OIL AND MINERALS PROCESSING

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Some questions from 1st lecture:

1. What's the diff. between a 130 engine and a 160 (or 180)?

Size of cylinder – bigger cylinder, more fuel taken in on each intake stroke → more power delivered when spark plug sparks.

2. What's the issue about lead in petrol?

During WWI, it was discovered that you can add a chemical called tetraethyl lead to gasoline and significantly improve its octane rating. Cheaper grades of gasoline could be made usable by adding this chemical. This led to the widespread use of "ethyl" or "leaded" gasoline. Unfortunately, the side effects of adding lead to gasoline are:

- Lead clogs a catalytic converter and renders it inoperable within minutes.
- The Earth became covered in a thin layer of lead, and lead is toxic to many living things (including humans).

When lead was banned, gasoline got more expensive because refineries could not boost the octane ratings of cheaper grades any more. Airplanes are still allowed to use leaded gasoline, and octane ratings of 115 are commonly used in super-high-performance piston airplane engines (jet engines burn kerosene, by the way).
Another common additive is MTBE. MTBE is the acronym for methyl tertiary butyl ether, a fairly simple molecule that is created from methanol. MTBE gets added to gasoline for two reasons:

1. It boosts octane
2. It is an oxygenate, meaning that it adds oxygen to the reaction when it burns. Ideally, an oxygenate reduces the amount of unburned hydrocarbons and carbon monoxide in the exhaust.

MTBE started getting added to gasoline in a big way after the Clean Air Act of 1990 went into effect. Gasoline can contain as much as 10 percent to 15 percent MTBE.

The main problem with MTBE is that it is thought to be carcinogenic and it mixes easily with water. If gasoline containing MTBE leaks from an underground tank at a gas station, it can get into groundwater and contaminate wells. Of course, MTBE isn't the only thing getting into the groundwater when a tank leaks -- so is gasoline and a host of other gasoline additives.

Principles of Distillation

What is distillation?

Distillation is defined as:

a process in which a liquid or vapour mixture of two or more substances is separated into its component fractions of desired purity, by the application and removal of heat.

Distillation is based on the fact that the vapour of a boiling mixture will be richer in the components that have lower boiling points.

Therefore, when this vapour is cooled and condensed, the condensate will contain more volatile components. At the same time, the original mixture will contain more of the less volatile material.

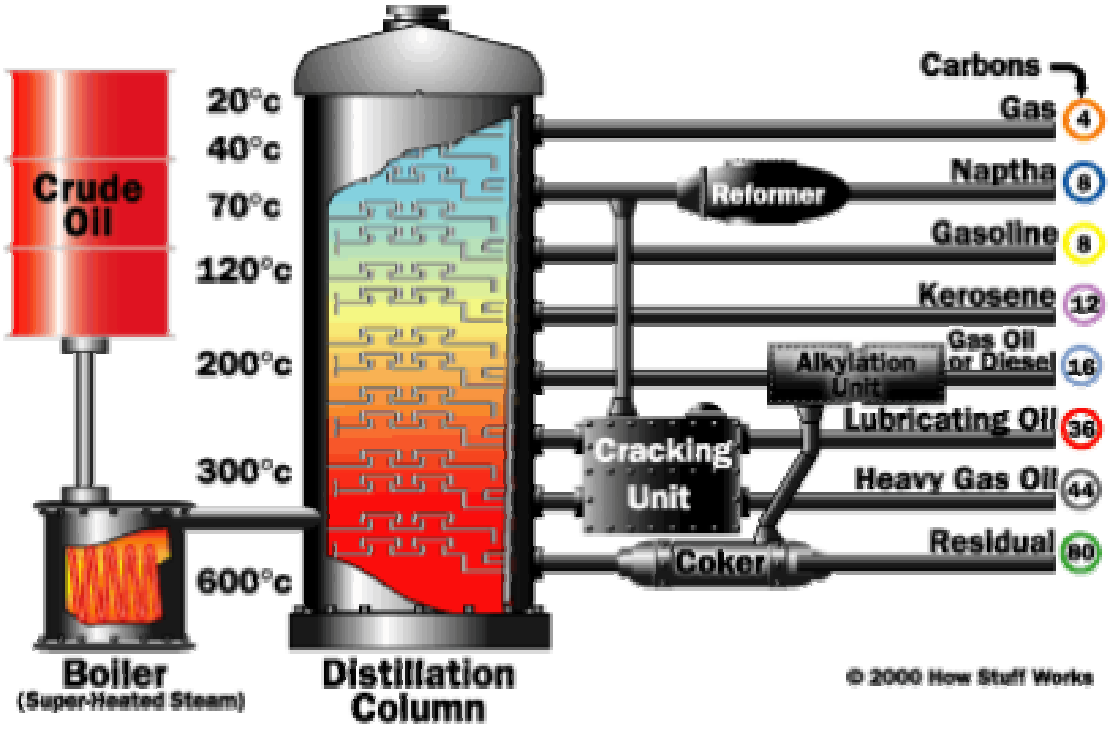
Distillation columns are designed to achieve this separation efficiently.

Although many people have a fair idea what “distillation” means, the important aspects that seem to be missed from the manufacturing point of view are that:

- distillation is the most common separation technique
- it consumes enormous amounts of energy, both in terms of cooling and heating requirements
- it can contribute to more than 50% of plant operating costs

The best way to reduce operating costs of existing units, is to improve their efficiency and operation via process optimisation and control. To achieve this improvement, a thorough understanding of distillation principles and how distillation systems are designed is essential.

Different hydrocarbon chain lengths all have progressively higher boiling points, so they can all be separated by distillation. This is what happens in an oil refinery - in one part of the process, crude oil is heated and the different chains are pulled out by their vaporization temperatures. Each different chain length has a different property that makes it useful in a different way.



To understand the diversity contained in crude oil, and to understand why refining crude oil is so important in our society, look through the following list of products that come from crude oil:

- **Petroleum gas** - used for heating, cooking, making plastics
    - small alkanes (1 to 4 carbon atoms)
    - commonly known by the names methane, ethane, propane, butane
    - boiling range = less than 104 degrees Fahrenheit / 40 degrees Celsius
    - often liquified under pressure to create LPG (liquified petroleum gas)
- **Naphtha** or **Ligroin** - intermediate that will be further processed to make gasoline
    - mix of 5 to 9 carbon atom alkanes
    - boiling range = 140 to 212 degrees Fahrenheit / 60 to 100 degrees Celsius
- **Gasoline** - motor fuel
    - liquid
    - mix of alkanes and cycloalkanes (5 to 12 carbon atoms)
    - boiling range = 104 to 401 degrees Fahrenheit / 40 to 205 degrees Celsius
- **Kerosene** - fuel for jet engines and tractors; starting material for making other products
    - liquid
    - mix of alkanes (10 to 18 carbons) and aromatics
    - boiling range = 350 to 617 degrees Fahrenheit / 175 to 325 degrees Celsius
- **Gas oil** or **Diesel distillate** - used for diesel fuel and heating oil; starting material for making other products
    - liquid
    - alkanes containing 12 or more carbon atoms
    - boiling range = 482 to 662 degrees Fahrenheit / 250 to 350 degrees Celsius
- **Lubricating oil** - used for motor oil, grease, other lubricants
    - liquid
    - long chain (20 to 50 carbon atoms) alkanes, cycloalkanes, aromatics
    - boiling range = 572 to 700 degrees Fahrenheit / 300 to 370 degrees Celsius
- **Heavy gas** or **Fuel oil** - used for industrial fuel; starting material for making other products
    - liquid
    - long chain (20 to 70 carbon atoms) alkanes, cycloalkanes, aromatics
    - boiling range = 700 to 1112 degrees Fahrenheit / 370 to 600 degrees Celsius
- **Residuals** - coke, asphalt, tar, waxes; starting material for making other products

- solid
- multiple-ringed compounds with 70 or more carbon atoms
- boiling range = greater than 1112 degrees Fahrenheit / 600 degrees Celsius

You may have noticed that all of these products have different sizes and boiling ranges. Chemists take advantage of these properties when refining oil.

The Refining Process

As mentioned previously, a barrel of crude oil has a mixture of all sorts of hydrocarbons in it. Oil refining separates everything into useful substances. Chemists use the following steps:

1. The oldest and most common way to separate things into various components (called **fractions**), is to do it using the differences in boiling temperature. This process is called **fractional distillation**. You basically heat crude oil up, let it vaporize and then condense the vapor.
2. Newer techniques use **Chemical processing** on some of the fractions to make others, in a process called **conversion**. Chemical processing, for example, can break longer chains into shorter ones. This allows a refinery to turn diesel fuel into gasoline depending on the demand for gasoline.
3. Refineries must **treat** the fractions to remove impurities.
4. Refineries **combine** the various fractions (processed, unprocessed) into mixtures to make desired products. For example, different mixtures of chains can create gasolines with different octane ratings.

Photo courtesy Phillips Petroleum Company

An oil refinery

The products are stored on-site until they can be delivered to various markets such as gas stations, airports and chemical plants. In addition to making the oil-based products, refineries must also treat the wastes involved in the processes to minimize air and water pollution.

Fractional Distillation

The various components of crude oil have different sizes, weights and boiling temperatures; so, the first step is to separate these components. Because they have different boiling temperatures, they can be separated easily by a process called **fractional distillation**. The steps of fractional distillation are as follows:

Photo courtesy Phillips Petroleum

Distillation columns in an oil refinery

1. You **heat** the mixture of two or more substances (liquids) with different boiling points to a high temperature. Heating is usually done with high pressure steam to temperatures of about 1112 degrees Fahrenheit / 600 degrees Celsius.
2. The mixture **boils**, forming vapor (gases); most substances go into the vapor phase.
3. The **vapor** enters the bottom of a long column (**fractional distillation column**) that is filled with trays or plates.
    - The trays have many holes or bubble caps (like a loosened cap on a soda bottle) in them to allow the vapor to pass through.
    - The trays increase the contact time between the vapor and the liquids in the column.
    - The trays help to collect liquids that form at various heights in the column.
    - There is a temperature difference across the column (hot at the bottom, cool at the top).
4. The **vapor rises** in the column.
5. As the vapor rises through the trays in the column, it **cools**.
6. When a substance in the vapor reaches a height where the temperature of the column is equal to that substance's boiling point, it will **condense** to form a liquid. (The substance with the lowest boiling point will condense at the highest point in the column; substances with higher boiling points will condense lower in the column.).
7. The trays **collect** the various liquid fractions.
8. The collected liquid fractions may:
    - pass to condensers, which cool them further, and then go to storage tanks
    - go to other areas for further chemical processing

Fractional distillation is useful for separating a mixture of substances with narrow differences in boiling points, and is the most important step in the refining process.

Very few of the components come out of the fractional distillation column ready for market. Many of them must be chemically processed to make other fractions. For example, only 40% of distilled crude oil is gasoline; however, gasoline is one of the major products made by oil companies. Rather than continually distilling large quantities of crude oil, oil companies chemically process some other fractions from the distillation column to make gasoline; this processing increases the yield of gasoline from each barrel of crude oil.