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OIL REFINERY CONVERTS CRUDE PETROLEUM PRODUCTS INTO USABLE PRODUCTS

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ABSTRACT
An oil refinery is a large industrial complex that transforms crude oil into valuable, usable products like gasoline, diesel, jet fuel, and heating oil through complex chemical processes. Operating 24/7, these plants use fractional distillation, cracking, and treatment to separate and convert raw hydrocarbons into high-demand fuels and petrochemical feed stocks.

KEYWORDS: Gasoline, diesel, petrol, jet fuel, asphalt, naptha, propane, butane.

Key Aspects of Oil Refineries

- **The Process:** Crude oil is heated and separated in distillation columns based on boiling points, then converted from heavy molecules to lighter ones using "cracking" units.
- **Products:** Major outputs include transportation fuels (gasoline, diesel, jet fuel), petrochemical feed stocks (ethylene, propylene), lubricants, and asphalt.
- **Significance:** They represent the "downstream" sector of the oil industry, crucial for converting raw, unusable oil into consumer goods.
- **Impact**: They are highly capital-intensive, often located near urban centers, and are significant sources of industrial air/water pollutants, requiring strict environmental management.
- **Global Capacity:** As of 2020, total global capacity was over 100 million barrels per day.[1]

Figure 1: Oil Refinery.

Crude oil is classified by its density and viscosity (API gravity) into light and heavy types, affecting refining, transport, and price. Light crude oil flows freely, has a high API (>31.1^{O}C), and yields more gasoline/diesel. Heavy oil is thick, viscous, has a low API (<22.3^{O}C), and requires advanced refining for products like asphalt.

Crude oils have different viscosities or "gravities." "Heavy" crude oil is more viscous, while "light" crude oil is thinner. Crude oils also have different sulphur content. Low-sulphur crude is called "sweet" and high-sulfur crude is called "sour."

Light Crude Oil
Properties: Low density, low viscosity (flows freely), and higher API gravity.

Refining: Easier to process, producing a high percentage of valuable products like gasoline, diesel, and kerosene.

Market: Generally commands a higher price because of its high-value refined products.

Examples: West Texas Intermediate (WTI), Brent Blend.

Heavy Crude Oil
Properties: High density, high viscosity (thick, sticky), and low API gravity (usually to). Extra-heavy oil is API.

Refining: Difficult to refine, requiring complex, expensive, and energy-intensive processes to produce usable products.

Uses: Primarily processed into heavy fuel oils, asphalt, and petrochemical feedstocks.

Transportation: Due to high viscosity, it often requires dilution with lighter hydrocarbons or heating to flow through pipelines.

Examples: Athabasca Bitumen, Venezuelan Extra-Heavy Oil.

Key Differences Summary
Table 1: Difference between Light Crude & Crude Oil.

Feature	Light Crude Oil	Crude Oil
API Gravity	High (>22^{O}-31.1^{O}+)	Low (<22^{O})
Density	Low (<0.9gm/ml)	High (>0.9gm/ml)
Viscosity	Low (flows easily)	High (thick/viscous)
Refining Cost	Lower (simple distillation)	Higher (complex processing)
Value	Generally Higher	Generally Lower

The Jamnagar Refinery owned by **Reliance Industries Limited in Gujarat, India**, is the world's largest and most complex single-site oil refinery. Operating since 1999, it boasts a processing capacity of roughly 1.24 million barrels of crude oil per day, significantly boosting India's energy self-sufficiency.[2]

Jamnagar refinery include
Capacity & Scope: It processes 1.24 million barrels of crude oil daily and features the world's largest Refinery Off-Gas Cracker (ROGC).

Complexity: The site is highly complex, with a N elson Complexity Index of 21.1, allowing it to process216 different grades of crude oil.

Expansion & Impact: The facility was expanded in 2008 to double its capacity, making it a pivotal asset in global oil refining.

Figure 2: Jamnagar of Gujarat.

Infrastructure: Located in Gujarat, the complex covers 7,500 acres and includes, among other infrastructure, the world's largest refinery off-gas cracker (ROGC). The refinery has made India a major exporter of petroleum products, including gasoline, diesel, and jet fuel.[3]

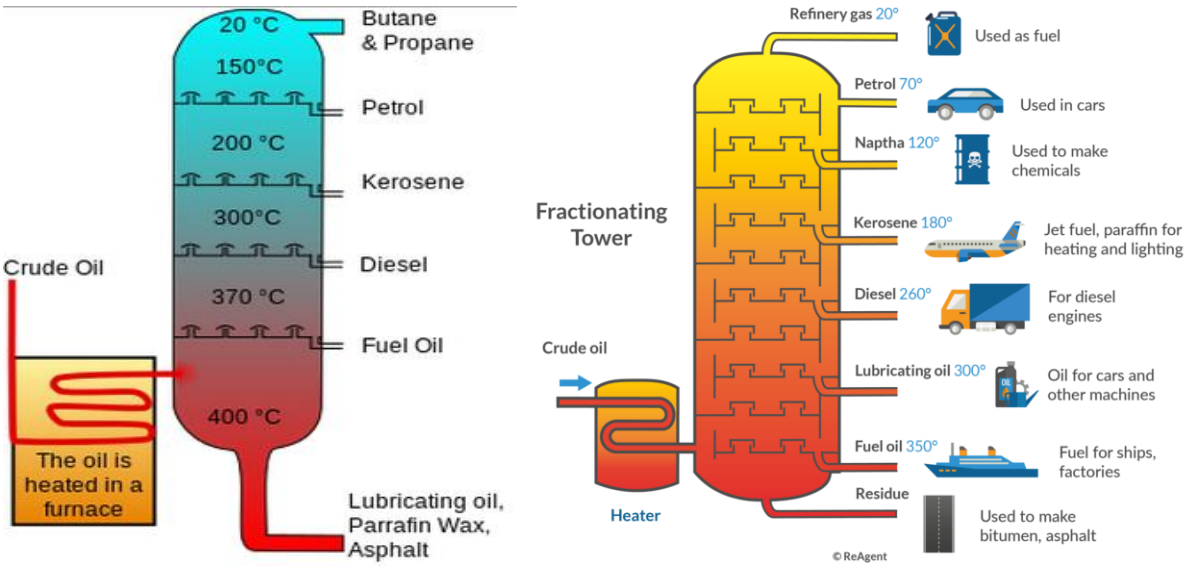

Figure 3: Fractional Distillation of Crude Oil.

Oil Refineries

A petroleum refinery is a massive, complex industrial installation that processes raw crude oil into valuable, usable products like gasoline, diesel, jet fuel, and asphalt. Using heat and chemical processes, refineries separate hydrocarbons based on boiling points, then "crack" or reform them into lighter, more valuable components. Major global hubs, such as those in India (e.g., Jamnagar, Vadinar), operate continuously to supply energy.

Refineries use a combination of physical and chemical processes to transform crude oil

Distillation: The initial, primary step where heated crude oil is separated in a distillation tower into different "fractions" (e.g., naphtha, kerosene, gas oils) based on boiling temperatures.

Cracking: A process that breaks large, heavy hydrocarbon molecules into smaller, lighter molecules, converting heavy, less valuable oils into lighter, high-value products like gasoline.[4]

Reforming: Rearranging hydrocarbon molecules to improve the quality, such as increasing the octane rating of gasoline.

Treatment & Separation: Removing contaminants like sulfur, nitrogen, and heavy metals from the products.

Common Refinery Products: A 42-gallon barrel of crude oil yields a variety of products, primarily transportation fuels:

Motor Gasoline: ~19-20 gallons.

Distillate Fuel (Diesel): ~11-13 gallons.

Jet Fuel (Kerosene): ~3-4 gallons.

Other: Liquefied petroleum gas (LPG), petrochemical feedstocks, lubricants, and asphalt.

Figure 4: Petroleum Refinery.

Industrial Significance: Refineries are high-cost, high-capacity facilities, with global capacity exceeding 100 million barrels per day. Key Indian players include Reliance Industries' Jamnagar refinery (one of the world's largest) and state-owned firms like Indian Oil Corporation (IOCL) and Bharat Petroleum (BPCL).

Fractional distillation of petroleum separates crude oil into useful components (fractions) based on their boiling points using a hot fractionating tower. Heated vapour rises, with lighter, lower-boiling point molecules (e.g., gasoline) condensing at the cooler top, and heavier, high-boiling point molecules (e.g., bitumen) at the hotter bottom, allowing for the continuous, efficient separation of hydrocarbons.[5]

Key Aspects of Petroleum Fractional Distillation

Process: Crude oil is heated to approximately. In a furnace, vaporized, and fed into the bottom of a fractionating column.

Column Design: The tower features numerous trays or plates equipped with bubble caps to facilitate cooling and condensation, separating the vapour into fractions.

Temperature Gradient: The tower is hotter at the bottom and cooler at the top.

Figure 5: Parts of Petroleum Distillate [asphalt, naphtha, petrol, kerosene, gasoline].

Separation: Substances with high boiling points (long-chain hydrocarbons) condense first at lower levels, while substances with low boiling points (short-chain hydrocarbons) rise higher, condensing at cooler levels.

Main Fractions and Their Uses
Refinery Gas (Top): Propane and butane used for cooking/heating.

Gasoline (Petrol): Fuel for cars.

Naphtha: Used in chemical production. Naphtha does not have a single CAS number but is a category of refined petroleum distillates with several common CAS identifiers, most notably 64742-89-8 (solvent naphtha, light aliphatic) and 8030-30-6 (naphtha, petroleum). Other common variants include 64742-48-9 (hydro treated heavy) and 64742-94-5 (heavy aromatic).

Kerosene: Fuel for jet engines and lamps.

Diesel: Fuel for Lorries and trains.

Fuel Oil: Used in ships and power stations.

Bitumen/Residue (Bottom): Used for road surfacing.
This method is crucial for turning useless, thick crude oil into usable, cleaner-burning, and specialized petrochemical products.

Kerosene, also known as paraffin, is a combustible hydrocarbon liquid derived from the fractional distillation of petroleum between 150-275°C. It is a clear, low-viscosity, and low-volatility fuel used globally for heating, lighting, cooking, and in jet engines.

Key Properties and Uses
Composition: Contains 10 to 16 carbon atoms per molecule (chains $C_{12}H_{26}$-$C_{15}H_{32}$).

Safety: Less volatile than gasoline, making it safer for household heating/lighting.

Grades: ASTM International defines 1-K (low sulfur, <0.04%) and 2-K (higher sulfur, 0.3%).

Applications: Used in aviation (jet fuel), as a solvent in industry, and in fire performances.

Density: Roughly 0.78–0.81bm/cm^3, allowing it to float on water.

Health Hazards: Toxic if ingested; can be fatal.

Handling: Vapours can be suppressed with foam.

Storage: Should be stored in sealed, labelled containers.

Origin and Distribution: Kerosene was introduced in the 1850s by Ignacy Łukasiewicz as a safer alternative to whale oil for lighting. It is still heavily used for domestic lighting in many developing nations, particularly in Asia and Africa.

Figure 6: Petroleum Refinery.

Bitumen is primarily used as a binder in road construction (asphalt) for highways and runways, and for waterproofing in roofing and basements due to its adhesive and water-resistant properties, with significant applications in damp-proofing, sealing, and various industrial coatings like cable protection and soundproofing.[6]

Primary Uses
Road Construction: The largest use (around 85%) is binding aggregates like crushed stone for pavements, driveways, parking lots, and airport runways.
Waterproofing: Applied as membranes, paints, and coatings for roofs, foundations, basements, and water tanks to prevent leaks.

Other Construction Uses
Damp-Proofing: Prevents moisture from rising in walls and floors.
Roofing: Used in shingles, felts, and membranes.
Coatings: Protects pipes, cables, and metal surfaces from corrosion.
Flooring: Enhances flooring protection and used in damp-proof coatings.

Industrial and Other Applications
Soundproofing: Used in construction materials to reduce noise.
Adhesive: Acts as a strong adhesive in various products.
Specialized Products: Used in explosives, paints, inks, and even for stabilizing soil.
Naphtha is a highly volatile, flammable, and colourless-to-straw-coloured liquid hydrocarbon mixture, primarily produced by refining petroleum or coal tar. It is a crucial, high-demand industrial feedstock for producing petrochemicals (plastics), gasoline blending, and as a solvent for cleaning and degreasing.

Key Aspects of Naphtha
Production & Properties: As a light distillate, it is intermediate between light gases (like butane) and heavier kerosene. It is a complex mix of hydrocarbons (C5-C9) with a boiling range typically between 35^{O}-210^{O}C.

Types: Light Naphtha (boiling range 35^{O}-130^{O}C higher paraffin content) and Heavy Naphtha (boiling range 130^{O}-210^{O}C higher naphthenes/aromatics).

Primary Uses
Petrochemicals: Acts as a feedstock in steam crackers to produce ethylene and propylene.
Refining: Used to improve the octane rating of gasoline.

Industrial/Consumer: Used as a solvent, dry cleaning agent, fuel in camping stoves (white gas), and in paints/varnishes.

Safety & Hazards: Extremely flammable, with vapours that can travel to ignition sources and flash back. It is toxic, can cause skin irritation/defatting, and poses risks to the central nervous system if inhaled.
Naphtha market prices are heavily tied to crude oil prices and demand for petrochemical products.

Gasoline, or petrol, is a transparent, petroleum-derived flammable liquid primarily used as fuel for spark-ignited internal combustion engines in automobiles, motorcycles, and machinery. It is a volatile mixture of hydrocarbons (C_4-C_{11}) to produce through fractional distillation and refining of crude oil. It is often blended with ethanol (e.g., 10%) and additives to enhance octane ratings and performance.[7]

Refinery gas (or still gas) is a mixture of light hydrocarbon gases—primarily methane, ethane, ethylene, propane, and butane—produced during crude oil distillation, cracking, and reforming processes. It is typically used as a high-value refinery fuel for heaters and boilers or as a feedstock for petrochemical production.

Key Aspects of Refinery Gas
Composition: Contains hydrogen (H_2) and light hydrocarbons (C_1-C_5) including both saturated (methane, ethane) and unsaturated (ethylene, propylene) compounds.

Production: It is a by-product of refining operations like catalytic cracking, hydro treating, and coking.

Uses

Refinery Fuel: Used internally to power process furnaces and boilers.

Petrochemical Feedstock: Used to produce petrochemicals.

LPG Component: Components like propane and butane can be extracted for Liquefied Petroleum Gas.

Characteristics: It is a non-condensable gas at ambient conditions in the refinery setting.

Environmental/Safety: It is managed to maintain consistent heating value, and its composition is monitored to optimize refinery performance. Refinery gas is distinct from natural gas, although it serves similar fuel purposes within the refinery. AI Overview.

Asphalt and pitch are both highly viscous, sticky, black, waterproofing materials, but they are not identical in origin.

Asphalt is a by-product of petroleum refining (or natural deposits), while pitch is generally a residue from distilling coal tar or plant resins. They are often used interchangeably as binders in paving and roofing.

Key differences between the two include

Source: Asphalt comes from petroleum, whereas pitch is typically derived from coal tar or plant materials.

Consistency: Both are viscous liquids that behave like solids, but pitch is often considered more solid than tar.

Interchangeability: While they share properties, they are distinct materials; for instance, in roofing, "coal tar pitch" behaves differently than "asphalt" when tested.

Terminology: In some contexts, particularly in older usage or in specific industries, "pitch" is used as a generic term for various black, bituminous substances. While asphalt is often referred to as "road pitch" or bitumen, it is technically the residue from refined crude oil.

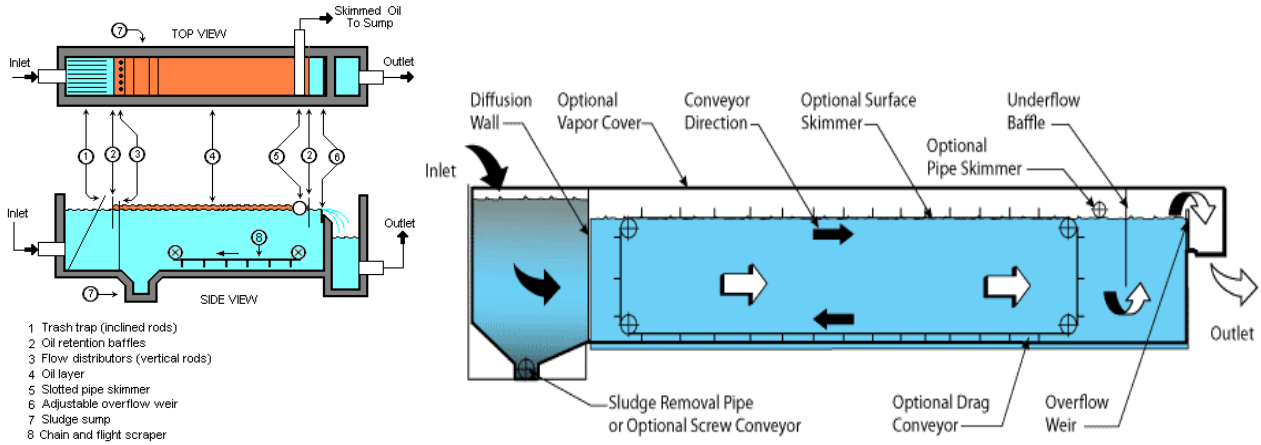

Figure 7: API Refinery.

In an oil refinery, "API" primarily refers to the American Petroleum Institute, which sets industry standards for equipment, safety, and operations. It also denotes API Gravity, a measure of how light or heavy crude oil is compared to water, and API separators, used to remove oil and solids from wastewater.

Refining

API Gravity: Measures the density of petroleum liquids. A higher API (above 10) means the oil is lighter, floats on water, and generally yields more gasoline/diesel. Lower API gravity indicates heavy, denser oil.

API Separators: Crucial, first-stage wastewater treatment devices designed using gravity (Stokes' Law) to separate oil from refinery water effluent.[8]

API Standards: Technical standards (e.g., for storage tanks, pipelines, pressure vessels) ensure safety, environmental protection, and operational efficiency.

API Gravity Impact: Refineries use API gravity to determine how to process different crude oils, with higher API, lighter crude often preferred for producing gasoline. These standards are developed through an ANSI-accredited process and are essential for maintaining equipment integrity, such as corrosion control and pressure management in refining operations. The American Petroleum Institute (API) is a global leader in developing standards for the oil and gas industry.

API standards are: API gravity is a measurement index developed by the American Petroleum Institute (API) that describes how heavy or light crude oil.

API Standards: The Backbone of Safety and Efficiency in Oil and Gas Pipelines | PT. Bakrie Pipe Industries.

The American Petroleum Institute (API) is a national trade association that develops standards for the oil and

natural gas industry. An API oil–water separator is a device designed to separate gross amounts of oil and suspended solids from industrial wastewater produced at oil refineries, petrochemical plants, chemical plants, natural gas processing plants and other industrial oily water sources. In an oil refinery, API refers primarily to the American Petroleum Institute, which sets industry standards for safety, equipment, and efficiency. Key applications include API Gravity (measuring crude oil density/quality), API oil-water separators for wastewater treatment, and API 580/510 standards for risk-based inspection of vessels and pipelines.[9]

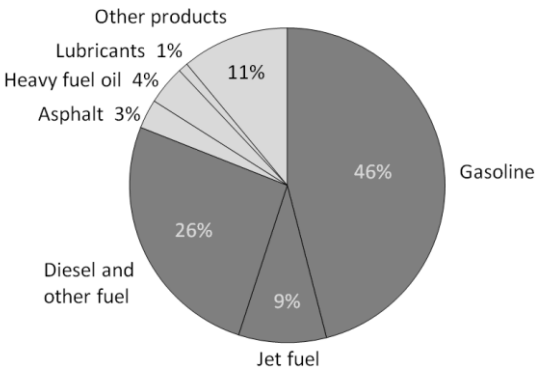

Figure 8: Fractions of petroleum distillate.

Key Aspects of API in Refineries
API Gravity: A measure of how heavy or light a petroleum liquid is compared to water.
Light Oil: API gravity > 10 (floats, higher value = higher quality/higher gasoline yield).
Heavy Oil: API gravity < 10 (sinks).

API Oil-Water Separator: A crucial device designed to remove oil and suspended solids from refinery wastewater, typically the first step in wastewater treatment.

API Standards and Inspection
API 510: Pressure Vessel Inspection Code.
API 570: Piping Inspection Code.
API 580/581: Risk-Based Inspection (RBI) management.

Safety & Quality: API standards guide the design, operation, and maintenance of refinery equipment to prevent failures.

These standards ensure operational safety, environmental protection, and product quality consistency across the industry.

API gravity (American Petroleum Institute gravity) is a measure of how light or heavy a petroleum liquid is compared to water. Measured in degrees (°API), a higher API number (>10) indicates lighter, less dense oil that floats, while a lower number (<10) indicates heavy, dense oil that sinks. It is defined by the formula:

Significance: It is the standard industry metric for density, directly impacting market price; lighter crude oils (>31.1 API) are often more valuable than heavier ones because they yield more gasoline and diesel.

Categories
Light: API Medium to API Heavy to API Extra Heavy. Higher API gravity means lower specific gravity (lighter oil), while lower API gravity means higher specific gravity (heavier oil).

What is crude oil fractional distillation? API oil distillation typically refers to the American Petroleum Institute (API) gravity—a measure of how light or heavy a petroleum liquid is compared to water—which determines its distillation characteristics and market value. Higher API gravity (>40^{O}) indicates light, easily refined crude, while lower gravity (<20) indicates heavy, difficult-to-process crude.[10]

API Gravity Classification
Light Crude: > 31.1° API (highly valued, produces more gasoline/diesel).
Medium Crude: 22.3°–31.1° API.
Heavy Crude: < 22.3° API.
Extra Heavy: < 10.0° API (denser than water).

Distillation Process: Crude oil is separated into fractions (gasoline, jet fuel, diesel, asphalt) in a distillation tower based on boiling points.

Atmospheric Distillation: Initial separation at standard pressure (approx. 340°C–350°C).

Vacuum Distillation: Further separates heavy residues at reduced pressure.

Refining Implications: Lighter, high-API crudes require simpler, less expensive distillation, while heavier, low-API crudes require complex, costly processing to break down heavy molecules.

API Gravity Calculation
The API gravity is calculated using the formula: 141.5/Specific gravity at 60^{O}F. This measurement tells refiners how "light" (easy to turn into high-value products like gasoline) or "heavy" (thick, low-value) the oil is.

CONCLUSION
An oil refinery or petroleum refinery is an industrial process plant where petroleum (crude oil) is transformed and refined into products such as gasoline (petrol), diesel fuel, asphalt base, fuel oils, heating oil, kerosene, liquefied petroleum gas and petroleum naphtha. Petrochemical feedstock like ethylene and propylene can also be produced directly by cracking crude oil without the need of using refined products of crude oil such as naphtha. The crude oil feedstock has typically been processed by an oil production plant. There is usually an

oil depot at or near an oil refinery for the storage of incoming crude oil feedstock as well as bulk liquid products. In 2020, the total capacity of global refineries for crude oil was about 101.2 million barrels per day.

Oil refineries are typically large, sprawling industrial complexes with extensive piping running throughout, carrying streams of fluids between large chemical processing units, such as distillation columns. In many ways, oil refineries use many different technologies and can be thought of as types of chemical plants. Since December 2008, the world's largest oil refinery has been the Jamnagar Refinery owned by Reliance Industries, located in Gujarat, India, with a processing capacity of 1.24 million barrels (197,000 m^3) per day.

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