 1.8% above the target of 162.658 MMT. Against planned the crude oil production target of 206.73 MMT in the eleventh plan, the actual achievement is only 177 MMT, that is, 14 per cent below the target. .and natural gas production was 212.54 BCM as against the production target of 255.76 BCM,. Refinery capacity addition too suffered: Just 88.42 per cent of the target was scaled and major projects, including the MRPL expansion and Paradip refinery projects have slipped into the Twelfth Plan.

1.3.5.7 Indian refinery throughput million ton

1960-61	6.130	95-96	58.74
65-66	10.233	99-2k	85.96
70-71	18.38	2k8	156.11
75-76	22.28	2k9	160.67
78-79	25.97	2011	206.121
80-81	26	2012	211.42
90-91	51.77		

1.	Domestic Gas Supply Outlook(MMSCMD)					
2.	Sources	07-08	08-09	09-10	10-11	11-12
3.	ONGC	47.28	48.42	45.69	44.67	41.08
4.	Pvt./JV	23.26	61.56	60.28	58.42	57.22
5.	Anticipated D6 (RIL)		20.00	30.00	40.00	
	GSPC			54	54	54

6.	Total	70.54	109.98	179.97	187.09	192.30

7. KG BASIN OFF-SHORE BASIN
8. Reliance produces 550,000BPA
9. Cairon produces 40,000BPA

ONGC's 3rd LPG plant at Uran on hold affected GAIL's plant at Usar, NG production is 47.56 billion cubic meteres less than 2011 by 8.92% (53Billion c.m) Oil imported was 171.73 million tons 4.5%increase over previous year. 9.7 Million ton LNG) Refinery products were 196.8Million tons during this period additionally 2.13 million tons of LPG form NG were available

1.3.5.8 LNG

Progress in LNG re-gasification capacity of 13.6 MMTPA,(2012) is expected to reach 53.5 MMTPA by 2016-17 with the commissioning of new terminals at:

10 MMTPA at PLL's terminal	12.5 MMTPA by 2013
Dahej	3.6 MMTPA
Shell's terminal at Hazira.	5 MMTPA in 2014-15.
RGPPL's Dabhol terminal	5 MMTPA in 2014-15.
GSPC-Adani's terminal at Mundra	5-MMTPA
IOC's terminal Ennore	5 MMTPA

With the production of naphtha rising from 12.6 MMT in 2003-04 to 19.4 MMT in 2010-11. In contrast, consumption of naphtha declined from 11.9 MMT to 10.7 MMT during the same period. the export of naphtha has increased from 2.2 MMT in 2003-04 to 10.7 MMT in 2010-11. In comparison, naphtha imports, after going up to 6 MMT in 2007-08, fell to 2.1 MMT in 2010-11

1.3.5.9 Reserves (See Figure 1.1b)

The reserves of India are going up day by day, due to the improved technological skills and massive investments. The 7th Plan additions itself constitute nearly 1000 M^2T of hydrocarbon deposits. The following are some known reserves.

KG offshore	13 M^2T oil and 3 BCUM gas
KG Basin	570 M^2T oil

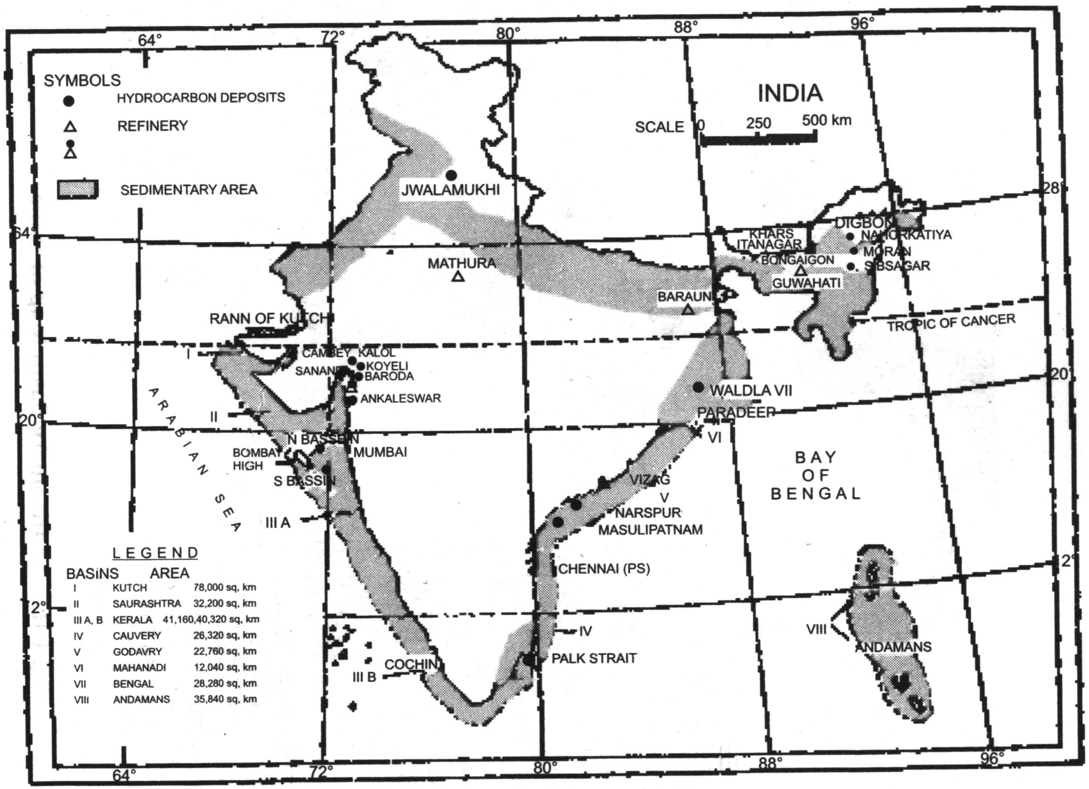


Figure 1.1*b* **Prospective and Existing Hydrocarbon Deposits and Other Petroleum Activities.**

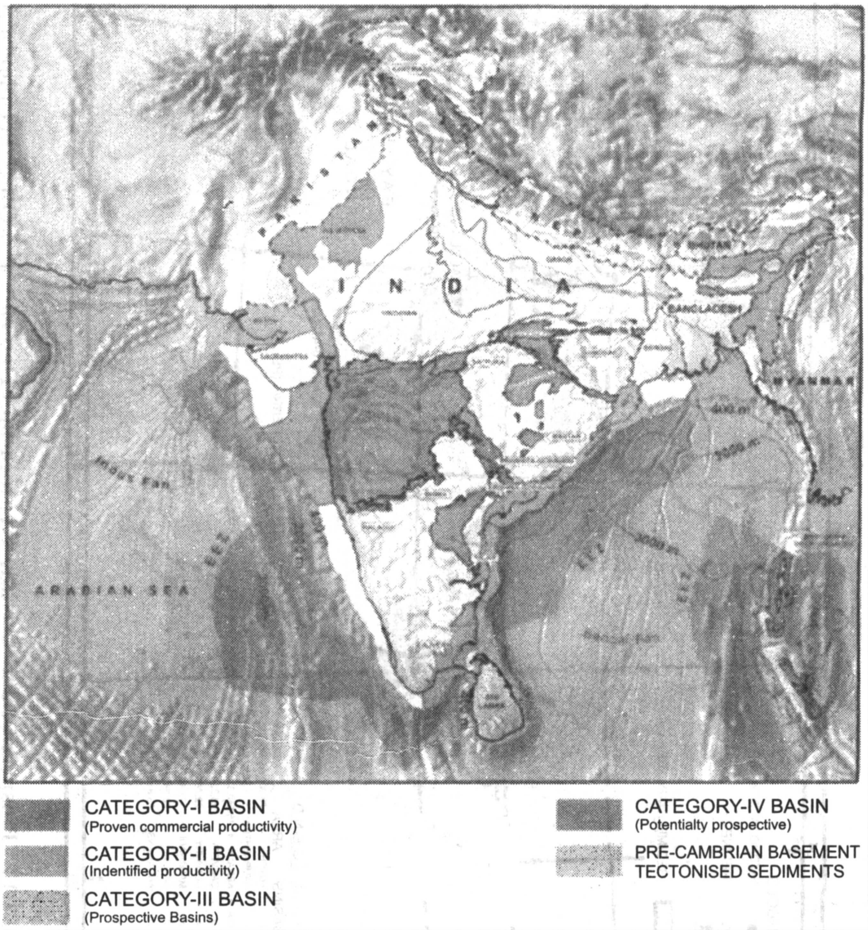


Fig. 1.1*b*2 : Sedimentary Basin Map of India

TABLE 3*b* : (*Contd.*) Data From DGH.

BREAK-UP OF DOMESTIC CRUDE OIL & NATURAL GAS

	2003-04		2004-05		2005-06 (Till Nov. 05)	
Company	**Crude** *(MMT)*	**N Gas** *(MCM)*	**Crude** *(MMT)*	**N Gas** *(MCM)*	**Crude** *(MMT)*	**N Gas** *(MCM)*
ONGC	26.057	23.584	26.484	22.971	16.241	15.000
OIL	3.002	1.887	3.196	2.005	2.192	1.513
Pvt/JV	4.314	6.491	4.300	6.77	2.962	4.832
Total	**33.373**	**31.962**	**33.980**	**31.746**	**21.395**	**21.345**

KG basin wells are producing initially 600 bbls/day. The production can be increased to 2000 bbls/day per well by introducing early production system (EPS) and the gas flow rates touch as high as 52,000 CUM per day.

Amalapuram wells	1,300 bbls/day
Mandapeta wells	52,000 CuM/day
Razole, Bhiminipally,	
Tatipaka, Pasarlapudi	3 M^2CuM/day
Cauvery Basin	370 M^2T
Vedanarayanapuram	
wells yield rich quality oil of	1500 bbls/day
	40% gasoline
	25% kerosene
	11% Diesel
Bhuvangiri wells	150-200 bbls/day
Gas	52,000 CuM/day
Nagapattanam wells	150-200 bbls/day
Madanam coast wells	4,300 bbls/day
Assam free gas	34 BCu M
Associate gas	27 BCu M
Assam/Arunachal	59 M^2T
Assam-Arkan Basin	3 Billion ton Hydro-Carbon
(One lakh sq km)	reserves
Tripura gas fields	881 BCu M
(Gas yields	1.3 lakh Cu M per day)
Rukia	4.5 lakh Cu M per day
Rajasthan :	
Bikaneer	25M^2T
Jaisalmeer	1 BCu M; 75 M^2T (Reserves)
	1.4 lakh Cu M/day (Production)
Tapati Structure	14.2 M^2 Cu M
Bombay High (1 RS)	1000 M^2T
BHN	100 M^2T

1.3.5.10 Energy Reserves

India is relatively well endowed with both renewable and exhaustible energy resources. Coal, oil, and natural gas are the primary commercial sources of energy. While the Indian coal reserves have increased from 62.54 BT (billion tonnes) in 1991 to 69.9 BT in 1997, the world coal reserves have declined from 1040.52 BT to 1031.6 BT for the same period. However, on a per capita basis, coal resources are well below the world average. The R/P (reserve-production) ratio for natural gas is higher than that of crude oil. This clearly brings out the possibility of a higher rate of production of natural gas than at present. India's R/P ratio for crude oil has fallen from 25.6 in 1991 to 15.6 in 1997. Table 1.3*a*1 shows proven reserves of fossil fuels and R/P (reserve-production) ratio. Gas hydrates to an extent of 1900 trillion cu m is another valuable addition to the hydrocarbon activity.

TABLE 1.3*a*1 Proven Reserves and R/P Ratios.

Fuel	End 1987				End 1997			
	Reserves		R/P ratio		Reserves		R/P ratio	
	India	World	India	World	India	World	India	World
Coal (billion tonnes)	62.54	1040.52	195.00	239.00	69.90	1031.60	212.00	219.00
Crude oil (billion tonnes)	0.80	135.40	25.60	43.40	0.60	140.90	15.60	40.90
Natural gas (trillion cubic metres)	0.70	124.00	48.80	58.70	0.49	144.80	22.90	64.01

TABLE 1.3*a*2 Energy Accommodation During Ninth–Plan.

Fuel	1996/97	1997/98	1998/99	1999/20	2000/01	2001/02
Coal (MMT)	311.00	323.40	334.00	359.90	392.80	405.70
Petroleum Products (MMT)	81.2	86.2	94.2	100.6	106.8	112.8
Natural Gas (mscmd)		76.64	79.70	82.68	82.68	82.68
Power (GW)	68.373	73.458	78.936	84.466	90.093	95.757

1.3.6 Estimation of Reserves

The estimation of hydrocarbon content in a reservoir under operation is usually done by material balance. However the estimation in a fresh finding is done by knowing the physical conditions of the reservoir. Usually the deposit occurs in the porous sedimentary region. The porosity of the reservoir ($\in$) multiplied by the volume of the reservoir is the maximum amount of the hydrocarbon that can be present in a reservoir. However it is accompanied by formation water which is known as connate water (S_W). Hence the total deposit will be exclusive of the water and is given by

The volume of the deposit = vol. of the reservoir $\times \in \times (1\text{-}S_W)$.

This is the volume of the deposit under reservoir conditions. Usually the deposit is several metres deep which experiences more than 100 atmospheres pressure. This keeps the deposit under compression. As the oil or gas comes out of the well the volume increases because of decrease in pressure. Thus when the amount of deposit is calculated it is usually expressed at the standard conditions of pressure and temperature. A correction coefficient known as liquid volume factor (B_0) or gas volume factor (B_g) is incorporated in the above calculation.

Liquid/gas volume factor is defined as the volume of barrel under reservoir conditions to surface conditions. In case of liquid the coefficient compression and coefficient of thermal expansion are small; for gases they are very high.

Thus the volume of deposit at surface conditions = Vol. of the reservoir $\times \in \times (1\text{-}S_W)\ B_g$.

Problem 1.1

A reservoir is having a volume of 1.35 kilometers cube. The porosity of the rock is given as 22%, the connate water is estimated to be of 16.5%. Find the volume of the oil deposit. Given the pressure of the reservoir 204.8 bars and temperature of the reservoir 39.8°C. B_0 given as 1.12 STB/bbl

Solution

Volume of deposit = $1.35 \times 10^9 \times 0.22 \times (1-0.165) \times 1.12 \times 5.043^* = 1.4007$ billion barrels

Problem 1.2

In a gas reservoir, the gas is flowing out at a rate of 2500 SCF per hour. The pressure of the reservoir is constant at 1575 psia. The residual gas saturation is assumed to be 23% and the gas volume factor at the reservoir pressure is 55.23 SCF/cft. and at surface condition it is 176.8 SCF/cft. Find the time taken for recovering 55%

*bbls per cubic meter

of the reservoir gas? Reservoir volume is 3.2 ac-ft. Porosity is 22% Connate water 18.6%.

Solution

Volume of the gas in the reservoir $= 3.2 \times 43560 \times 0.22 \times (1 - 18.6) \times 176.8$ SCF

$= 441.334 \times 10^6$

Volume of the gas, retained in the reservoir $= 3.2 \times 43560 \times 0.22 \times 0.23 \times 55.23$ SCF

$= 389, 550$

Net available gas $= 440.944 \times 10^6$ at surface

Time taken $= 440.944 \times 10^6 \times 0.55/2500 \times 24 \times 360$

$= 11.2$ years

1.4 COMPOSITION OF PETROLEUM

Petroleum occurs in nature in all three possible states solid, liquid and gas. The liquid petroleum is usually coloured from dark brown to bluish black or black, exhibiting sometimes bloom or fluorescence. The semi-solid or solid petroleum is well known by the name pitch, usually black in colour. The famous pitch lake of Trinidad is an example of such vast deposits of petroleum in solid state. Such kind of deposits are assumed to form after the evaporation or migration of lighter fractions. The gaseous deposits of petroleum are known as natural gas deposits, where sometimes wild gasolines are also accompanied. Gas from condensate reservoirs contain a good portion of lighter fractions of a boiling point upto 30°C. Associated reservoirs contain gas mainly in the dissolved form in liquid petroleum.

Although the composition of petroleum depends not very much on the origin of formation, but certainly change with the time of formation, storage and different stratas through which it migrated. It is a homogeneous mixture of various hydrocarbons of saturates and ring-structures. The average ultimate composition of petroleum is mainly given in terms of constituents of hydrocarbons, namely carbon and hydrogen as follows:

Carbon	:	84-86%
Hydrogen	:	11-14%

The other major elements of importance are sulfur, oxygen and nitrogen. These elements in hydrocarbons are usually treated as impurities because of their inherent properties like odour, colour corrosiveness etc. Generally these three elements combined do not exceed 5% on an average. Exception to this statement can be traced in some Gulf crudes, Russian crudes and Mexican crudes. Ratwi (Neutral zone) contain as much as 5% of sulfur alone. Middle East and Gulf crudes contain upto 3%, compared to these, crudes from East possess very less amount of sulfur, examples being Indonesian, Indian, Nigerian, and Libyan crudes.[26] The crudes of U.K., like Beryl, contain upto 0.5% sulfur.

The bulk of petroleum is made up of hydrocarbons of saturated compounds like paraffins, naphthenes and unsaturated cyclic compounds mainly aromatics.

The highest carbon atom present in the crude is C_{70}. Further, except first few hydrocarbons, all other hydrocarbons exhibit isomerism. The general properties of these homologous series are discussed below:

1.4.1 Paraffins

C_nH_{2n+2} is the general formula of paraffins. First three compounds are gases while compounds upto C_{16} are liquids and beyond that, they assume semisolid consistancy. Well beyond C_{30} assume the shape of solid blocks, sometimes even crystalline forms. There are number of isomeric compounds for each compound, profoundly differing in properties. For example, upto C_3 no isomers are possible, C_4 exhibits only two isomers, as shown here:

n-butane *i*-butane

And C_5 exhibits three isomers. The number of isomers increases as the number of carbon atoms increase. $C_{13}H_{28}$ exhibits 802 isomeric forms.

1.4.1.1 General Properties of Paraffins

Paraffins are stable, not attacked by sulphuric acid or other oxidising agents. However, paraffins of higher order > C_{30} are prone to oxidation. Even usual oxidising agents like potassium permanganate can cause good amount of oxidation. The aptitude to contribute the substituted products with halogens has magnified the petrochemical industry. Higher paraffins are very much insoluble in water; though the lower ones are soluble in ethers and alcohols (Figure 1.2).

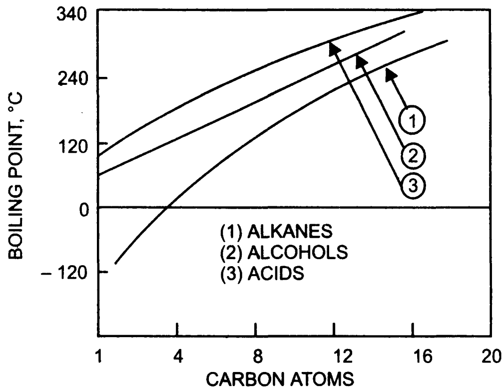


Figure 1.2 Boiling Points of First Few Alkanes, Alcohol and Acids.

Paraffins upto 3 carbon atoms have inclination to form hydrates such as $CH_4\ 7H_2O$, $C_2H_6\ 7H_2O$ and these hydrates offer clogging and corrosion difficulties. Hence drying is essential before usage.

The specific gravity of the series increases with molecular weight, still paraffins have less specific gravity and boiling point than aromatics. Viscosity of paraffins is less but viscosity index is high in contrast to aromatics. The smoke point of the paraffins is very high, with poor illuminating characteristics. The pour point of paraffins is usually high; due to this paraffin rich crudes and products bring difficulties in transportation and storage.

Isomers differ from *n*-paraffins by having slightly low boiling points, low pour points, high viscosity and viscosity index. Usually *i*-paraffins, are more reactive than *n*-paraffins but burn like *n*-paraffins without much illumination and smoking.

High molecular compounds ($>/C_{20}$) may be of saturated or unsaturated nature and decompose if exposed to a temperature of above 370°C. Vacuum distillation is essential for distilling such boiling stocks to prevent them from thermal degradation.

1.4.2 Unsaturates (Olefins and Properties)

Olefins are represented by the general formula C_nH_{2n}. The first four are gases and upto C_{15} are liquids and beyond C_{15} are solids. The boiling points of olefins are generally lower by few degrees than the saturated compounds of the same carbon number. Chemically these differ very much from paraffins. They are easily attacked by sulfuric acid and some of them even polymerize. Treatment with sulfuric acid and subsequent hydrolysis yields alcohols (e.g. isopropyl alcohol) and with permagnate oxidation, glycols are formed. Unsaturated compounds like olefins, diolefins, in general, do not appear in crudes to measurable quantities, however they are detected in some crudes. These unsaturates are mainly formed during cracking operations. The absence of unsaturates to a large extent can be best judged by the probable catalytic activity of the earth's crust in converting unsaturates to saturates and ring structures.

1.4.3 Acetylenes and Properties (Alkynes)

The general formula for this series is C_nH_{2n-2}. These are isomeric with diolefins. Acetylenes yield crystalline compounds with ammoniacal solution of copper salts and are attacked by sulfuric acid. Acetylenes can be readily hydrogenated to give stable compounds.

1.4.4 Diolefins

These are represented by the formula C_nH_{2n-2}. Like other unsaturates, these are produced during cracking reactions. These can be distinguished from acetylenes as they do not form salts with ammoniacal solutions of copper salts. But with mercuric chloride these form precipitates and sulfuric acid polymerises these unsaturates.

1.4.5 Naphthenes

(These are saturated ring compounds bearing the general formula C_nH_{2n}. The prominency of ring structure starts with five carbon atoms. Although C_3 and C_4 ring structures,[27] are in existence, their stability is decreased because of excessive strain (Bayer's Strain Theory). Naphthenes are isomeric with olefins but differ profoundly in properties. Naphthenes exhibit both the properties of saturated paraffins and unsaturated aromatics, the result of which, all the properties like sp. gravity, viscosity, pour point, thermal characteristics lie in between the two mentioned homologues. Usually, all the ring structures are having branched chains, where the isomeric character predominantly occurs, followed by positional isomerism in rings (Figure 1.3).

1.4.6 Aromatics

The first and smallest of the aromatics is benzene; other simple aromatics to follow are toluene, xylene, cumene etc. Even though benzene is unsaturated, yet it follows the principles of substitution with halogens rather than addition. This is mainly due to symmetric grouping of closed ring structure and resonance.

Aromatics are usually having high boiling points, low pour points (freezing points), high octane numbers, high viscosity and low viscosity index and these burn characteristically with a red flame with much soot. As these behave like saturates, they resist oxidation. In petroleum fractions aromatics beyond 3-ring structure (Anthracenes) are probably non-existent. Aromatics usually extend their presence from a temperature of 80°C onwards and well dominate in lower middle cuts and heavy cuts. Actually the light aromatics (BTX) do not exceed even 5% of crudes of general nature. Bulk of the aromatics are with side chains together with naphthenes exist in heavier portion of crudes.

1.4.7 Inorganics

Sulfur compounds: Sulfur is found in most of the crudes in variable amounts. Generally sulfur compounds are present in more quantities in higher molecular weight stocks. Usually the sulfur content does not exceed 5%, however rare exemptions are: Venezuela (5.25%), California (USA 5.21%), Qaiyarah (Iraq—7%) etc. crudes.

Sulfur in crude occurs in different forms like free sulfur, hydrogen sulfide, mercaptans and thiophenes etc. These are frequently occurring compounds in almost all fractions of the crude though to a different degree. Heavier fractions contain sulfides, polysulfides, sulphonates and sulphates.

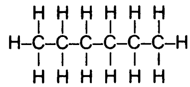
Sulfur occupies prominent position in refining due to its ominous problems of corrosion and odour. Pollution problems and following cost of waste treatment is punitive for all refiners with high sulfur-stocks. However, refiners habitually remove more detrimental sulfur compounds and leave the less harmful ones into the products, as seen in the case of sulfides converted to disulfides in gasolines. Some of the sulphonates are regarded as good emulsifiers and detergents, hence promptly extracted for use in cutting oils. Conspicuous effect of sulfur is reflected in increasing the density of crude.

A correlation presented by Obolentsev[28] shows the influence of sulfur on gravity

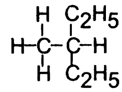
$$(\delta \text{at } 20°C)\ \rho = 0.0087\ (S\%)^2 + 0.0607\ (S\%) + 0.7857$$

ALKANES (C_nH_{2n+2})

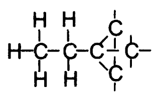
n - HEXANE



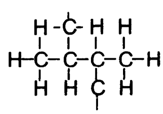
ISOMERS of C_6



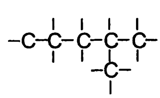
Methyl diethyl methane	CH. $(C_2 H_5)_2$ (CH_3)	2, Ethyl Ethane



Di methyl butane	$(CH_2)_3$.C.CH_2. CH_2	2, 2 Dimethyl butane



Dimethyl butane	$C_4H_8(CH_3)_2$	2, 3 Dimethyl butane



Methyl pentane	C_5H_{11} CH_3	2, Methyl pentane

Figure 1.3 Structures of Some Organic Compounds.

OLEFIN (TERPENS) C_nH_{2n-4}

Triotafins	C_nH_{2n-6}
Di-acetylenes	C_nH_{2n-6}

AROMATICS

Benzene series	C_nH_{2n-6}
Nephthalene series	$C_{10}H_8$

Diacetylenes
H – C≡C – C≡C – H

ISOMERISM IN AROMATICS

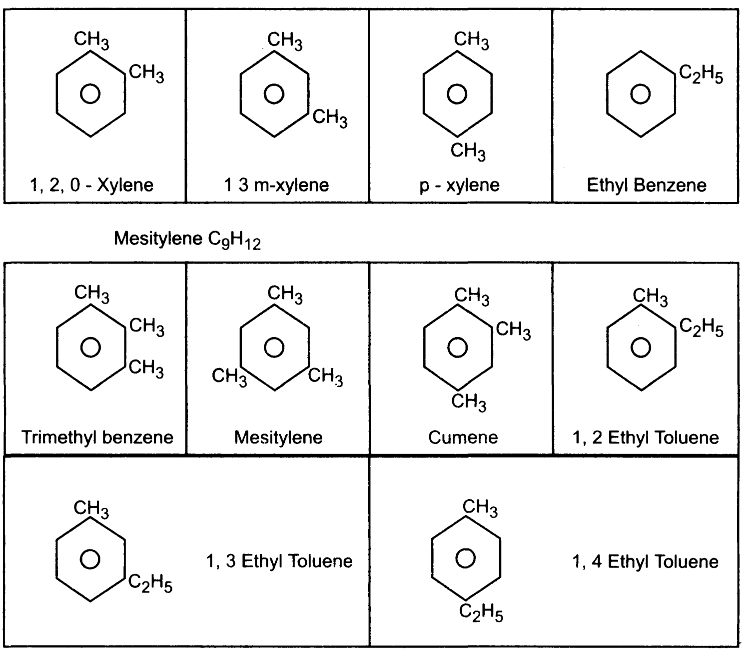


Figure 1.3 : (*Contd.*)

OLEFINS (C_nH_{2n})

C = C – C – C	α - Butylene
C – C = C – C	β - Butylene
C — C = C | C	γ - Butylene (iso - butylene)

CYCLQ - PARAFFINS ($C_n\ H_{2n}$)

	Cyclo - hexane
	Cyclo - butane
	Cyclo - pentane

DI - OLEFINS ($C_n\ H_{2n-2}$)

$CH_2 = C = CH_2$	Allene
$CH_2 = CH.CH = CH_2$	Divinyl (butadiene)
$CH_2 = C(CH_3).CH = CH_2$	Isoprene (2 methyl, 1, 4 divinyl)
$CH_2 = C = CH.CH_3$	1, 2 divinyl

ACETYLENE ($C_n\ H_{2n-2}$)

C≡C

$HC \equiv C - CH_3$	Methyl acetylene or Propyne- 1 or Allyne
$CH_3 - C \equiv C - CH_3$	Crotonylene or Butyne -2
$C_2H_5 - C \equiv C - CH_3$	Ethyl methyl acetylene or Pentyne -2

Figure 1.3 : (*Contd.*)

SULPHUR COMPOUNDS

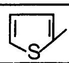
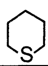
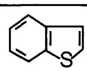
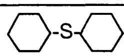
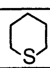
Mercaptans	$C_nH_{n+1}SH$	
	C_2H_5SH	Ethyl mercaptan
Sulphones	RSO_2	
	$C_7H_{15}SO_2$	Heptyl Sulphone
Sulphides	R_2S	
	$(CH_3)_2S$	Dimethyl sulphide
D$_i$ Sulphides	R_2S_2	
	CH_3 S.S CH_3	Dimethyl disulphide
Sulfoxides	R, R >SO	
	CH_3, CH_3 >SO	Dimethyl sulfoxide
Thio phenes		
	 CH_3-S-C_6	Thio deeyl thiophene
Thio phanes	$C_nH_{2n}S$	
	 -C_4	Butyl thio cyclohexane
Sulphates	$(C_nH_{2n+1})\ SO_4\ R_2SO_4$	
		Thio benzols
Sulphonates	 SO_3 R SO_3	
Carbonyl Sulphide	COS	
		Cyclohexyl sulphide
	 -C	Thio cyclo heptane

Figure 1.3 : (*Contd.*)

NITROGEN COMPOUNDS

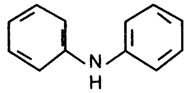
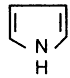
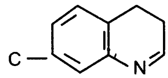
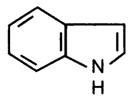
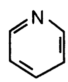
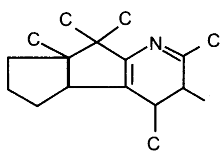
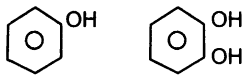
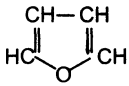
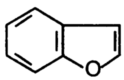
Carbozole	
Pyrole	
Methyl Quinoline	
Indoles	
Quinoline	$C_9 H_7 N$ $C_{12} H_{17} N$ $C_{13} H_{18} N$ $C_{14} H_{19} N$ $C_{15} H_{19} N$
Pyridine	
Pyrroles	

Figure 1.3 : (*Contd.*)

OXYGEN (Naphthenic Acids) Compounds



$C_6H_{11}COOH$	Hepta naphthenic
$C_7H_{13}COOH$	Octa naphthenic
	Furan
	Benzo Furan

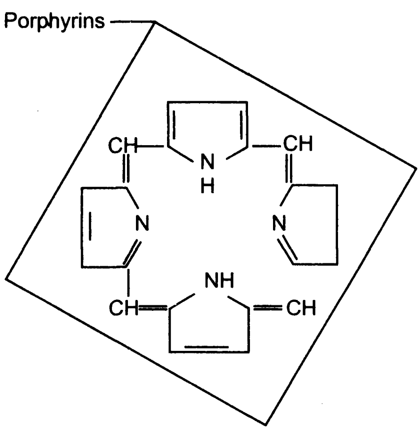


Figure 1.3 : (*Contd.*)

Different crudes are presented in Table 1.1. It clearly shows the effect of sulfur on API gravity of crude and pour point of crude. All sulfur crudes mysteriously exhibit low pour points.

Further, sulfur containing residuums when cracked leaves cross linked structures, resembling the phenomenon of valcanization of rubber and offer perennial problems in desulfurisation. Its presence in different fractions complicates the refining and treatment methods. Yet another problem is, it desists the effects of additives. Sulfur in gasoline inevitably depresses the effect of lead and demands more amount of additive. When crude contains more than 0.5% S, it is denoted as high sulfur crude. A terse distinction, at this juncture between sour crudes and sulfur crudes is desirable. Free hydrogen sulfide is available in some crudes, which naturally fosters corrosion.

TABLE 1.1 Effect of Sulfur on Gravity and Pour Point.[29]

Crude	API	Pour Point °C	Sulfur %
Cyrus (Iran)	19.0	–23.3	3.48
Iranian Heavy	30.8	–20.6	1.6
Kuwait	31.2	–17.8	2.50
North Slope (USA)	26.8	–20.6	1.04
Quatar Marine (Quatar)	37.0	–3.9	1.50
Romashkinskaya (USSR)	32.6	–28.9	1.61
Bassein (India)	38.45	+30	0.15
Nahorkatiya	31.0	+30	0.16
Ankleshwar	47.0	+15	0.05
Bombay High	38.0	+30	very low
Arabian (Light) (S. Arabia)	33.4	–34.4	1.80
Arabian (Heavy) (S. Arabia)	28.2	–34.4	2.84
Arjuna (Indonesia)	37.7	+26.7	0.12
Bu Attifel (Libya)	40.6	+39.0	0.10
Basrah (Iraq)	33.9	+15.0	2.05
Brass (Nigeria)	43.0	–20.6	0.08
Darius (Iran)	33.9	–17.9	2.45

Such crudes are classified as sour crudes; other sulfur bearing compounds are not taken into this account. The crudes containing sulfur compounds other than hydrogen sulfide and exceeding 0.5% are denoted as high sulfur crudes.

1.4.8 Oxygen and Nitrogen

Oxygen and nitrogen do not occur in free state either in crudes or in fractions. Nitrogen presence in free form is well known in natural gas only. Oxygen occurs as oxygenated compounds like phenols, cresols, naphthenic acids, sulphonates, sulphates and sulfoxides.

Nitrogen exists in the form of indoles, pyridines, quinolines and amines, usually well below 2%. Nitrogen compounds exasperate problems in processing and stability of products. Catalyst deactivation or poisoning, gum formation are some of the offshoots of nitrogen. Nitrogen is present in two forms, basic and non-basic. Basic[30] nitrogen is characterised by its titratability with perchloric acids, whereas nonbasic nitrogen is not titratable hence no possibility of extraction. Most of the nitrogen[31] pigments impart color to crude and fractions. The most interesting compounds of nitrogen are porphyrins. These are obtained from living organisms and preserved in petroleum. It stands to reason that aneorobic conditions were prevailing during petroleum formation; otherwise oxidation would have destroyed them. Chlorophyll[32] is also a complex of porphyrin, where central atom is magnesium instead of nickel or vanadium or iron. Iron porphyrins are also known as heme, the constituents of red cell in the blood.

Porphyrin[33,34] pigments are usually associated in complex form with metals like, copper, iron, vanadium and nickel. The proper understanding of these pigments[35,36,37], may augment the knowledge of origin and formation of petroleum. The following is an example of nitrogen complex:

Gravity API	—	38.8
Sulfur wt. %	—	0.2-0.0%
Vanadium ppm.	—	0.5-2.5%
Nickel ppm.	—	1.0-170
Vanadyl porphyrin ppm.		0.7-1130
Nickel porphyrin ppm.		1.0-390

1.4.9 Asphalts, Resins and Bitumen

Asphalts are high molecular weight complex molecules, black in color, soluble preferably in aromatic solvents and carbon disulphide.

TABLE 1.2*a* World Oil Well Completions During 1975.

Country	Oil	Gas	Dry	Others	Average Depth Metres
N. America (Total)	17,449	9,615	14,404	1,243	1,407
U.S.A.	16,626	7,437	13,203	1,121	1,451
Venezuela	246	6	35	96	1,806
Africa					
(Total)	273	14	332	151	1,852
Algeria	65	10	8	20	2,417
Nigeria	57	–	178	111	1,621
Middle East					
(Total)	409	20	140	191	2,330
Iran 95	11	29	18	2,775	
Iraq 36	–	9	–	2,699	
Saudi Arabia	101	–	16	95	2,135
Asia					
(Total)	576	81	358	51	1,691
India	90	6	19	8	2,171
Indonesia	410	38	145	37	1,283
World					
(Total)	20,089	9,995	16,047	1,807	1,472

Resins are mostly compounds of highly condensed ring structures, containing oxygen, sulfur and nitrogen, sometimes inorganics too. Though bitumen is a manufactured product, it is essentially made up of three components, asphalts, resins and mineral oil. These three components comprise a colloidal system; asphalts are suspended in oil and resins contribute to the stability of the system.

1.4.10 Less Inorganics

The other elements present are nickel, vanadium, iron, silica, sodium, magnesium, and halogens etc. Even though the analysis is not desirable as these metals hardly exceed 0.01%, yet may be analysed for sensitive purposes. The ash formation is mainly due to these metals and inorganics. Sometimes organometallic compounds are available in colloidal form. Inorganics always leave a marked influence on fractions, for example halides may give off halogens during hydrolysis or thermal decomposition. Corrosion, pollution, ash etc. are mainly contributed by inorganics and the quality of crude and fractions are always debased by these small amounts.

Table 1.2*a* shows some statistics on completed oil wells during 1975 in the world.

TABLE 1.2*b* **World Primary Energy Consumption During 1985.**

	(MillionTons)			(Power MW)		
	Liquid fuels	Gas	Solid fuels	Hydro	Nuclear	Thermal
USA	442.714	391.714	464.249	84,986	81,516	533,611
Canada	120.800	108.973	50.738	57,458	10,889	30,937
L/S America	256.251	59.268	13.319	57,853	1,675	33,601
U.K.	182.670	56.761	76.809	4,190	7,064	56,356
W. Germany	5.861	19.926	117.327	6,668	16,095	69,938
M.E.	760.971	40.129	0.900	2,973	–	43,784
Japan	0.786	3.245	14.580	34,337	24,686	110,291
USSR	851.665	755.758	514.284	61,259	28,100	229,936
China	178.421	17.129	591.468	26,500	–	55,700
World	4224.358	2051.537	2978.168	545,463	250,697	1,607,712

TABLE 1.2*c* Utilisation of Natural Gas and Oil by Different Countries.

Country	Utilisation of Natural Gas (10^6 Cu.M.) (1974)	Growth of World wide resources (10^3 Barrels) (1977)	Oil produced (10^3 Barrels) (1975)
North America	697,673	37,199	3,570,926
U.S.A.	611,662		
Latin America	45,938	29,609	1,603,695
Western Europe	163,305 }	24,539	3,955,917
Eastern Europe	309,773 }		
U.S.S.R.	261,000		
Middle East	41 ,934	367,681	7,143,494
Africa	16,617	60,570	1,821,954
Asia	63,380	19,391 }	
India	1,010	}	1,377,919
China	33,980	}	
World (Total)	1,338,602	640,081	19,473,903

(Source for Tables 1.2*a*, & *c* 1.3*a* to 1.3*c* Oil Statistics New Delhi) 1975 & 1976; Petroleum Information Service.

TABLE 1.3*a* Oil and Gas Reserves (India).

Area	1966	1970	1975	1977	1978*	1979*	1980*
1. Crude Oil @ (MillionTonnes)							
On Shore	153.00	127.84	130.13	127.90	125.99	128.15	135.38
Off Shore	–	–	13.77	175.28	221.04	226.29	230.95
Total	153.00	127.84	143.90	303.18	347.03	354.44	366.33
2. Natural Gas @ (Billion Cubic Metres)							
On Shore	63.15	62.48	81.39	80.39	79.71	79.58	80.95
Off Shore	–	–	6.28	148.08	186.15	264.64	270.96
Total	63.15	62.67	87.67	228.47	265.86	344.22	351.91

*As on 1st January of each year.
@Proved and indicated balance recoverable reserves.

TABLE 1.3*b* Production of Crude Oil and Natural Gas.

Company	1960-61	1965-66	1970-71	1975-76	1978-79	1979-80	1980-81*
1. Crude Oil Production ('000 tones)							
(a) On Shore							
AOC	176	151	104	66	53	40	48
OIL	272	1895	3084	3103	2671	2215	1241
ONGC	–	1427	3634	5279	5599	5091	4229
Total (a)	448	3473	6822	8448	8323	7346	5518
Of which							
Gujarat	–	1427	3455	4148	4238	3768	3808
Assam	448	2049	3367	4300	4085	3578	1710
(b) Off Shore		–	–	–	3310	4422	4985
ONGC	–						
GRAND TOTAL	448						
(a+b)		3473	6822	8448	11633	11768	10503

(Contd.)

TABLE 1.3*b* : *(Contd.)*

Company	1960-61	1965-66	1970-71	1975-76	1978-79	1987-88	1980-81*
2. Natural Gas Production (Million Cubic Metres)							
(a) On Shore							
AOC	–	–	65.24	40.33	44.33	1.390	38.14
OIL	–	–	905.25	1404.88	1256.79	1.390	709.19
ONGC	–	–	474.41	822.06	1124.45	3.311	933.16
Total (a)	–	–	1444.90	2367.27	2425.57	4.701	1680.49
of which							
Gujarat	–	–	464.94	773.08	907.60		838.91
Assam	–	–	979.96	1594.49	1517.86		841.58
(b) Off Shore						10.760	
ONGC	–	–	–	–	385.87	365**	673.23
Grand Total (a + b)	–	–	1444.90	2367.27	2811.44	15.826	2353.72

* Provisional – Not Available
** K.G. & Cauvery Basins

TABLE 1.3*c* Refinery Crude Throughput.

('000 Tonnes)

	Refinery	1960-61	1965-66	1970-71	1975-76	1977-78	1978-79	1979-80	1980-81*
(a)	PUBLIC SECTOR	–	1966	10820	17045	24364	25450	27066	25334
	BPCL, Bombay	–	–	–	–	4512	4693	4821	4901
	CORIL/HPCL/ (VMU)/(4)	–	–	–	–	1304	1329	1100	1319
	CRL, Cochin	–	–	2498	2294	2933	2862	2866	2912
	HPCL, Bombay	–	–	–	2830	2897	2800	3130	3113
	IOC, Barauni	–	753	2191	2949	3060	2661	2285	505
	IOC, Gauhati	–	804	686	827	817	825	646	639
	IOC, Gujarat	–	409	3463	4107	4129	5251	6714	6974
	IOC, Haldia	–	–	–	1348	2096	2213	2492	2308
	MRL, Madras	–	–	1982	2690	2616	2759	2822	2611
	BRPL, Assam @	–	–	–	–	–	57	190	52
(b)	PRIVATE SECTOR	6130	8267	7559	5238	534	524	408	503
	AOC, Digboi	446	488	476	527	534	524	408	503
	BSR, Bombay (1)	2879	3989	3541	3630	–	–	–	–
	CORIL, Vizag (2)	901	1118	1175	1081	–	–	–	–
	ESRC, Bombay (3)	1904	2672	2367	–	–	–	–	–
	Total Crude THROUGHPUT (a+b)	6130	10233	18379	22283	24898	25974	27474	25837

(1) BSR was taken over by the Govt. in Jan. 1976 and renamed as Bharat Petroleum Corporation Ltd.
(2) CORIL was taken by the Govt. in Dec. 1976.
(3) ESRC was taken over by the Govt. in March 1974 and renamed as Hindustan Petroleum Corporation Ltd. in July 1974.
(4) CORIL was merged with HPCL on 9th May 1978.
@ BRPL came in production on 6-2-1979.

*Provisional

TABLE 1.3*d* Refinery Production.

('000 Tonnes)

Products	1960-61	1965-66	1970-71	1975-76	1984-85	1988-89	1979-80	1980*-'81
TOTAL PRODUCTION	5777	9561	17110	20829	35.600	48,000	25794	24124
1. Light Distillates	1050	1770	3021	3630			4459	4098
of which								
LPG	8	45	169	331	596.3	10,222	406	367
Mogas	1037	1421	1526	1275	2153.5	2,000	1512	1519
Naphtha	–	181	1205	1910	–		2415	2111
2. Middle Distillates	2593	4543	8562	10769		22,274	13080	12119
of which								
Kerosene	929	1463	2896	2439	3351.3		2539	2396
ATF	–	128	710	925	1336.9		1104	1000
HSD	1063	1816	3840	6285	11086.2		7975	7371
LDO	525	789	986	946	1251.6		1230	1110
3. Heavy Ends	2134	3448	5527	6430		10,294	8255	7907
of which FO	1342	2455	2987	3595			4086	4040
Fuel Oil (Total)	1641	2709	4090	5083	7953.5	8,300	6351	6124
Lube Oils	22	46	231	342	414.1	614	487	426
Bitumen	421	562	805	697	421	500	1103	1081
Petroleum coke	13	88	151	160	100	110	99	85

* Provisional

(contd.)

TABLE 1.3*d* : (*contd.*)

'000 Tonnes

Products	1980-81	1990-91	1995-96	1996-97	1997-98	1998-99	1999-00
	(a) From Crude Oil						
Light Distillates of which	4101	10023	12433	12883	13032	13776	18314
LPG	366	1221	1539	1598	1666	1724	2487
Mogas	1519	3552	4462	4704	4849	5573	6232
Naphtha	2115	4859	5975	6123	6103	6081	8170
Others	101	391	457	458	414	398	1425
Middle Distillates of which	12115	26344	29941	32423	33933	36168	44995
Kerosene	2396	5471	5267	6236	6701	5341	5735
ATF/RTF/Jet A-1	1001	1801	2127	2119	2147	2289	2292
HSD	7371	17185	20661	22202	23354	26716	34793
LDO	1108	1509	1351	1286	1246	1336	1624
Others	239	378	535	580	485	486	551
Heavy Ends of which	7907	12195	12707	13698	14343	14600	16102
Furnace Oil	4041	4879	5351	5980	6771	6407	6559
LSHS/HHS							
RFO	2079	4550	4228	4318	4309	4623	4793
Lube Oil	426	561	633	619	593	586	728
Bitumen	1082	1603	2032	2283	2158	2419	2485
Petroleum Coke	86	229	256	246	282	286	465
Paraffin Wax	–	49	43	31	27	40	47
Other Waxes	–	46	63	56	45	63	70
Others	193	278	101	165	158	167	955
Total							
(1+2+3)	24123	48562	55081	59004	61308	64544	79411
	(a) From Natural Gas						
LPG		929	1715	1780	1787	2207	1989

TABLE 1.3e Installed Capacity and Refinery Crude Throughput.

'000 Tonnes

Refinery	Installed Capacity as on 1.4.2000	1980-81	1990-91	1995-96	1996-97	1997-98	1998-99	1999-00
		Refinery Crude Throughput						
(A) Public/joint Sector	85540	25333	51772	58702	59958	61313	64469	74052
IOC, Guwahati	1000	639	783	839	848	856	836	914
IOC, Barauni	4200	504	2416	2322	1895	2181	2204	3411
IOC, Gujarat	12500	6974	9334	10167	10352	10694	10935	11109
IOC, Haldia	3750	2308	2835	3416	3451	4706	4714	4105
IOC, Mathura	7500	-	7808	8332	8113	8565	8909	8125
IOC, Digbol	650	-	566	559	477	502	553	603
IOC, Panipat @ @	6000	-	-	-	-	-	2208	4153
BPCL, Mumbai	6900	4901	6957	7460	7640	7996	8878	8907
HPCL, Mumbai	5500	3113	5766	5965	6534	6378	5203	6007
HPCL, Visakha	7500	1319	3464	5037	4847	2467	3861	4555
CRL, Cochin	7500	2912	6006	7421	7293	7729	7770	7830
MRL, Chennai	6500	2611	5698	5599	6621	6965	6101	6377
MRL, Narimanam	600	-	-	370	345	556	644	636
BRPL, Assam	2350	52	1139	1215	1542	1718	1653	1905
NRL, Assam #	3000	-	-	-	-	-	-	215
MRPL, Mangalore @	9690	-	-	39	2912	3853	4069	5200
(B) Private Sector	27000	503	-	39	2912	3853	4069	11912
AOC, Digboi (1)	-	503	-	-	-	-	-	-
RPL, Jamnagar ##	27000	-	-	-	-	-	-	11912
Total (a + b)	112040	25836	51772	58741	62870	65166	68538	85964

(1): AOC refinery was taken over by the Govt. in Oct. 1981 & merged with IOC
@ : Commenced production from 25.3.1999
#: Commenced production from April 1999
@ @: Commenced production from May 1998
'##: Commenced production from July 1999

Source: Ministry of Petroleum & Natural Gas

TABLE 1.3*f* World Oil Production Capacity by Region and Country, Reference Case, 1990-2020

(Million Barrels per Day)

	History (Estimates)			Projections		
Region/Country	1990	1999	2005	2010	2015	2020
OPEC						
Persian Gulf						
Iran	3.2	3.9	4.0	4.3	4.6	4.8
Iraq	2.2	2.8	3.1	3.8	4.7	5.8
Kuwait	1.7	2.6	2.8	3.5	4.1	5.0
Qatar	0.5	0.6	0.5	0.6	0.7	0.7
Saudi Arabia	8.6	11.4	12.6	14.7	18.4	23.1
United Arab Emitates	2.5	2.7	3.0	3.5	4.4	5.1
Total Persian Gulf	18.7	24.0	26.0	30.4	36.9	44.5
Other OPEC						
Algeria	1.3	1.4	1.9	2.1	2.3	2.5
Indonesia	1.5	1.7	1.5	1.5	1.5	1.5
Libya	1.5	1.5	2.1	2.5	2.8	3.2
Nigeria	1.8	2.2	2.8	3.2	4.0	4.7
Venezuela	2.4	3.4	4.2	4.6	5.0	6.0
Total Other OPEC	8.5	10.2	12.5	13.9	15.6	17.9
Total OPEC	27.2	34.2	38.5	44.3	52.5	62.4
Non-OPEC						
Industrialized						
United States	9.7	9.3	9.0	8.7	9.0	9.3
Canada	2.0	2.7	3.0	3.2	3.4	3.5
Mexico	3.0	3.5	4.1	4.2	4.4	4.4
Australia	0.7	0.8	0.8	0.8	0.8	0.8
North Sea	4.2	6.3	6.6	6.5	6.2	6.0
Other	0.5	0.7	0.8	0.8	0.8	0.7
Total Industrialized	20.1	23.3	24.3	24.2	24.6	24.7
Eurasia						
China	2.8	3.2	3.1	3.1	3.0	3.0
Former Soviet Union	11.4	7.2	9.6	11.9	13.6	14.8
Eastern Europe	0.3	0.3	0.3	0.3	0.3	0.4
Total Eurasia	14.5	10.7	13.0	15.3	16.9	18.2
Other Non-OPEC						
Central and South America	2.3	3.6	4.2	4.8	5.5	6.4
Middle East	1.4	1.9	2.2	2.4	2.5	2.4
Africa	2.2	2.8	3.1	3.8	4.6	5.8
Asia	1.7	2.2	2.6	2.6	2.6	2.5
Total Other Non-OPEC	7.6	10.5	12.1	13.6	15.2	17.1
Total Non-OPEC	42.2	44.5	49.4	53.1	56.7	60.0
Total World	69.4	78.7	87.9	97.4	109.2	122.4

Note: OPEC = Organization of Petroleum Exporting Countries.

TABLE 1.3*g* Growth of Indian Petroleum Industry at a Glance.

Parameters	Unit	1980-81	1990-91	1995-96	1996-97	1997-98	1998-99	1999-00
1. Reserves @ (Balance Recoverable)								
(i) Crude Oil	Mn. Tonnes	366	739	732	727	747	715	658
(ii) Natural Gas	Bn. Cub. Mtr.	352	686	660	640	692	675	628
2. Consumption								
(i) Crude Oil								
(in terms of refinery								
crude throughput)	Mn. Tonnes	25.84	51.77	58.74	62.82	65.17	68.54	85.96
(i) Petroleum								
Products (excl. RBF)		30.90	55.04	74.67	79.16	84.29	90.56	93.91
3. Production								
(i) Crude Oil		10.51	33.02	35.17	32.90	33.86	32.72	31.95
(ii) Petroleum Products	Mn. Tonnes	24.12	48.56	55.08	59.01	61.31	64.54	79.41
4. Imports & Exports								
(i) Gross imports :								
(a) Qty : Crude Oil		16.25	20.70	27.34	33.91	34.49	39.81	44.99
Pol. Products	Mn. Tonnes	7.29	8.66	20.34	20.26	19.53	18.78	13.07
Total (a) by IOC		23.54	29.36	47.68	54.17	54.02	58.59	58.06
(b) Value: Crude Oil		3349	6118	11517	18538	15897	14876	30695
Pol. Products		1917	4660	12578	15634	12432	9837	11119
Total (b) by IOC	Rs. Crores	5266	10778	24095	34172	28329	24713	41814
Pol. imports as per DGCI & C				25174	35629	30341	26919	45421
(ii) Exports : @ @								
(a) Qty : Crude Oil		–	-	-	-	-		
Pol. Products	Mn. Tonnes	0.04	2.65	3.44	3.16	2.93	1.40	.09
Total (a)		0.04	2.65	3.44	3.16	2.93	1.40	.09
Value : Crude		-	-	-	-	-	-	
(b) Oil								
Pol. Products	Rs. Crores	8	1004	1832	2085	1820	856	633
Total (b)		8	1004	1832	2085	1820	856	633

TABLE 1.4*a*   Indian Refineries and Cracking Practice.

		Types of Refinery Units	Capacity MMTA	Cracking BPSD	Refining
1.	Assam Oil Company, Digboi	$D_1D_2/D_C/L/B$	0.5	2300^x	
2.	(Bharat Petroleum) Burmah Shell, Bombay	$D_1D_2/C_C/R/B$	3.5 (5.0)	7000*FCC	7000^xR
3.	Hindustan Petroleum Corporation Ltd., (Formerly ESSO), Bombay	$D_1/C_C/B$	3.5	11000^xFCC	
4.	-do- (Formerly CALTEX), Vizag	$D_1/C_C/B$	1.2 (3.5)	9600*FCC	
5.	Cochin Refineries Ltd., Cochin	D_1/Vis/R/B	2.5 (3.5)		6000^xR 33,043* HDS
6.	Madras Refineries Ltd., Madras	D_1D_2/C/R/Vis/B/L	2.8 (5.6)	5950 (C) 6460(Vis)	2158* R 31,820 HDT

TABLE 1.4*a* : (*Contd.*)

		Type of Refinery Units	*Capacity MMTA*	*Cracking BPSD*	*Refining*
7. Indian Oil Corporation					
	Gauhati	D_1/C	0.75	6200	
8. ″	Barauni	D_1D_2/C/B/L	2.5(3.4)	12000	
9. ″	Baroda	D_1/R/Vis	4.5(7.3)		7500*(R)
10. ″	Haldia	D_1D_2/Vis/R/B/L	2.5(5.5)	9000(Vis)	4900*(R) 4500 HDT
					13000 HDS
11.	Mathura[1-A]	D/R/C_C/B/Vis	6	20000^x	5000^x
12. Bongaigon Refinery &					
Petro-chemicals (Complex)		D_1/R/isomerisation Unit	1		80000
150000 (isomerisation)					

(Nomenclature): D_1 : Atmospheric column, D_2:VDC,C_c: Cat-Cracking, D_c: Dubbs cracking,
C : Thermal cracking/coking, L: Lube oil, B: Bitumen, Vis: Visbreaking, R: Reforming, HDT: Hydrotreating, HDS: Hydrodesulfurisation

1 -A : Mathura Refinery Products: *CEW*, Oct. 1981, p. 22, HSD: over 2MMTA, Naphtha: 8,09,000 TA, Kerosene: 6,58,000 TA, Petrol: 3,50,000 TA, LPG: 1,80,000 TA

(Fig. in brackets shows the expansions in progress)

Ref: X: *Petroleum Times* 8th March 1974,* *Oil & Gas. J.* Dec. 27, 1976, p. 149

TABLE 1.4*b* Capacity of Refineries (M^2T).

			85-86	86-87	89-90	(Actually Processed) 85-86	86-87	89
X_1	BPC	Bombay	6.00	6.00	6.00	6.389	5.580	6.500
	HPC	Bombay	3.50	3.50	3.50	4.375	5.013	5.365
X	CRL	Cochin	4.50	4.50	4.50	2.749	4.166	4.500
X_1	MRL	Madras	5.60	5.60	5.60	5.057	5.192	5.400
X_1	HPC	Vizag	4.50	4.50	4.50	2.659	3.715	4.500
	10 C	Haldia	2.50	2.50	2.75	2.822	2.622	2.750
XX	″	Koyali	7.30	8.10	9.50	7.830	7.835	8.100
	″	Barauni	3.30	3.30	3.30	2.766	2.860	2.860
	″	Guwahati	0.85	0.85	0.85	0.766	0.811	0.810
X	″	Mathura	6.00	6.00	7.50	6.075	6.353	6.500
	″	Digboi	0.50	0.50	0.50	0.529	0.551	0.550
	BPRL	Bongaigon	1.00	1.00	1.35	0.890	1.011	1.100
		Karnal		–	–	–	–	
		Mangalore	–	–	–	–		
	Total		45.55	46.70	51.85	42.910	45.701	50.935
	Additional swing capacity		2.00	2.00	2.00			
	at HPC, Bombay		47.55	48.70	53.85			

X_1 0.6 M^2T FCC units
X 1.0 M^2T ″ ″
XX 1M^2T FCC & Hydrocraker.
These have increased the secondary processing facilities by 8 million tons.

TABLE 1 4c Process Used by Various Lube Units.

Refinery	Finished base stock capacity Tonnes/Year	1	2	3	4	5	6	7	8	9	10
1. Assam Oil Co.	66,150	x		x			x			–x	
2. Barauni Refinery	49,100	x				x		x		–x	
3. Madras Oil Refinery	200,000	x			x			x			x
4. Lube India Ltd.	162,000	x				x			x	x	x
5. Haldia Refinery	200,000	x	x		x			x			x

Key for the Table

1. Vacuum distillation; 2. Deasphalting; 3. Acid alkali-treatment; 4. Furfural extraction;
5. Phenol extraction; 6. Chilling and Pressing; 7. MEK dewaxing; 8. Propane dewaxing;
9. Clay contacting; 10. Hydro-finishing.

Note: (x) Units mentioned. x* Acid some stock.

Ref:
P.K. Goel : Chemical Age of India
Himmat Singh : April 1971: p. 51
J.M. Sagar
K.K. Bhattacharya
B.S. Gulati

TABLE 1.4*d* Transformer Oils.

Apar Pvt. Ltd. Bombay	15,000 MT	Total licenced capacity: 65,000 MT
Nagpal Ambadi Petro-Chemical Ltd. Madras	15,000 MT	Production 35,000 MT
Savita Chemicals Ltd. Bombay	10,000 (licensed for 40,000 MT).	
Universal Petro-Chemical Ltd. Kolkata (Registered only)	10,000 MT	
		(Source: N.D. Desai 2nd LAWPSP Symposium January 1981, I.I.T. Bombay p. 4)
Lube India Ltd. (Base Stock for Transformer oils only)	17,000 MT	

TABLE 1.5 A Vista of Indian Petroleum Industry.

1866		First oil well, Nahorpung (Assam)
1890		Discovery of Digboi oil field
1893		Refinery at Mergherita
1899		A.O.C. Registration
1923		First geophysical survey by A.O.C.
1953		Discovery of Nahorkatiya field
1954		ESSO Establishment
1955		Burmah Shell
1956	(August)	ONGC was set up
1957		Caltex
1958	(18th February)	O.I.L India
1959		Lumej field
1960		Ankaleswar oil field 1960-11 P. Dehra Dun
1961		Discovery of Rudrasagar
1961		Gas field Kalol
1962		Noonmathti Refinery (Rumanian Collaboration)
1962		Gas field, Sonand
1963		Nawagam field
1963		Crude Oil produced by O.I.L
1964		Lakwa Oil field
1964		Barauni Refinery (Soviet Collaboration)
1964	(Sept.)	Establishment of I.O.C
1965		Koyali Refinery (Soviet Collaboration)
1966		Cochin Refinery (Phillips Petroleum)
1968		Gelki Oil field
1969		Madras Refinery (National Iranian and AMOCO)
1970	(Feb.)	Lube India Refinery foundation
1972	(Jan.)	Bongaigon Refinery & Petro-chemical Complex Foundation
1973		Haldia Refinery (French & Soviet)
1973		Acquisition of jack up rig Sagar Samrat
1973		ONGC entered into agreement with Iraq for exploration in southern parts of Iraq.
1974		Bombay High Discovery, Haldia Trial runs.
1974		Oil found in Bombay High.
1974		Taking over ESSO by G.O.I.
1976		Discovery of Bassein, near Bombay High
1976	(May)	Commercial production of oil from Bombay High two wells.
1976		Baramura gas field, Tripura
1978		Mathura Refinery foundation
1978		Mahim gas field at Bombay
1980	(Sept.)	Oil struck in Godavari delta (Off Shore one well & On Shore two wells near Narsapur)
1981	(Sept.)	Take over of Burmah Oil & A.O.C. by Government of India
1982		Kharsang, Oil field (Oil Ltd.) Arunachal
1982	(August)	First LNG plant Duliajan
1987		FCCs Introduction in refineries
1988		First Hydrocraker construction begins at Gujarat Refy.
1988		HBJ Line, GAIL
1988		Maharashtra Gas Cracker Plant
1989		S.B. Gas Structure
1994		ONGC Reliance Refinery Corporation

TABLE 1.6 Characteristics of Crudes Processed in India.

Crude Characteristics	Nahorkatia (Assam)	Ankleswar (Gujarat)	Light (Iranian)	Darius	Digboi
°API	31.0	47.0	34.4	34.1	
Sp. gravity 60/60°F	0.8710	0.80	0.8535	0.8280	0.84
Sulphur, wt%	0.16	0.05	1.35	2.47	0.20
Pour point, °C	30	15	–21	–40	29.8
Total C_4 minus wt.%	2.5	4.36	1.80	1.65	
C_5 to140°C wt.%	17.0	23.14	14.45	15.85	
RON clear	75.0	59.0	55.0	58	
140-250°C, wt.%	20.5	27.5	19.30	15.5	
Freezing point, °C	–60	–42	-56	–51	
Sulphur, wt.%	0.06	0.002	0.18	0.30	
Smoke point, mm	14	30	22	25	
250-371°C, wt%	24.0	23.2	21.80	20.5	
Sulphur, wt%	0.22	0.025	1.10	1.72	
Diesel index	39	66	53	55	
Pour point, °C	6	6	0	–3	
371°C + wt.%	36.0	21.8	42.65	46.5	
Sulphur, wt.%	0.38	0.12	0.53	4.2	
Viscosity cS @ 50°C	160	25	700	560	
Pour point °C	51	48	48	25	
Salt content NaCI wt.%	.0005				0.0005

(*Contd.*)

TABLE 1.6 : (*Contd.*)

		Bombay High	Gelki	Digboi	
API		39.2	32.1		
Sp. gravity		0.8440	–		
Sulfur wt%		0.12	–		
Pour point °C		27 – 29	33		
Viscosity at 37.8°C		–	–	5 (CS)	
		Distillation Data,		IBP : 72°C	
	°C	Volume % (Cumulative)			
	50	4.5	3.0	(75°C)	0.5
	100	11	9.7		4.0
	150	23	17.5		19.0
	175	29	21.7		25.0
	200	33.5	25.6		30.0
	225	36	29.5		35.0
	250	43	33.1		41.0
	275	54	38.9		45.0
	300	60	44.6		54.5
	325	65	49.2		
	350	70	54.7		
	370	74	57.0		

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Table 1.2*b* shows the world Primary Energy Consumption during 1985.

Table 1.2*c* shows utilisation of natural gas and oil by different countries.

Indian statistics on Oil and Gas reserves are shown in Table 1.3*a*.

Production statistics of crude oil and natural gas in India since 1960 to 1981 are shown in Table 1.3*b*.

Refining activity of Indian Refineries is shown in Table 1.3*c*.

Different products, produced by Indian refineries is shown in Table 1.3*d*.

Consumption pattern of petroleum products in India is presented in Table 1.3*e*.

Refining capacity and statistics on crude and gas reserves of some countries are presented in Table 1.3*f* Indian Refineries, Crude through put and various units are shown in Tables 1.4*a, b & c*.

Table 1.5 shows the milestones in Indian Petroleum Industry.

Table 1.6 shows the properties of different crudes processed in India.

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