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To Study The process of crude oil refining and Ways To Improve Octane Number: A Review

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Abstract : Once crude oil is extracted from the ground, it must be transported and refined into petroleum products that have any value. Those products must then be transported to end-use consumers or retailers (like gasoline stations or the company that delivers heating oil to your house, if you have an oil furnace). The overall well-to-consumer supply chain for petroleum products is often described as being segmented into three components .

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Upstream activities involve exploring for crude oil deposits and the production of crude oil. Examples of firms that would belong in the upstream segment of the industry include companies that own rights to drill for oil (e.g., ExxonMobil) and companies that provide support services to the drilling segment of the industry (e.g. Halliburton).

Midstream activities involve the distribution of crude oil to refiners; the refining of crude oil into saleable products; and the distribution of products to wholesalers and retailers. Examples of firms that would belong in the midstream segment of the industry include companies that transport oil by pipeline, truck or barge (e.g., Magellan Pipeline); and companies that refine crude oil (e.g., Tesoro).

Downstream activities involve the retail sale of petroleum products. Gasoline stations are perhaps the most visible downstream companies, but companies that deliver heating oil or propane would also fall into this category.

Distillation

We will start with the first step in all refineries: distillation. Essentially, distillation is a process that heats the crude oil and separates it into fractions. It is the most important process of a refinery. Crude oil is heated, vaporized, fed into a column that has plates in it, and the materials are separated based on boiling point. Figure 2.2 shows the first stage of the refinery. It indicates that as the liquids are separated, the top end materials are gases and lighter liquids, but as you go down the column, the products have a higher boiling point, the molecular size gets bigger, the flow of the materials gets thicker (i.e., increasing viscosity), and the sulfur (S) content typically stays with the heavier materials. Notice we are not using the chemical names, but the common mixture of chemicals. Gasoline represents the carbon range of ~ C5-C8, naptha/kerosene (aka jet fuel) C8-C12, diesel C10-C15, etc. As we discuss the refinery, we will also discuss important properties of each fuel.

The most important product in the refinery is gasoline. Consumer demand requires that 45-50 barrels per 100 barrels of crude oil processed are gasoline. The issues for consumers are, then: 1) quality suitability of gasoline and 2) quantity suitability. The engine that was developed to use gasoline is known as the Otto engine. It contains a four-stroke piston (and engines typically have 4-8 pistons). The first stroke is the intake stroke - a valve opens, allows a certain amount of gasoline and air, and the piston moves down. The second stroke is the compression stroke - the piston moves up and valves close, so that the gasoline and air that came in the piston during the first stroke are compressed. The third stroke happens because the spark plug ignites the gasoline/air mixture, pushing the piston down. The fourth stroke is the exhaust stroke, where the exhaust valve opens and the piston moves back up.

Petroleum refineries are large-scale industrial complexes that produce saleable petroleum products from crude oil (and sometimes other feedstocks like biomass). The details of refinery operations differ from location to location, but virtually all refineries share two basic processes for separating crude oil into the various product components. Actual refinery operations are very complicated. The link below will take you to a 10-minute long video that provides more details on the various refining processes.

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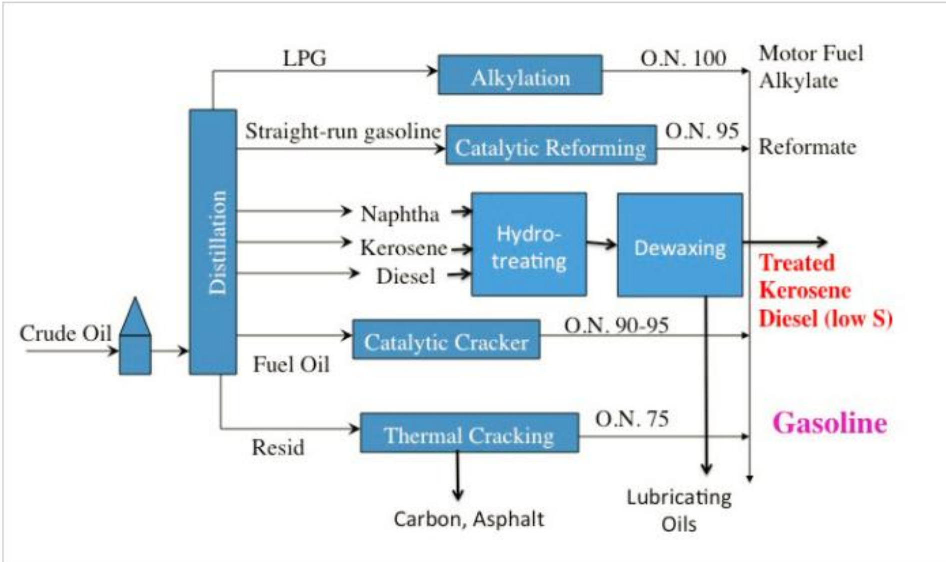
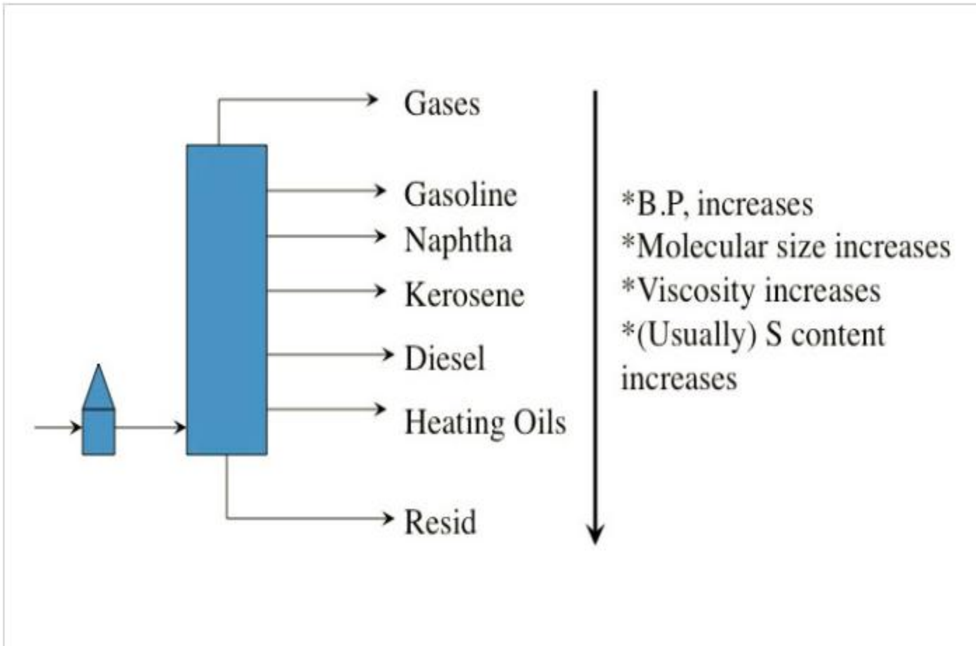


The first process is known as distillation. In this process, crude oil is heated and fed into a distillation column. A schematic of the distillation column is shown in Figure 2.2. As the temperature of the crude oil in the distillation column rises, the crude oil separates itself into different components, called "fractions." The fractions are then captured separately. Each fraction corresponds to a different type of petroleum product, depending on the temperature at which that fraction boils off the crude oil mixture.



The second process is known as cracking and reforming. Figure 2.3 provides a simplified view of how these processes are used on the various fractions produced through distillation. The heaviest fractions, including the gasoils and residual oils, are lower in value than some of the lighter fractions, so refiners go through a process called “cracking” to break apart the molecules in these fractions. This process can produce some higher-value products from heavier fractions. Cracking is most often utilized to produce gasoline and jet fuel from heavy gasoils. Reforming is typically utilized on lower-value light fractions, again to produce more gasoline. The reforming process involves inducing chemical reactions under pressure to change the composition of the hydrocarbon chain.

Ways To Improve Octane Number:

Thermal cracking

One way to improve gasoline yield is to break the bigger molecules into smaller molecules - molecules that boil in the gasoline range. One way to do this is with "thermal cracking." Carbon Petroleum Dubbs was one of the inventors of a successful thermal cracking process. The process produces more gasoline, but the ON was still only ~70-73, so the quality was not adequate.

Catalytic cracking

Eugene Houdry developed another process; in the late 1930s, he discovered that thermal cracking performed in the presence of clay minerals would increase the reaction rate (i.e., make it faster) and produce molecules that had a higher ON, ~100. The clay does not become part of the gasoline - it just provides an active surface for cracking and changing the shape of molecules. The clay is known as a "catalyst," which is a substance that changes the course of a chemical reaction without being consumed. This process is called "catalytic cracking" (see Figure 2.4). Figure 2.4 shows the reactants and products for reducing the hexadecane molecule using both reactions. Catalytic cracking is the second most important process of a refinery, next to distillation. This process enables production of ~45% gasoline with higher ON.

Alkylation

The alkylation process takes the small molecules produced during distillation and cracking and adds them to medium sized molecules. They are typically added in a branched way in order to boost

Catalytic Reforming

A molecule may be of the correct number of carbon atoms, but need a configuration that will either boost ON or make another product. The example in Figure 2.8 shows how reforming n-octane can produce 3,4-dimethylhexane.

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