

OIL AND MINERALS PROCESSING

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1. What is Crude Oil

The "crude oil" (unprocessed oil) pumped out of the ground is a black liquid called **petroleum**. **Crude oils vary in color**, from clear to tar-black, **and in viscosity**, from water to almost solid. This liquid contains **aliphatic hydrocarbons**, or hydrocarbons composed of nothing but hydrogen and carbon. The carbon atoms link together in chains of different lengths. (*What is the status with the Organic Chemistry course?*)

Hydrocarbon molecules of different lengths have different properties and behaviors. Hydrocarbons can take on many different forms. The smallest hydrocarbon is **methane** (CH₄), which is a gas that is lighter than air. As the chains get longer, they get heavier.

The first four chains -- CH₄ (methane), C₂H₆ (ethane), C₃H₈ (propane) and C₄H₁₀ (butane) -- are all gases, and they boil at -107, -67, -43 and -18 degrees C respectively. The chains up through C₁₈H₃₂ or so are all liquids at room temperature, and the chains above C₁₉ are all solids at room temperature.

Hydrocarbons contain a lot of **energy**. Many of the things derived from crude oil like gasoline, diesel fuel, paraffin wax and so on take advantage of this energy. On average, crude oils are made of the following elements or compounds:

Carbon - 84%

Hydrogen - 14%

Sulfur - 1 to 3% (hydrogen sulfide, sulfides, disulfides, elemental sulfur)

Nitrogen - less than 1% (basic compounds with amine groups)

Oxygen - less than 1% (found in organic compounds such as carbon dioxide, phenols, ketones, carboxylic acids)

Metals - less than 1% (nickel, iron, vanadium, copper, arsenic)

Salts - less than 1% (sodium chloride, magnesium chloride, calcium chloride)

RESERVES & SOURCES OF OIL & GAS:

- ROCKS 10 TO 100'S OF MILLION YEARS AGO
- PRODUCTS OF HEAT & PRESSURE ON MARINE ANIMALS & PLANTS THAT DIED IN LOW- O_2 WATERS AND DID NOT DECOMPOSE - BURIED UNDER SEDIMENT LAYERS.
- CONVERSION PROCESS CONTROVERSIAL: ONE THEORY IS:
 - BACTERIA CONVERTED MARINE LIFE FATS \rightarrow FATTY ACIDS
 - FATTY ACIDS \rightarrow KEROGEN (ASPHALTIC MATERIAL)
 - KEROGEN $\xrightarrow[\text{MILLIONS OF YEARS}]{T, P, \text{CATALYSTS}}$ OIL & GAS

MODERN OIL INDUSTRY STARTED WITH CRUDE OIL DISCOVERY IN W. ONTARIO IN 1857 AND PENNSYLVANIA IN 1859.

MAJOR PRODUCING COUNTRIES ARE:

MIDDLE EAST (SAUDI ARABIA, KUWAIT, IRAN, IRAQ, UAE) etc.)

CIS (FORMER SOVIET UNION) - $12 \cdot 10^6$ BBL/D

USA - $10 \cdot 10^6$ BBL/D

VENEZUELA, CANADA, MEXICO, INDONESIA, NIGERIA,

LIBYA, UK, NORWAY

Deposited of technical expertise
OPEC PRODUCTION : $\sim 22 \cdot 10^6$ BBL/D

NON-OPEC PRODUCTION : $\sim 40 \cdot 10^6$ BBL/D

CURRENT NATURAL GAS PRODUCTION : $\sim 5,2 \cdot 10^9$ m³/D

PROVED RECOVERABLE RESERVES:

$$\begin{aligned} \text{OIL: } & 907 \cdot 10^9 \text{ BBL} \div 84 \cdot 10^6 = 10797 \text{ Days} \approx 36 \text{ Yrs} \\ & = 29 \text{ Yrs} \\ \text{GAS: } & 110 \cdot 10^{12} \text{ m}^3 \end{aligned}$$

Oil Producing Countries (2005 figures)

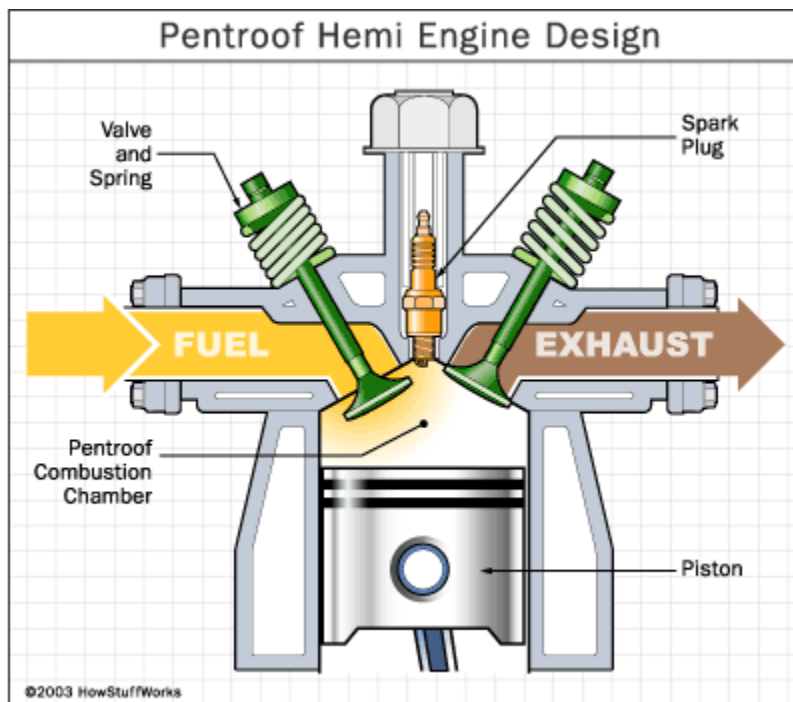
Rank	Country	Billion barrels (nb: 1 barrel = 158.99 liters)
1	Saudi Arabia	265.3
2	Iraq	115
3	Kuwait	98.8
4	Iran	96.4
5	United Arab Emirates	62.8
6	Russia	54.3
7	Venezuela	47.6
8	China	30.6
9	Libya	30
10	Mexico	26.9
11	Nigeria	24.1
12	United States	22
13	Algeria	12.7
14	Norway	10.1
15	Indonesia	9.7
16	Angola	9
17	Brazil	8.5
18	Oman	5.8
19	Canada	5.6
19	Qatar	5.6

The major classes of **hydrocarbons in crude oils** include:

- **Paraffins**
 - general formula: C_nH_{2n+2} (n is a whole number, usually from 1 to 20)
 - straight- or branched-chain molecules
 - can be gasses or liquids at room temperature depending upon the molecule
 - examples: methane, ethane, propane, butane, isobutane, pentane, hexane
 - **Aromatics**
 - general formula: $C_6H_5 - Y$ (Y is a longer, straight molecule that connects to the benzene ring)
 - ringed structures with one or more rings
 - typically liquids
 - examples: benzene, naphthalene
 - **Napthenes or Cycloalkanes**
 - general formula: C_nH_{2n} (n is a whole number usually from 1 to 20)
 - ringed structures with one or more rings
 - rings contain only single bonds between the carbon atoms
 - typically liquids at room temperature
 - examples: cyclohexane, methyl cyclopentane
 - Other hydrocarbons
 - **Alkenes**
 - general formula: C_nH_{2n} (n is a whole number, usually from 1 to 20)
 - linear or branched chain molecules containing one carbon-carbon double-bond
 - can be liquid or gas
 - examples: ethylene, butene, isobutene
 - **Dienes and Alkynes**
 - general formula: C_nH_{2n-2} (n is a whole number, usually from 1 to 20)
 - linear or branched chain molecules containing two carbon-carbon double-bonds
 - can be liquid or gas
 - examples: acetylene, butadienes
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2. How does a car engine work

The purpose of a gasoline car engine is to convert gasoline into motion so that your car can move. Currently the easiest way to create motion from gasoline is to burn the gasoline inside an engine. Therefore, a car engine is an **internal combustion engine** -- combustion takes place internally. There is such a thing as an **external** combustion engine. A steam engine in old-fashioned trains and steam boats is the best example of an external combustion engine. The fuel (coal, wood, oil, whatever) in a steam engine burns outside the engine to create steam, and the steam creates motion inside the engine. Internal combustion is a lot more efficient (takes less fuel per mile) than external combustion, plus an internal combustion engine is a lot smaller than an equivalent external combustion engine.



Inside a typical car engine

Almost all cars today use a reciprocating internal combustion engine because this engine is:

- **Relatively efficient** (compared to an external combustion engine)
- **Relatively inexpensive** (compared to a gas turbine)
- **Relatively easy to refuel** (compared to an electric car)

These advantages beat any other existing technology for moving a car around.

Combustion Is Key

To understand the basic idea behind how a reciprocating internal combustion engine works, it is helpful to have a good mental image of how "internal combustion" works.

Example: war cannon

Internal Combustion

The cannon uses the basic principle behind any reciprocating internal combustion engine: If you put a tiny amount of high-energy fuel (like gasoline) in a small, enclosed space and ignite it, an incredible amount of energy is released in the form of expanding gas. You can use that energy to propel a potato 500 feet. In this case, the energy is translated into potato motion. You can also use it for more interesting purposes. For example, if you can create a cycle that allows you to set off explosions like this hundreds of times per minute, and if you can harness that energy in a useful way, what you have is the core of a car engine!

Almost all cars currently use what is called a **four-stroke combustion cycle** to convert gasoline into motion. The four-stroke approach is also known as the **Otto cycle**, in honor of Nikolaus Otto, who invented it in 1867. The four strokes are illustrated in **Figure 1**. They are:

- Intake stroke
- Compression stroke
- Combustion stroke
- Exhaust stroke

The piston is connected to the **crank shaft** by a **connecting rod**. As the crankshaft revolves, it has the effect of "resetting the cannon." Here's what happens as the engine goes through its cycle:

1. The piston starts at the top, the intake valve opens, and the piston moves down to let the engine take in a cylinder-full of air and gasoline. This is the **intake stroke**. Only the tiniest drop of gasoline needs to be mixed into the air for this to work.
2. Then the piston moves back up to compress this fuel/air mixture. **Compression** makes the explosion more powerful.
3. When the piston reaches the top of its stroke, the [spark plug](#) emits a spark to ignite the gasoline. The gasoline charge in the cylinder **explodes**, driving the piston down.

4. Once the piston hits the bottom of its stroke, the exhaust valve opens and the **exhaust** leaves the cylinder to go out the tail pipe.

Now the engine is ready for the next cycle, so it intakes another charge of air and gas.

Notice that the motion that comes out of an internal combustion engine is **rotational**, while the motion produced by a potato cannon is **linear** (straight line). In an engine the linear motion of the pistons is converted into rotational motion by the crank shaft. The rotational motion is nice because we plan to turn (rotate) the car's wheels with it anyway.

Now let's look at all the parts that work together to make this happen.

Counting cylinders

The core of the engine is the cylinder, with the piston moving up and down inside the cylinder. The engine described above has one cylinder. That is typical of most lawn mowers, but most cars have more than one cylinder (four, six and eight cylinders are common). In a multi-cylinder engine, the cylinders usually are arranged in one of three ways: inline, V or flat (also known as horizontally opposed or boxer), as shown in the following figures.

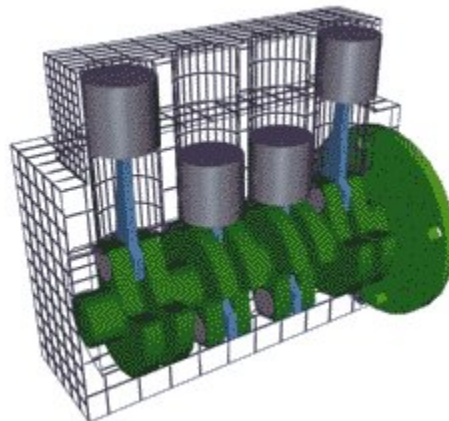


Figure 2. Inline - The cylinders are arranged in a line in a single bank.

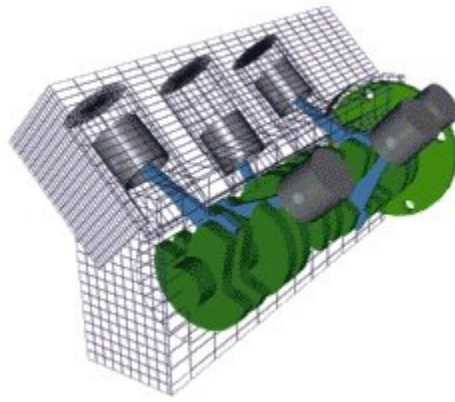


Figure 3. V - The cylinders are arranged in two banks set at an angle to one another.

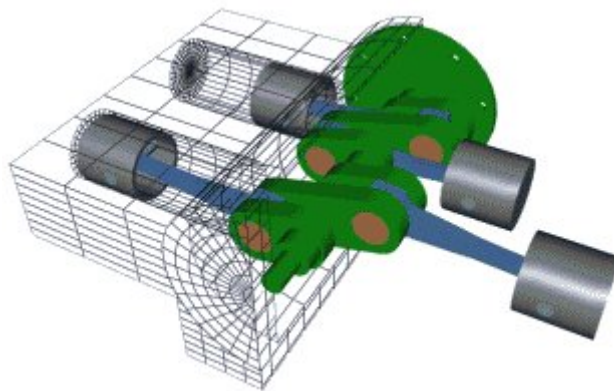


Figure 4. Flat - The cylinders are arranged in two banks on opposite sides of the engine.

Different configurations have different advantages and disadvantages in terms of smoothness, manufacturing-cost and shape characteristics. These advantages and disadvantages make them more suitable for certain vehicles. The **octane rating** of gasoline tells you how much the fuel can be compressed before it spontaneously ignites. When gas ignites by compression rather than because of the spark from the spark plug, it causes **knocking** in the engine. Knocking can damage an engine, so it is not something you want to have happening. Lower-octane gas (like "regular" 87-octane gasoline) can handle the least amount of compression before igniting. The compression ratio of your engine determines the octane rating of the gas you must use in the car. One way to increase the [horsepower](#) of an engine of a given displacement is to increase its compression ratio. So a "high-performance engine" has a higher compression ratio and requires higher-octane fuel. The advantage of a high compression ratio is that it gives your engine a higher horsepower rating for a given engine weight -- that is what makes the engine "high performance." The disadvantage is that the gasoline for your engine costs more. The name "octane" comes from the following fact: When you take crude oil and "crack" it in a [refinery](#), you end up getting **hydrocarbon chains** of different lengths. These different chain lengths can then be separated from each other and blended to form different fuels. For example, methane, propane and butane are all hydrocarbons. Methane has a single carbon atom. Propane has three carbon atoms chained together. Butane has four carbon atoms chained together. Pentane has five, hexane has six, heptane has seven and octane has **eight carbons** chained together. It turns out that heptane handles compression very poorly. Compress it just a little and it ignites spontaneously. Octane handles compression very well -- you can compress it a lot and nothing happens. Eighty-seven-octane gasoline is gasoline that contains 87-percent octane and 13-percent heptane (or some other combination of fuels that has the same performance of the 87/13 combination of octane/heptane). It spontaneously ignites at a given compression level, and can only be used in engines that do not exceed that compression ratio.