Fuel oil

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Fuel oil, (also known as **heavy oil**, **marine fuel** or **furnace oil**) is a fraction obtained from petroleum distillation, either as a distillate or a residue. Broadly speaking, fuel oil is any liquid fuel that is burned in a furnace or boiler for the generation of heat or used in an engine for the generation of power, except oils having a flash point of approximately 107 °F (42 °C) and oils burned in cotton or wool-wick burners. In this sense, diesel is a type of fuel oil. Fuel oil is made of long hydrocarbon chains, particularly alkanes, cycloalkanes and aromatics. The term *fuel oil* is also used in a stricter sense to refer only to the heaviest commercial fuel that can be obtained from crude oil, i.e., heavier than gasoline and naphtha.

In some countries, the term "fuel oil" usually refers specifically to diesel fuel while in Australia, diesel fuel itself is commonly known as *distillate*.[1]

an oil tanker taking on fuel, or "bunkering."

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Classes

Although the following trends generally hold true, different organizations may have different numerical specifications for the six fuel grades. The boiling point and carbon chain length of the fuel increases with fuel oil number. Viscosity also increases with number, and the heaviest oil has to be heated to get it to flow. Price usually decreases as the fuel number increases.[2]

Number 1 fuel oil is a volatile distillate oil intended for vaporizing pot-type burners.[3] It is the kerosene refinery cut that boils off right after the heavy naphtha cut used for gasoline. Older names include coal oil, stove oil and range oil.[2]

Number 2 fuel oil is a distillate home heating oil.[3] This fuel is sometimes known as **Bunker A**. Trucks and some cars use similar diesel fuel with a cetane number limit describing the ignition quality of the fuel. Both are typically obtained from the light gas oil cut. Gas oil refers to the original use of this fraction in the late 19th and early 20th centuries – the gas oil cut was used as an enriching agent for carburetted water gas manufacture.[2]

Number 3 fuel oil was a distillate oil for burners requiring low-viscosity fuel. ASTM merged this grade into the number 2 specification, and the term has been rarely used since the mid-20th century.[3]

Number 4 fuel oil is a commercial heating oil for burner installations not equipped with preheaters.[3] It may be obtained from the heavy gas oil cut.[2]

Number 5 fuel oil is a residual-type industrial heating oil requiring preheating to 170–220 °F (77–104 °C) for proper atomization at the burners.[3] This fuel is sometimes known as **Bunker B**. It may be obtained from the heavy gas oil cut,[2] or it may be a blend of residual oil with enough number 2 oil to adjust viscosity until it can be pumped without preheating.[3]

Number 6 fuel oil is a high-viscosity residual oil requiring preheating to 220–260 °F (104–127 °C). Residual means the material remaining after the more valuable cuts of crude oil have boiled off. The residue may contain various undesirable impurities including 2 percent water and one-half percent mineral soil. This fuel may be known as residual fuel oil (RFO), by the Navy specification of **Bunker C**, or by the Pacific Specification of PS-400.[3]

Mazut is a residual fuel oil often derived from Russian petroleum sources and is either blended with lighter petroleum fractions or burned directly in specialized boilers and furnaces. It is also used as a petrochemical feedstock. In the Russian practice, though, "mazut" is an umbrella term roughly synonymous with the fuel oil in general, that covers most of the types mentioned above, except types 1 and 2/3, for which separate terms exist (kerosene and diesel fuel/solar oil respectively — Russian practice doesn't differentiate between diesel fuel and heating oil). This is further separated in two grades, "naval mazut" being analogous to grades 4 and 5, and "furnace mazut", a heaviest residual fraction of the crude, almost exactly corresponding to the number 6 fuel oil and further graded by viscosity and sulphur content.

Bunker fuel

Small molecules like those in propane, naphtha, gasoline for cars, and jet fuel have relatively low boiling points, and they are removed at the start of the fractional distillation process. Heavier petroleum products like diesel and lubricating oil are much less volatile and distill out more slowly, while bunker

oil is literally the bottom of the barrel; in oil distilling, the only things more dense than bunker fuel are carbon black feedstock and bituminous residue which is used for paving roads (asphalt) and sealing roofs.


A sample of residual fuel oil

Bunker fuel or **bunker crude** is technically any type of fuel oil used aboard vessels. It gets its name from the tanks on ships and in ports that it is stored in; in the early days of steam they were coal bunkers but now they are bunker fuel tanks. The Australian Customs and the Australian Tax Office define a bunker fuel as the fuel that powers the engine of a ship or aircraft. Bunker A is No. 2 fuel oil, bunker B is No. 4 or No. 5 and bunker C is No. 6. Since No. 6 is the most common, "bunker fuel" is often used as a synonym for No. 6. No. 5 fuel oil is also called **Navy Special Fuel Oil** (**NSFO**) or just **navy special**; No. 5 or 6 are also commonly called **heavy fuel oil** (**HFO**) or **furnace fuel oil** (**FFO**); the high viscosity requires heating, usually by a recirculated low pressure steam system, before the oil can be pumped from a bunker tank. Bunkers are rarely labeled this way in modern maritime practice.

Since the 1980s the International Organization for Standardization (ISO) has been the accepted standard for marine fuels (bunkers). The standard is listed under number 8217, with recent updates in 2005 and 2010. The standard divides fuels into residual and distillate fuels. The most common residual fuels in the shipping industry are RMG and RMK.[4] The differences between the two are mainly the density and viscosity, with RMG generally being delivered at 380 centistokes or less, and RMK at 700 centistokes or less. Ships with more advanced engines can process heavier, more viscous, and thus cheaper, fuel. Governing bodies (i.e., California, European Union) around the world have established Emission Control Areas (ECA) which limit the maximum sulfur of fuels burned in their ports to limit pollution, reducing the percentage of sulfur and other particulates from 4.5% m/m to as little as .10% as of 2015 inside an ECA. As of 2013 3.5% continued to be permitted outside an ECA, but the International Maritime Organization has planned to lower the sulfur content requirement outside the ECA's to 0,5% m/m.[5] This is where Marine Distillate Fuels and other alternatives[6] to use of heavy bunker fuel come into play. They have similar properties to diesel #2, which is used as road diesel around the world. The most common grades used in shipping are DMA and DMB.[7] Greenhouse gas emissions resulting from the use of international bunker fuels are currently included in national inventories.[8][9]

Table of fuel oils

Name	Alias	Alias	Type	Chain length
No. 1 fuel oil	No. 1 distillate	No. 1 diesel fuel	Distillate	9-16
No. 2 fuel oil	No. 2 distillate	No. 2 diesel fuel	Distillate	10-20
No. 3 fuel oil	No. 3 distillate	No. 3 diesel fuel	Distillate	
No. 4 fuel oil	No. 4 distillate	No. 4 residual fuel oil	Distillate/Residual	12-70
No. 5 fuel oil	No. 5 residual fuel oil	Heavy fuel oil	Residual	12-70
No. 6 fuel oil	No. 6 residual fuel oil	Heavy fuel oil	Residual	20-70

Uses

Oil has many uses; it heats homes and businesses and fuels trucks, ships and some cars. A small amount of electricity is produced by diesel, but it is more polluting and more expensive than natural gas. It is often used as a backup fuel for peaking power plants in case the supply of natural gas is interrupted or as the main fuel for small electrical generators. In Europe, the use of diesel is generally restricted to cars (about 40%), SUVs (about 90%), and trucks and buses (virtually all). The market for home heating using fuel oil, called heating oil, has decreased due to the widespread penetration of natural gas as well as heat pumps. However, it is very common in some areas, such as the Northeastern United States.

A fuel station in Zigui County on the Yangtze River

Fuel oil truck making a delivery in North Carolina, 1945.

Residual fuel oil is less useful because it is so viscous that it has to be heated with a special heating system before use and it may contain relatively high amounts of pollutants, particularly sulfur, which forms sulfur dioxide upon combustion. However, its undesirable properties make it very cheap. In fact, it is the cheapest liquid fuel available. Since it requires heating before use, residual fuel oil cannot be used in road vehicles, boats or small ships, as the heating equipment takes up valuable space and makes the vehicle heavier. Heating the oil is also a delicate procedure, which is inappropriate to do on small, fast moving vehicles. However, power plants and large ships are able to use residual fuel oil.

HAZMAT class 3 fuel oil

Use of residual fuel oil was more common in the past. It powered boilers, railroad steam locomotives, and steamships. Locomotives, however, have become powered by diesel or electric power; steamships are not as common as they were previously due to their higher operating costs (most LNG carriers use steam plants, as "boil-off" gas emitted from the cargo can be used as a fuel source); and most boilers now use heating oil or natural gas. Some industrial boilers still use it and so do some old buildings, including in New York City. The City estimates that the 1% of its buildings that burn fuel oils No. 4 and No. 6 are responsible for 86% of the soot pollution generated by all buildings in the city. New York has made the phase out of these fuel grades part of its environmental plan, PlaNYC, because of concerns for the health effects caused by fine particulates.[10]

Residual fuel's use in electrical generation has also decreased. In 1973, residual fuel oil produced 16.8% of the electricity in the US. By 1983, it had fallen to 6.2%, and as of 2005, electricity production from all forms of petroleum, including diesel and residual fuel, is only 3% of total production. The decline is the result of price competition with natural gas and environmental restrictions on emissions. For power plants, the costs of heating the oil, extra pollution control and additional maintenance required after burning it often outweigh the low cost of the fuel. Burning fuel oil, particularly residual fuel oil, produces uniformly higher carbon dioxide emissions than natural gas.[11]

Heavy fuel oils continue to be used in the boiler "lighting up" facility in many coal-fired power plants. This use is approximately analogous to using kindling to start a fire. Without performing this act it is difficult to begin the large-scale combustion process.

The chief drawback to residual fuel oil is its high initial viscosity, particularly in the case of No. 6 oil, which requires a correctly engineered system for storage, pumping, and burning. Though it is still usually lighter than water (with a specific gravity usually ranging from 0.95 to 1.03) it is much heavier and more viscous than No. 2 oil, kerosene, or gasoline. No. 6 oil must, in fact, be stored at around 100 °F (38 °C) heated to 150–250 °F (66–121 °C) before it can be easily pumped, and in cooler temperatures it can congeal into a tarry semisolid. The flash point of most blends of No. 6 oil is, incidentally, about 150 °F (66 °C). Attempting to pump high-viscosity oil at low temperatures was a frequent cause of damage to fuel lines, furnaces, and related equipment which were often designed for lighter fuels.

For comparison, BS 2869 Class G heavy fuel oil behaves in similar fashion, requiring storage at 104 °F (40 °C), pumping at around 122 °F (50 °C) and finalising for burning at around 194–248 °F (90–120 °C).

Most of the facilities which historically burned No. 6 or other residual oils were industrial plants and similar facilities constructed in the early or mid 20th century, or which had switched from coal to oil fuel during the same time period. In either case, residual oil was seen as a good prospect because it was cheap and readily available. Most of these facilities have subsequently been closed and demolished, or have replaced their fuel supplies with a simpler one such as gas or No. 2 oil. The high sulfur content of No. 6 oil—up to 3% by weight in some extreme cases—had a corrosive effect on many heating systems (which were usually designed without adequate corrosion protection in mind), shortening their lifespans and increasing the polluting effects. This was particularly the case in furnaces that were regularly shut down and allowed to go cold, since the internal condensation produced sulfuric acid.

Environmental cleanups at such facilities are frequently complicated by the use of asbestos insulation on the fuel feed lines. No. 6 oil is very persistent, and does not degrade rapidly. Its viscosity and stickiness also make remediation of underground contamination very difficult, since these properties reduce the effectiveness of methods such as air stripping.

When released into water, such as a river or ocean, residual oil tends to break up into patches or tarballs—mixtures of oil and particulate matter such as silt and floating organic matter- rather than form a single slick. An average of about 5-10% of the material will evaporate within hours of the release, primarily the lighter hydrocarbon fractions. The remainder will then often sink to the bottom of the water column.

Maritime

In the maritime field another type of classification is used for fuel oils:

- **MGO (Marine gas oil)** - roughly equivalent to No. 2 fuel oil, made from distillate only
- **MDO (Marine diesel oil)** - A blend of heavy gasoil that may contain very small amounts of black refinery feed stocks, but has a low viscosity up to 12 cSt so it need not be heated for use in internal combustion engines
- **IFO (Intermediate fuel oil)** A blend of gasoil and heavy fuel oil, with less gasoil than marine diesel oil
- **MFO (Marine fuel oil)** - same as HDO (just another "naming")
- **HFO (Heavy fuel oil)** - Pure or nearly pure residual oil, roughly equivalent to No. 6 fuel oil

Marine diesel oil contains some heavy fuel oil, unlike regular diesels.

Standards and classification

CCAI and CII are two indexes which describe the ignition quality of residual fuel oil, and CCAI is especially often calculated for marine fuels. Despite this, marine fuels are still quoted on the international bunker markets with their maximum viscosity (which is set by the ISO 8217 standard - see below) due to the fact that marine engines are designed to use different viscosities of fuel.[12] The unit of viscosity used is the Centistoke and the fuels most frequently quoted are listed below in order of cost, the least expensive first.

- **IFO 380** - Intermediate fuel oil with a maximum viscosity of 380 Centistokes (<3.5% sulphur)
- **IFO 180** - Intermediate fuel oil with a maximum viscosity of 180 Centistokes (<3.5% sulphur)
- **LS 380** - Low-sulphur (<1.0%) intermediate fuel oil with a maximum viscosity of 380 Centistokes
- **LS 180** - Low-sulphur (<1.0%) intermediate fuel oil with a maximum viscosity of 180 Centistokes
- **MDO** - Marine diesel oil.
- **MGO** - Marine gasoil.
- **LSMGO** - Low-sulphur (<0.1%) Marine Gas Oil - The fuel is to be used in EU community Ports and Anchorages. EU Sulphur directive 2005/33/EC
- **ULSMGO** - Ultra Low Sulphur Marine Gas Oil - referred to as Ultra Low Sulfur Diesel (sulphur 0.0015% max) in the US and Auto Gas Oil (sulphur 0.001% max) in the EU. Maximum sulphur allowable in US territories and territorial waters (inland, marine and automotive) and in the EU for inland use.

The density is also an important parameter for fuel oils since marine fuels are purified before use to remove water and dirt from the oil. Since the purifiers use centrifugal force, the oil must have a density which is sufficiently different from water. Older purifiers work with a fuel having a maximum of 991 kg/m3; with modern purifiers it is also possible to purify oil with a density of 1010 kg/m3.

The first British standard for fuel oil came in 1982. The latest standard is ISO 8217 from 2005. The ISO standard describe four qualities of distillate fuels and 10 qualities of residual fuels. Over the years the standards have become stricter on environmentally important parameters such as sulfur content. The latest standard also banned the adding of used lubricating oil (ULO).

Some parameters of marine fuel oils according to ISO 8217 (3. ed 2005):

Marine distillate fuels						
Parameter	**Unit**	**Limit**	**DMX**	**DMA**	**DMB**	**DMC**
Density at 15 °C	kg/m^3	Max	-	890.0	900.0	920.0
Viscosity at 40 °C	mm^2/s	Max	5.5	6.0	11.0	14.0
	mm^2/s	Min	1.4	1.5	-	-
Water	% V/V	Max	-	-	0.3	0.3
Sulfur[1]	% (m/m)	Max	1.0	1.5	2.0	2.0
Aluminium + Silicon[2]	mg/kg	Max	-	-	-	25
Flash point[3]	°C	Min	43	60	60	60
Pour point, Summer	°C	Max	-	0	6	6
Pour point, Winter	°C	Max	-	-6	0	0
Cloud point	°C	Max	-16	-	-	-
Calculated Cetane Index		Min	45	40	35	-

Marine residual fuels												
Parameter	**Unit**	**Limit**	**RMA 30**	**RMB 30**	**RMD 80**	**RME 180**	**RMF 180**	**RMG 380**	**RMH 380**	**RMK 380**	**RMH 700**	**RMK 700**
Density at 15 °C	kg/m^3	Max	960.0	975.0	980.0	991.0	991.0	991.0	991.0	1010.0	991.0	1010.0
Viscosity at 50 °C	mm^2/s	Max	30.0	30.0	80.0	180.0	180.0	380.0	380.0	380.0	700.0	700.0
Water	% V/V	Max	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Sulfur[1]	% (m/m)	Max	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Aluminium + Silicon[2]	mg/kg	Max	80	80	80	80	80	80	80	80	80	80
Flash point[3]	°C	Min	60	60	60	60	60	60	60	60	60	60
Pour point, Summer	°C	Max	6	24	30	30	30	30	30	30	30	30
Pour point, Winter	°C	Max	0	24	30	30	30	30	30	30	30	30

1. Maximum sulfur content in the open ocean is 3.5% since January 2012. Maximum sulfur content in designated areas is 0.1% since 1 January 2015. Before then it was 1.00%.
2. The content of Aluminium and silicon is limited because those metals are dangerous for the engine. Those elements are present because some components of the fuel are manufactured with Fluid Catalytic Cracking process, which makes use of catalyst containing Aluminium and silicon.
3. The flash point of all fuels used in the engine room should be at least 60 °C. (DMX is used for things like emergency generators and not normally used in the engine room. Gaseous fuels such as LPG/LNG have special class rules applied to the fuel systems.)

Transportation

Fuel oil is transported worldwide by fleets of oil tankers making deliveries to suitably sized strategic ports such as Houston, Singapore, Fujairah, Balboa, Cristobal, Sokhna (Egypt), Algeciras and Rotterdam. Where a convenient seaport does not exist, inland transport may be achieved with the use of barges. Lighter fuel oils can also be transported through pipelines. The major physical supply chains of Europe are along the Rhine.

Environmental issues

Emissions from bunker fuel burning in ships contribute to air pollution levels in many port cities, especially where the emissions from industry and road traffic have been controlled. The switch of auxiliary engines from heavy fuel oil to diesel oil at berth can result in large emission reductions,

especially for SO_2 and PM. CO_2 emissions from bunker fuels sold are not added to national GHG emissions. For small countries with large international ports, there is an important difference between the emissions in territorial waters and the total emissions of the fuel sold.[9]

Meanings of "bunkering"

The term "bunkering" broadly relates to storage of petroleum products in tanks (among other, disparate meanings.) The precise meaning can be further specialized depending on context. Perhaps the most common, more specialized usage refers to the practice and business of refueling ships. Bunkering operations are located at seaports, and they include the storage of "bunker" (ship) fuels and the provision of the fuel to vessels.[13]

Alternatively the term "bunkering" may apply to the shipboard logistics of loading fuel and distributing it among available "bunkers" (on-board fuel tanks.)[14]

Finally, in the context of the oil industry in Nigeria, the term "bunkering"[15] has come to refer to the illegal diversion of crude oil (often subsequently refined in makeshift facilities into lighter transportation fuels) by the unauthorized cutting of holes into transport pipelines, often by very crude and hazardous means.

See also

- Coconut oil: an important fuel for ships in regions such as the Philippines, Papua New Guinea, Vanuatu[16]
- Diesel fuel
- Gasoline
- Heating oil
- Jet fuel
- Kerosene
- Lubricant
- Naphtha
- Gas Oil Separation Plant
- Fuel management systems
- Fuel price risk management
- Marine fuel management
- Hot-bulb engine
- Pyrolysis oil

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1. Bunker Pricing Methodologies (http://www.platts.com/MethodologyAndSpecifications/Shipping)

External links

- National Park Service - Fuel Oil (http://www.nature.nps.gov/hazardssafety/toxic/fueloil.pdf)
- World Bunker Prices (http://navigatemag.ru/bunker/)
- How Stuff Works - Oil Refining (http://science.howstuffworks.com/oil-refining2.htm)
- Identity and Analysis of Total Petroleum Hydrocarbons (http://www.atsdr.cdc.gov/toxprofiles/tp123-c3.pdf)
- The International Bunkering Industry Association (http://www.ibia.net)
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- Economy HFO on boiler. Industrial test. 4% (http://www.energy-saving-technology.com/test/rsal-test-noname-en.pdf)
- [1] (https://www.crownoil.co.uk/faq/fuels-the-what-who-why-of-fuel)