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Petroleum Refining:

Distillation

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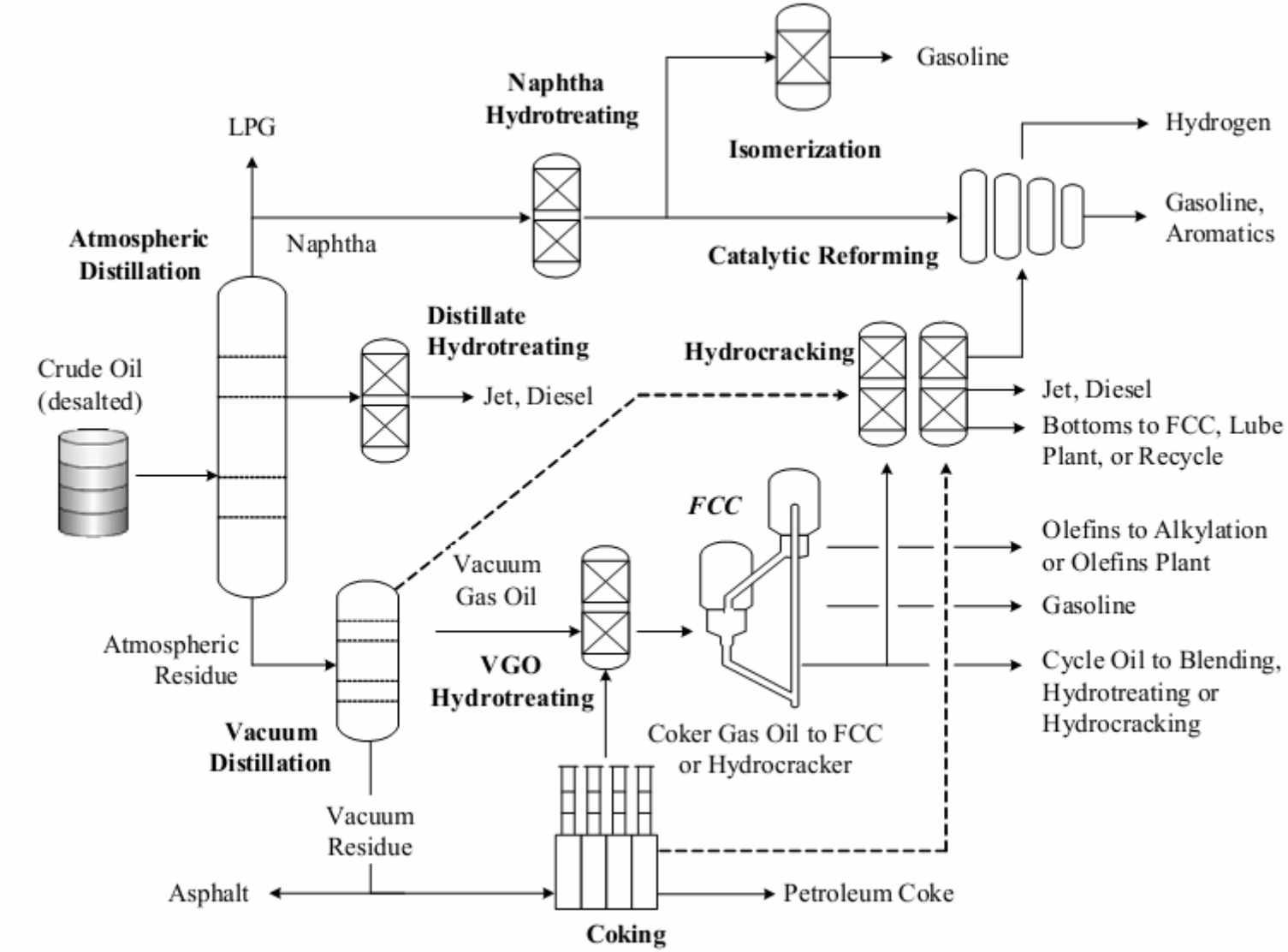
Typical layout for an oil refinery



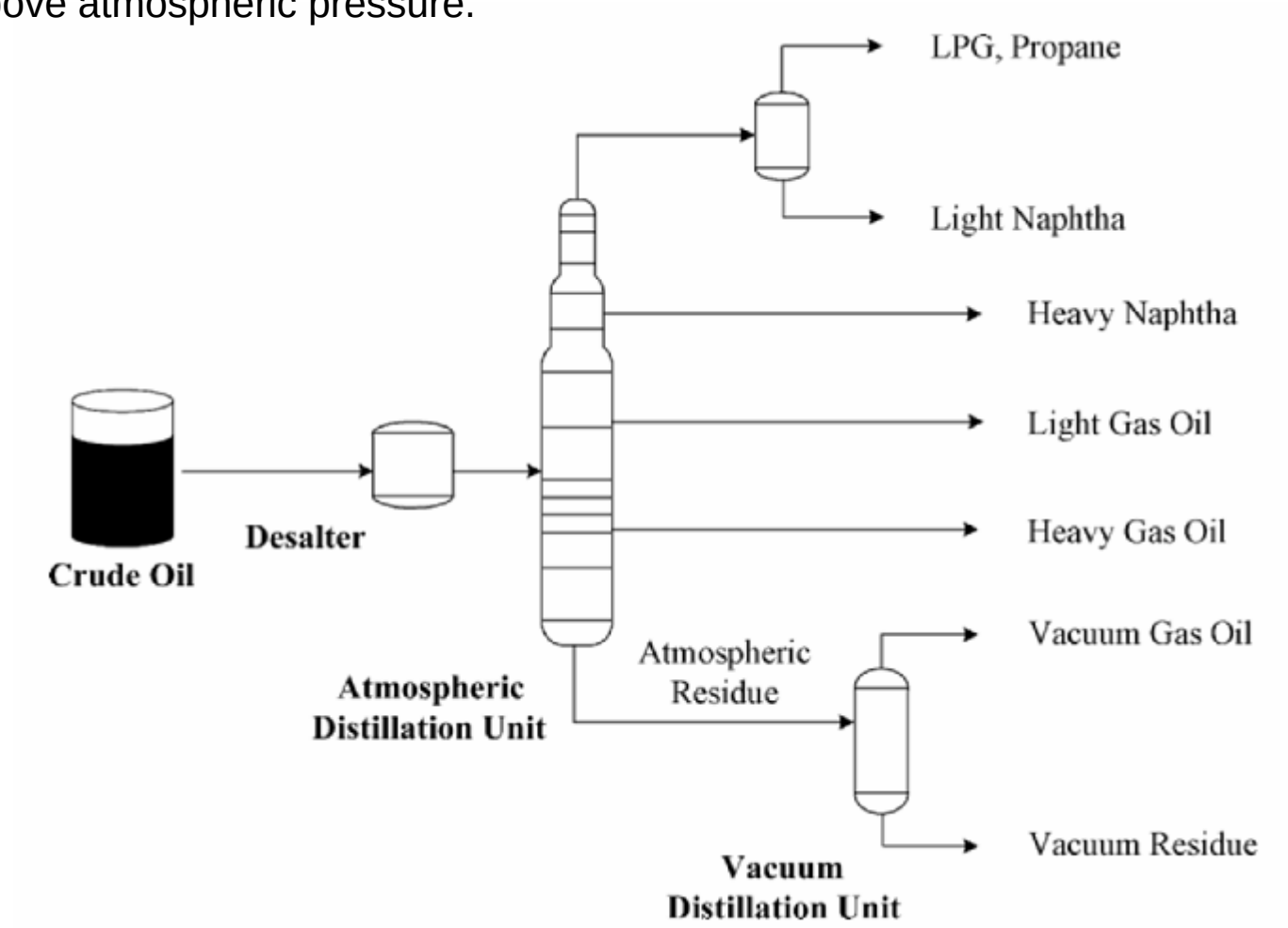
Seven Basic Operations in Petroleum Processing

Separation	**Combination**
• Distillation	• Catalytic polymerization
• Solvent refining	• Alkylation
Conversion	**Treating, finishing, blending**
• Carbon removal	• Gasoline, kerosene and diesel
• Hydrogen addition	• Lubes and waxes
Reforming	• Asphalt
• Catalytic reforming	**Protecting the Environment**
• Steam/hydrocarbon reforming	• Waste water treatment
Rearrangement	• Disposal of solids
• Isomerization	• Sulfur recovery

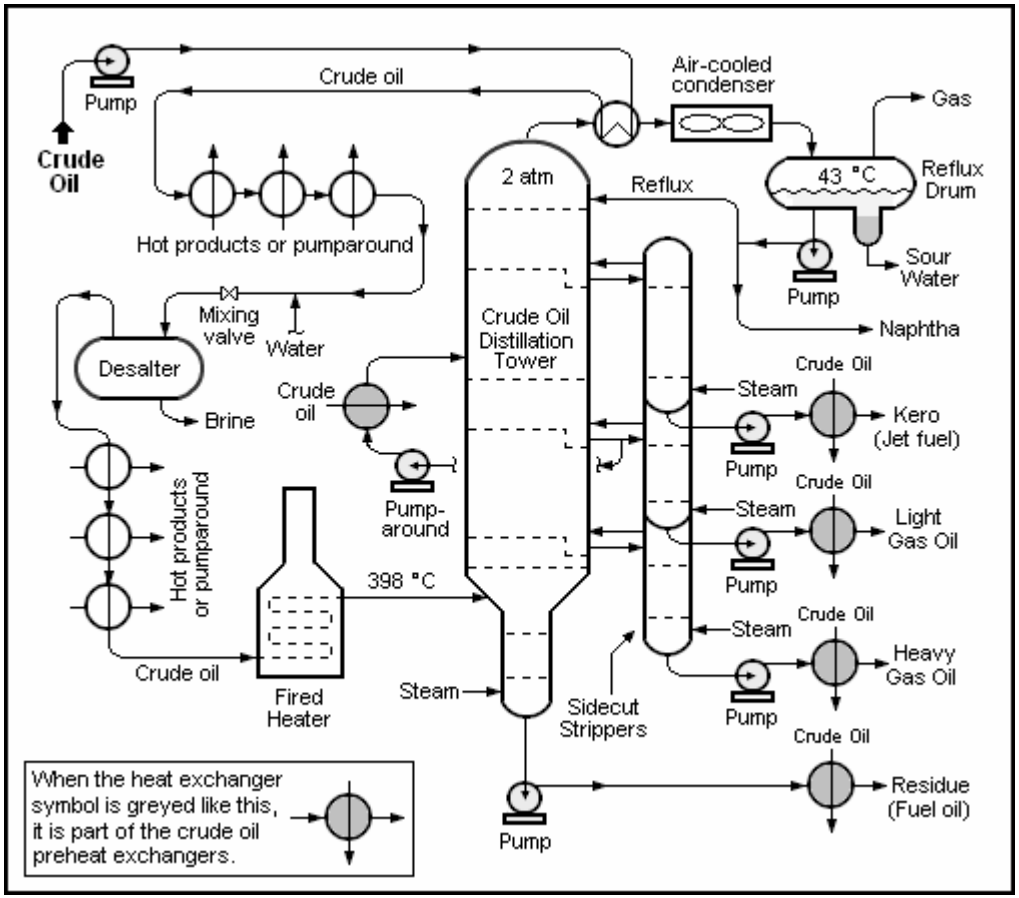
Crude oil distillation unit

The crude oil distillation unit (CDU) is the first processing unit in virtually all petroleum refineries.

The CDU distills the incoming crude oil into various fractions of different boiling ranges, each of which are then processed further in the other refinery processing units.
The CDU is often referred to as the *atmospheric distillation unit* because it operates at slightly above atmospheric pressure.



Schematic flow diagram of a typical crude oil distillation unit as used in petroleum crude oil refineries.



The overhead distillate fraction from the distillation column is naphtha.
The fractions removed from the side of the distillation column at various points between the column top and bottom are called *sidecuts*.

Each of the sidecuts (i.e., the kerosene, light gas oil and heavy gas oil) is cooled by exchanging heat with the incoming crude oil.

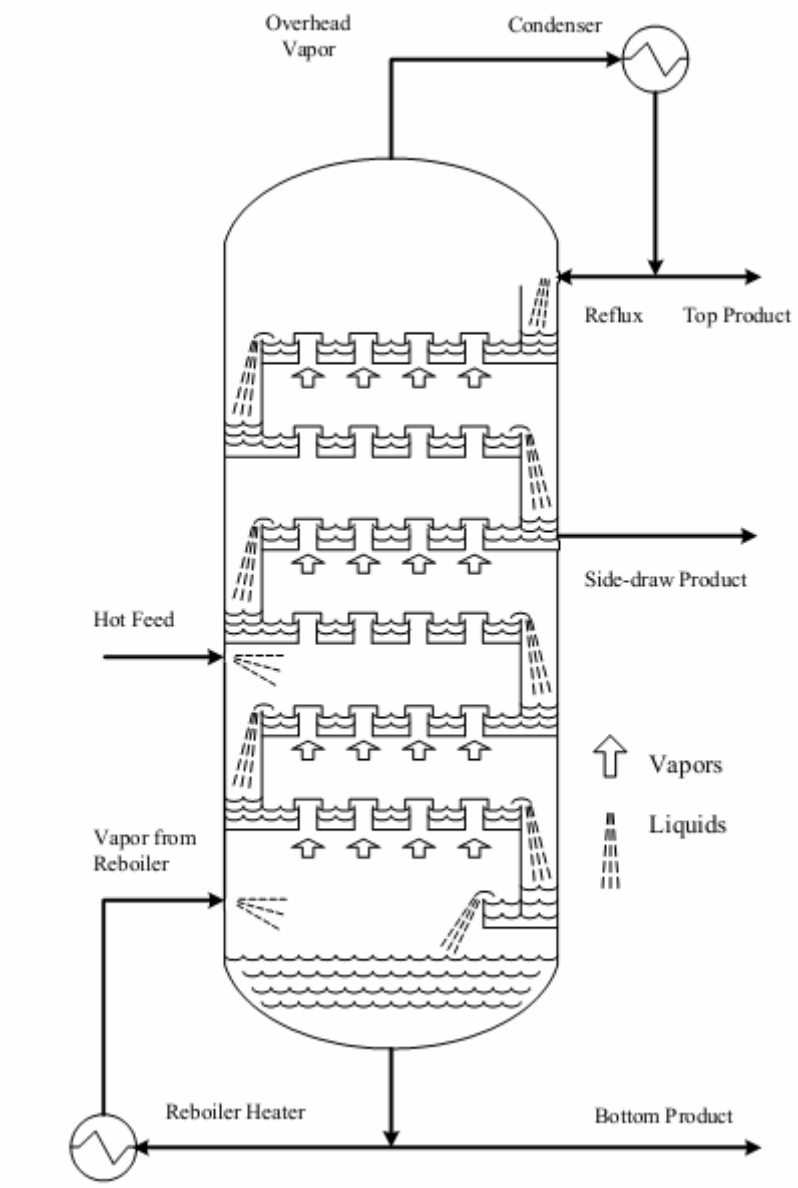
After leaving the tower, all of the fractions (i.e., the overhead naphtha, the sidecuts and the bottom residue) / product streams
go to holding, intermediate storage tanks or directly to downstream process units.

The incoming crude oil is preheated by exchanging heat with some of the hot, distilled fractions and other streams. It is then desalted to remove inorganic salts (primarily sodium chloride).
Following the desalter, the crude oil is further heated by exchanging heat with some of the hot, distilled fractions and other streams. It is then heated in a fuel-fired furnace to a temperature of about 398 °C and routed into the bottom of the distillation unit.
The cooling and condensing of the distillation tower overhead is provided partially by exchanging heat with the incoming crude oil and partially by either an air-cooled or water-cooled condenser. Additional heat is removed from the distillation column by a pumparound system.

Destinations for Straight-Run Distillates

Fraction	Approx. Boiling Range °C	°F	Next Destination	Ultimate Product(s)
LPG	-40 to 0	-40 to 31	Sweetener	Propane fuel
Light Naphtha	39 - 85	80 - 185	Hydrotreater	Gasoline
Heavy Naphtha	85 - 200	185 - 390	Cat. Reformer	Gasoline, aromatics
Kerosene	170 - 270	340 - 515	Hydrotreater	Jet fuel, No. 1 diesel
Gas Oil	180 - 340	350 - 650	Hydrotreater	Heating Oil, No. 2 diesel
Vacuum Gas Oil	340 - 566	650 - 1050	FCC	Gasoline, LCO, gases
			Hydrotreater	Fuel oil, FCC feed
			Lube Plant	Lube basestock
			Hydrocracker	Gasoline, jet, diesel, FCC feed, lube basestock
Vacuum Residue	>540	>1000	Coker	Coke, coker gas oil
			Visbreaker	Visbreaker gas oil, resid
			Asphalt Unit	Deasphalted oil, asphalt
			Hydrotreater	FCC feed

Distillation column with bubble-cap trays



Modern crude distillation towers can process 200,000 barrels of oil per day. They can be up to 150 feet (50 meters) tall and **contain 20 to 40 fractionation trays spaced at regular intervals**. In some towers, the trays in the top section are replaced with structured packing.
Before reaching the tower, **desalted oil goes through a network of pre-heat exchangers to a fired heater**, which brings the temperature up to about **350 °C**.
If the oil gets much hotter that this, it starts to crack and deposit carbon inside the pipes and equipment through which it flows.

The hot crude enters the distillation tower just above the bottom.
Steam is added to enhance separation; it does so largely by decreasing vapor pressure in the column.
When hot oil enters the tower, most of it vaporizes.
Unvaporized heavy fuel oil and/or asphalt residue drops to the bottom of the tower, where it is drawn off. The vapors rise through the distillation trays, which contain perforations and bubble caps.
Each tray permits vapors from below to bubble through the cooler, condensed liquid on top of the tray.
This provides excellent vapor/liquid contacting.
Condensed liquid flows down through a pipe to the hotter tray below, where the higher temperature causes re-evaporation.
A given molecule evaporates and condenses many times before finally leaving the tower.

Products are collected from the top, bottom and side of the column.
Side-draw products are taken from trays at which the temperature corresponds to the cutpoint for a desired product.
In modern towers, a portion of each side-draw stream is returned to the tower to control tray temperatures and further enhance separation.
Part of the top product is also returned; this “reflux” flow plays a major role in controlling temperature at the top of the tower.

Vacuum Distillation

The residue from an atmospheric distillation tower can be sent to a vacuum distillation tower, which recovers additional liquid at 4.8 to 10.3 kPa.

The vacuum, which is created by a vacuum pump or steam ejector, is pulled from the top of the tower.

Relative to atmospheric columns, vacuum columns have larger diameters and their internals are simpler. Often, instead of trays, random packing and demister pads are used.

The overhead stream – **light vacuum gas oil** – can be used as a lube base stock, heavy fuel oil, or as feed to a conversion unit.
Heavy vacuum gas oil is pulled from a side draw.
The **vacuum residue** can be use to make asphalt, or it can be sent to a coker or visbreaker unit for further processing.