CRUDE OIL & PETROLEUM PRODUCTS

Petroleum products are materials derived from crude oil (petroleum) as it is processed in oil refineries. Unlike petrochemicals, which are a collection of well-defined usually pure organic compounds, petroleum products are complex mixtures. Most petroleum is converted into petroleum products, which include several classes of fuels.

PETROLEUM (CRUDE OIL)

Petroleum, commonly known as crude oil or simply oil, is a naturally occurring liquid mixture with a yellowish-black hue, primarily composed of hydrocarbons. It is found in geological formations and encompasses both unprocessed crude oil and refined petroleum products.

Oil drilling is the primary method for petroleum extraction, conducted following studies of structural geology, sedimentary basin analysis, and reservoir characterization. Unconventional reserves such as oil sands and oil shale also exist.

In the petroleum industry, crude oil is classified based on its production location (e.g., West Texas Intermediate, Brent, or Oman), API gravity (a density measure), and sulfur content. Density categorizes crude oil as light, medium, or heavy, while sulfur content distinguishes between sweet (low sulfur) and sour (high sulfur) varieties.

Geographic location is crucial, affecting transportation costs to refineries. Light, sweet crude oil is preferable as it yields more gasoline and commands higher prices due to environmental advantages and lower refining requirements to meet sulfur standards. Crude oil assay analysis in laboratories reveals unique molecular characteristics of each oil.

Benchmark oils, such as West Texas Intermediate (WTI), Brent Blend, Dubai-Oman, Tapis, Minas, OPEC Reference Basket, Midway Sunset Heavy, and Western Canadian Select, are used for pricing worldwide. However, declining production of these benchmarks has led to the increasing use of other oils in actual trades.

Upon extraction, crude oil undergoes refining and separation, primarily through distillation, yielding various products for direct use or manufacturing. These products range from petrol (gasoline), diesel, and kerosene to asphalt and chemical reagents (ethylene, propylene, butene, acrylic acid, para-xylene), essential in the production of plastics, pesticides, and pharmaceuticals.

FUEL OIL

Fuel oil encompasses various fractions obtained through the distillation of petroleum (crude oil), including distillates (lighter fractions) and residues (heavier fractions). This category includes diverse types such as heavy fuel oil (bunker fuel), marine fuel oil (MFO), furnace oil (FO), gas oil (gasoil), heating oils (e.g., home heating oil), and diesel fuel.

The term "fuel oil" broadly encompasses any liquid fuel burned in furnaces or boilers for heat generation (heating oils) or used in engines for power generation (motor fuels). However, it typically excludes other liquid oils with a flash point of approximately 42 °C (108 °F) and oils burned in cotton- or wool-wick burners. In a more stringent sense, fuel oil specifically refers to the heaviest commercial fuels derived from crude oil, exceeding the weight of gasoline (petrol) and naphtha.

Comprising long-chain hydrocarbons, including alkanes, cycloalkanes, and aromatics, fuel oil exhibits a composition distinct from smaller molecules like propane, naphtha, gasoline, and kerosene, which have lower boiling points and are separated at the initial stages of fractional distillation. On the contrary, heavier petroleum-derived oils like diesel fuel and lubricating oil are less volatile and distill more slowly.

In the United States, various fuel grades are classified based on specific characteristics. While trends generally hold true, different organizations may have distinct numerical specifications for these fuel grades. The following outlines key aspects of six fuel grades:

NUMBER 1 FUEL OIL:

Also known as Diesel No. 1, kerosene, and jet fuel. Volatile distillate oil designed for vaporizing pot-type burners and high-performance/clean diesel engines. Boils off immediately after the heavy naphtha cut used for gasoline. Former names include coal oil, stove oil, and range oil.

NUMBER 2 FUEL OIL:
Distillate home heating oil. Used in trucks and some cars as diesel No. 2 with a cetane number limit describing ignition quality. Typically obtained from the light gas oil cut. Historical use of the term "gasoil" refers to its use in enriching water gas manufacture.

NUMBER 3 FUEL OIL:
Formerly a distillate oil for burners requiring low-viscosity fuel. ASTM merged this grade into the Number 2 specification, and the term has rarely been used since the mid-20th century.

NUMBER 4 FUEL OIL:
Also known as Bunker A. Commercial heating oil for burner installations lacking preheaters. May be obtained from the heavy gas oil cut.

NUMBER 5 FUEL OIL:
Residual-type industrial heating oil requiring preheating to 77–104 °C (171–219 °F) for proper atomization at burners. Sometimes referred to as Bunker B. May be obtained from the heavy gas oil cut or be a blend of residual oil with enough Number 2 oil to adjust viscosity for pumpability without preheating.

NUMBER 6 FUEL OIL:
High-viscosity residual oil requiring preheating to 104–127 °C (219–261 °F). Residual means the material remaining after more valuable cuts of crude oil have boiled off. May be known as residual fuel oil (RFO), Bunker C by Navy specification, or PS-400 by Pacific Specification. Contains impurities such as 2% water and 0.5% mineral oil.

HEAVY FUEL OIL (HFO) OR BUNKER FUEL

Heavy fuel oil (HFO), also known as bunker fuel or residual fuel oil, falls into the category of fuel oils characterized by a tar-like consistency. It is the residual product remaining after the distillation and cracking processes of petroleum. Due to its origin, HFO contains various contaminants, including aromatics, sulfur, and nitrogen. Consequently, when HFO is burned, the emissions produced are generally more polluting compared to other cleaner fuel oils.

HFO is primarily utilized as a fuel source for marine vessel propulsion, particularly in marine diesel engines. This preference is largely driven by its relatively low cost compared to cleaner fuel alternatives like distillates. However, it is essential to note that the environmental impact of HFO combustion has raised concerns due to its higher emissions of pollutants. Efforts to address environmental sustainability in the maritime industry often involve exploring cleaner and more eco-friendly alternatives to heavy fuel oil.

MARINE FUEL OIL (MFO)

In the maritime industry, a distinct classification system is employed for different types of fuel oils:

- MGO (Marine Gas Oil): Roughly equivalent to no. 2 fuel oil, MGO is produced exclusively from distillate. It is characterized by its relatively cleaner composition.
- MDO (Marine Diesel Oil): Roughly equivalent to no. 3 fuel oil, MDO is a blend of heavy gasoil that may contain minimal amounts of black refinery feedstocks. It possesses a low viscosity, up to 12 cSt, allowing it to be used in internal combustion engines without the need for heating.
- IFO (Intermediate Fuel Oil): Roughly equivalent to no. 4 fuel oil, IFO is a blend of gasoil and heavy fuel oil. It contains less gasoil than marine diesel oil.
- HFO (Heavy Fuel Oil): Pure or nearly pure residual oil, HFO is roughly equivalent to no. 5 and no. 6 fuel oil. It is a dense and viscous fuel commonly used in marine applications.
- NSFO (Navy Special Fuel Oil): Another term for no. 5 HFO, often used in naval applications.
- MFO (Marine Fuel Oil): Another term for no. 6 HFO, frequently utilized in marine propulsion systems.

It's noteworthy that marine diesel oil contains some heavy fuel oil, distinguishing it from regular diesel, and is designed to meet the specific requirements of marine engines. This classification system is essential for the maritime industry to ensure proper fuel selection based on the specific needs and characteristics of different types of vessels and engines.

HEATING OIL (HHO)

Heating oil, a type of fuel oil, refers to any petroleum product or oil used for heating purposes. This commonly includes low viscosity grades of fuel oil utilized in furnaces or boilers for home heating and in other buildings. The abbreviation HHO is often used for home heating oil.

In terms of chemical composition, most heating oil products are very similar to diesel fuel employed as motor fuel. However, motor fuel is typically subjected to higher fuel taxes. To prevent tax evasion, many countries incorporate fuel dyes into heating oil. These dyes enable law enforcement to verify if a driver is avoiding fuel taxes. In the European Union, Solvent Yellow 124 has been added as a "Euromarker" since 2002. In the United Kingdom, untaxed diesel is commonly referred to as "red diesel."

DIESEL FUEL OR GASOIL

Diesel fuel, also known as diesel oil or historically heavy oil, is a specialized liquid fuel designed for use in diesel engines—internal combustion engines that achieve fuel ignition through compression of inlet air, followed by fuel injection, without the need for a spark. Therefore, diesel fuel must possess favorable compression ignition characteristics.

The predominant form of diesel fuel is a specific fractional distillate derived from petroleum fuel oil. However, alternative sources like biodiesel, biomass to liquid (BTL), or gas to liquid (GTL) diesel are gaining prominence. To distinguish these alternatives, diesel derived from petroleum is occasionally termed Petro diesel in academic contexts.

Diesel fuel is standardized in many countries, with the European Union adopting the EN 590 standard. Ultra-low-sulfur diesel (ULSD), characterized by significantly reduced sulfur content, is widely prevalent in the United Kingdom, mainland Europe, and North America as of 2016.

Diesel fuel goes by various colloquial names, commonly referred to as simply diesel. In the United Kingdom, road-use diesel is known as diesel or, at times, white diesel to differentiate it from red diesel—a subsidized agricultural-only product with a distinctive colored dye. The official term for white diesel is DERV, representing diesel-engine road vehicle. In Australia, diesel fuel is referred to as distillate (distinct from an older sense of "distillate" referring to a different motor fuel), while in Indonesia (as well as in Israel), it is recognized as Solar, a trademarked name from the national petroleum company Pertamina. The term gas oil (French: gazole) is also occasionally used to refer to diesel fuel.

To ensure consistent quality, diesel fuel undergoes standardization, defining properties such as cetane number, density, flash point, sulfur content, or biodiesel content. Diesel fuel standards include EN 590 (European Union), ASTM D975 (United States), GOST R 52368 (Russia), NATO F 54 (NATO), and DIN 51601 (formerly used in West Germany, now obsolete).

Historically, diesel fuel contained higher sulfur levels. European emission standards and preferential taxation have compelled oil refineries to significantly reduce sulfur levels in diesel fuels. In the European Union, sulfur content has notably decreased over the past two decades. The current standard, Euro 5 implemented in 2009, allows for a maximum sulfur content of 10 ppm.

GASOLINE (PETROL)

Gasoline, also referred to as petrol or gas, is a clear, yellowish, and flammable liquid widely utilized as a fuel for spark-ignited internal combustion engines. It is produced through the fractional distillation of petroleum and enhanced with additives, constituting organic compounds.

The fuel characteristics of a gasoline blend, crucial for preventing engine knocking and ensuring efficiency in reciprocating engines, are determined by its octane rating. Lead compounds are generally excluded in modern automotive gasoline, except for specific applications in aviation, off-road vehicles, and racing cars.

Gasoline has the potential to enter the environment in various forms-uncombusted liquid, flammable liquid, or vapor-during its production, handling, transport, and delivery stages, posing environmental and health concerns. The combustion of gasoline releases carbon dioxide (CO_2), contributing to climate change. In 2021, oil products, including gasoline, were responsible for approximately 32% of global CO_2 emissions.

Commercial gasoline is a complex mixture of hydrocarbons designed to meet diverse engine performance specifications. The chemical composition of gasoline is not precisely defined, varying with factors such as season, crude oil sources, refinery processing units, and chosen blend stocks during production.

Produced in oil refineries, gasoline is derived from crude oil through distillation. Roughly 72 liters of gasoline can be obtained from a 160-liter barrel of crude oil. Virgin or straight-run gasoline, separated through distillation, does not meet modern engine specifications but can be blended to meet the required standards.

The primary components of gasoline include a homogeneous mix of small hydrocarbons (C_4-C_{12}), encompassing paraffins, olefins, and naphthenes. The specific ratio of molecules depends on variables such as the refinery, crude oil feed, and gasoline grade.

Key refinery streams employed in gasoline production include:

- Straight-run gasoline (naphtha): Distilled directly from crude oil, low in aromatics, and devoid of olefins, contributing up to 20% to the finished gasoline.
- Reformate: Produced in a catalytic reformer, featuring high octane and a notable aromatic content.
- Catalytic cracked gasoline: Produced with a catalytic cracker, characterized by a moderate octane, high olefin content, and moderate aromatics.
- Hydrocrackate: Produced with a hydrocracker, featuring a medium to low octane and moderate aromatic levels.
- Alkylate: Produced in an alkylation unit, lacking aromatics or olefins and boasting a high Motor Octane Number.
- Isomerate: Obtained by isomerizing low-octane straight-run gasoline, featuring a medium Research Octane Number (RON) and Motor Octane Number (MON).
- Butane: Blended in limited quantities, subject to Reid Vapor Pressure (RVP) specifications.

The octane rating, measured relative to a mixture of 2,2,4-trimethylpentane and n-heptane, exhibits global variations. Different countries adhere to diverse octane rating conventions, such as Research Octane Number (RON) or Anti-Knock Index (AKI). Standard gasoline options may include 95 RON, while premium or high-performance alternatives offer higher ratings. In the U.S., unleaded fuels range from 85 to 94 AKI (91-99 RON).

KEROSENE

Kerosene, or paraffin, is a combustible hydrocarbon liquid which is derived from petroleum. It is widely used as a fuel in aviation as well as households. It is sometimes spelled kerosine in scientific and industrial usage.

Kerosene is widely used to power jet engines of aircraft (jet fuel), as well as some rocket engines in a highly refined form called RP-1. It is also commonly used as a cooking and lighting fuel, and for fire toys such as poi. In parts of Asia, kerosene is sometimes used as fuel for small outboard motors or even motorcycles. World total kerosene consumption for all purposes is equivalent to about 5,500,000 barrels per day as of July 2023.

The term kerosene is common in much of Argentina, Australia, Canada, India, New Zealand, Nigeria, and the United States, while the term paraffin (or a closely related variant) is used in Chile, Eastern Africa, South Africa, Norway, and the United Kingdom. The term lamp oil, or the equivalent in the local languages, is common in the majority of Asia and the Southeastern United States.

To prevent confusion between kerosene and the much more flammable and volatile gasoline (petrol), some jurisdictions regulate markings or colorings for containers used to store or dispense kerosene. For example, in the United States, Pennsylvania requires that portable containers used at retail service stations for kerosene be colored blue, as opposed to red (for gasoline) or yellow (for diesel).

JET FUEL OR AVIATION TURBINE FUEL (ATF)

Jet fuel or aviation turbine fuel (ATF, also abbreviated AVTUR) is a type of aviation fuel designed for use in aircraft powered by gas-turbine engines. It is colorless to straw-colored in appearance. The most commonly used fuels for commercial aviation are Jet A and Jet A-1, which are produced to a standardized international specification. The only other jet fuel commonly used in civilian turbine-engine powered aviation is Jet B, which is used for its enhanced cold-weather performance.

Jet fuel is a mixture of a variety of hydrocarbons. Because the exact composition of jet fuel varies widely based on petroleum source, it is impossible to define jet fuel as a ratio of specific hydrocarbons. Jet fuel is therefore defined as a performance specification rather than a chemical compound. Furthermore, the range of molecular mass between hydrocarbons (or different carbon numbers) is defined by the requirements for the product, such as the freezing point or smoke point. Kerosene-type jet fuel (including Jet A and Jet A-1, JP-5, and JP-8) has a carbon number distribution between about 8 and 16 (carbon atoms per molecule); wide-cut or naphtha-type jet fuel (including Jet B and JP-4), between about 5 and 15.

Most jet fuels in use are kerosene-based. British standards derived from standards for kerosene use for lamps—known as paraffin in the UK—whereas American standards derived from aviation gasoline practices.

Jet A specification fuel has been used in the United States since the 1950s and is usually not available outside the United States and a few Canadian airports such as Toronto and Vancouver, whereas Jet A-1 is the standard specification fuel used in the rest of the world other than Russia and the CIS members where TS-1 is the most common standard. Both Jet A and Jet A-1 have a flash point higher than 38 °C (100 °F), with an autoignition temperature of 210 °C (410 °F).

DIFFERENCES BETWEEN JET A AND JET A-1

The primary difference is the lower freezing point of A-1:

Jet A's is −40 °C (−40 °F)
Jet A-1's is −47 °C (−53 °F)
The other difference is the mandatory addition of an anti-static additive to Jet A-1.

JET B

Jet B is a naphtha-kerosene fuel that is used for its enhanced cold-weather performance. However, Jet B's lighter composition makes it more dangerous to handle. For this reason, it is rarely used, except in very cold climates. A blend of approximately 30% kerosene and 70% gasoline, it is known as wide-cut fuel. It has a very low freezing point of −60 °C (−76 °F), and a low flash point as well. It is primarily used in some military aircraft. It is also used in northern Canada, Alaska, and sometimes Russia, because of its low freezing point.

TS-1

TS-1 is a jet fuel made to Russian standard GOST 10227 for enhanced cold-weather performance. It has somewhat higher volatility than Jet A-1 (flash point is 28 °C (82 °F) minimum). It has a very low freezing point, below −50 °C (−58 °F).

BITUMEN

Bitumen, an extremely viscous component of petroleum, can exist as a sticky, black liquid or a seemingly solid mass that exhibits liquid-like behavior over extended time scales. In the United States, this substance is commonly known as asphalt. Whether found in natural deposits or derived from petroleum refining, bitumen is categorized as a pitch.

Seventy percent of annual bitumen production is dedicated to road construction, its primary application. In this context, bitumen serves to bind aggregate particles such as gravel, creating a material known as asphalt concrete, colloquially referred to as asphalt. Its additional key uses include bituminous waterproofing products like roofing felt and roof sealant.

In materials sciences and engineering, the terms "asphalt" and "bitumen" are often used interchangeably, encompassing both natural and manufactured forms of the substance. However, there is regional variation in the prevalence of these terms. Geologists worldwide typically favor the term "bitumen" for the naturally occurring material. Conversely, for the manufactured material, a refined residue from the distillation process of specific crude oils, "bitumen" is the more prevalent term in many regions. In American English, however, "asphalt" is more commonly employed. To mitigate confusion, the phrases "liquid asphalt," "asphalt binder," or "asphalt cement" are used in the U.S.

PETROLEUM NAPHTHA

Petroleum naphtha is an intermediate hydrocarbon liquid stream obtained from the refining of crude oil, identified by CAS number 64742-48-9. Typically, it undergoes a desulfurization process followed by catalytic reforming. This reforming process serves to rearrange or restructure the hydrocarbon molecules present in the naphtha, as well as break down some molecules into smaller components. The end result is a high-octane element used in the production of gasoline (or petrol).

Given the diverse sources of petroleum crude oil globally, each with its unique composition or assay, and the variety of petroleum refineries worldwide, each designed for specific crude oils, naphtha is a broad term. Refineries produce their own naphthas, each with distinct initial and final boiling points, as well as other physical and compositional characteristics.

Naphthas can also be derived from alternative sources such as coal tar, shale deposits, tar sands, and the destructive distillation of wood. This diversity in origins contributes to the range of naphtha types with varying properties and applications.

LIQUEFIED PETROLEUM GAS (LPG)

Liquefied Petroleum Gas (LPG), also known as Liquid Petroleum Gas, is a fuel gas composed of a flammable mixture of hydrocarbon gases, including propane, propylene, butylene, isobutane, and n-butane.

LPG finds application as a fuel gas in heating appliances, cooking equipment, and vehicles. Additionally, it is increasingly utilized as an aerosol propellant and refrigerant, serving as an environmentally friendly alternative to chlorofluorocarbons, contributing to efforts to reduce damage to the ozone layer. In the context of vehicle fuel, LPG is commonly referred to as autogas or simply gas.

The production of LPG involves refining petroleum or "wet" natural gas, and it is predominantly derived from fossil fuel sources. This manufacturing process occurs during the refining of petroleum (crude oil) or by extracting it from petroleum or natural gas streams as they emerge from the ground. Currently, LPG contributes approximately 3% of all energy consumed, burning relatively cleanly with minimal soot and sulfur emissions. As a gaseous fuel, it does not pose ground or water pollution hazards, but it can contribute to air pollution. LPG boasts a typical specific calorific value of 46.1 MJ/kg, surpassing the values of 42.5 MJ/kg for fuel oil and 43.5 MJ/kg for premium-grade petrol (gasoline).

Beyond its role as an energy carrier, LPG holds promise as a feedstock in the chemical industry for synthesizing olefins such as ethylene and propylene.