Distillation Application in Petroleum
Distillation

Distillation separates chemicals by the difference in how easily they vaporize. The two major types of classical distillation include continuous distillation and batch distillation. Continuous distillation, as the name says, continuously takes a feed and separates it into two or more products. Batch distillation takes on lot (or batch) at a time of feed and splits it into products by selectively removing the more volatile fractions over time.
Other ways to categorize distillation are by the equipment type (trays, packing), process configuration (distillation, absorption, stripping, azeotropich, extractive, complex), or process type (refining, petrochemical, chemical, gas treating).
Many industries use distillation for critical separations in making useful products. These industries include petroleum refining, beverages, chemical processing, petrochemicals, and natural gas processing.
Distillation Categories

System composition

System refers to the chemical components present in the mixture being distilled. The two main groups are binary distillation and multicomponent distillation.
Binary distillation is a separation of only two chemicals. A good example is separating ethyl alcohol (ethanol) from water. Most of the basic distillation teaching and a lot of theoretical work starts with looking at binary distillation; it's a lot simpler.

Multicomponent distillation is the separation of a mixture of chemicals. A good example is petroleum refining. Crude oil is a very complex mixture of hydrocarbons with literally thousands of different molecules. Nearly all commercial distillation is multicomponent distillation. The theory and practice of multicomponent distillation can be very complex.
Processing Mode

► Processing mode refers to the way in which feed and product are introduced and withdrawn from the process. Distillation occurs in two modes, continuous distillation and batch distillation.

► Continuous distillation is feed is sent to the still all the time and product is drawn out at the same time. The idea in continuous distillation is that the amount going into the still and the amount leaving the still should always equal each other at any given point in time.
Batch distillation is when the amount going into the still and the amount going out of the still is not supposed to be the same all the time. The easiest example to use is like old fashioned spirit making. The distiller fills a container at the start, then heats it, as time goes by the vapors are condensed to make the alcoholic drink. When the proper quantity of overhead (drink) is made, the distiller stops the still and empties it out ready for a new batch. This is only a simple case, in industrial usage what goes on gets very complex.
Processing Sequence

- Fractionation systems have different objectives. The major processing objectives set the system type and the equipment configuration needed. The common objectives include removing a light component from a heavy product, removing a heavy component from a light product, making two products, or making more than two products. We will call these major categories are called stripping, rectification, fractionation, and complex fractionation.
- Stripping systems remove light material from a heavy product.
- Rectification systems remove heavy material from a light product.
- Fractionation systems remove a light material from a heavy product and a heavy material from a light product at the same time.
Complex fractionation makes multiple products from either a single tower or a complex of towers combined with recycle streams between them. A good example of a multiple product tower is a refinery crude distillation tower making rough cuts of naphtha (gasoline), kerosene (jet fuel), and diesel from the same tower. A good example of a complex tower with internal recycle streams is a Petlyck (baffle) tower making three on-specifications products from the same tower.
System Type

- The behavior of the chemicals in the system also determines the system configuration for the objectives. The three major problems that limit distillation processes are close-boilers, distributed keys, and azeotropes.
Close boiler systems include chemicals that boil at temperatures very close to each other. So many stages of distillation or so much reflux may be required that the chemicals cannot be separated economically. A good example is separation of nitro-chloro-benzenes. Up to 600 theoretical separation stages with high reflux may be required to separate different isomers.

Distributed keys are systems where some chemicals that we do not want in either the heavy or the light product boil at a temperature between the heavy and the light product.
Azeotropic systems are those where the vapor and the liquid reach the same composition at some point in the distillation. No further separation can occur. Ethanol-water is a perfect example. Once ethanol composition reaches 95% (at atmospheric pressure), no further ethanol purification is possible.
Reaction

Reactive distillation uses a reaction in the distillation equipment to help the separation. The reaction may or may not use a catalyst. DMT manufacture uses reactive distillation without a catalyst. One process to make methy-tert-butyl-ether uses a catalyst inside the distillation tower. The reaction changes the composition, allowing the distillation to work better.
**Equipment Type**

- Distillation equipment includes two major categories, trays and packing.
- Trays force a rising vapor to bubble through a pool of descending liquid.
- Packing creates a surface for liquid to spread on. The thin liquid film has a high surface area for mass-transfer between the liquid and vapor.
PETROLEUM

Petroleum is a complex mixture of organic liquids called crude oil and natural gas, which occurs naturally in the ground and was formed millions of years ago. Crude oil and natural gas are of little use in their raw state; their value lies in what is created from them: fuels, lubricating oils, waxes, asphalt, petrochemicals and pipeline quality natural gas.
Oil was formed from the remains of animals and plants that lived millions of years ago in a marine (water) environment before the dinosaurs. Over the years, the remains were covered by layers of mud. Heat and pressure from these layers helped the remains turn into what we today call crude oil. The word "petroleum" means "rock oil" or "oil from the earth."
Tiny sea plants and animals died and were buried on the ocean floor. Over time, they were covered by layers of silt and sand.

Over millions of years, the remains were buried deeper and deeper. The enormous heat and pressure turned them into oil and gas.

Today, we drill down through layers of sand, silt, and rock to reach the rock formations that contain oil and gas deposits.
Where We Get Oil?

The world's top five crude oil-producing countries are:

- Saudi Arabia
- Russia
- United States
- Iran
- China
Petroleum Hydrocarbon Structures

- Paraffins
- Hydrocarbons
- Naphthenes
Oil Refining Production Process

- Desalting and Dewatering
- Distillation
- Reforming
- Cracking
- Alkylation
- Isomerisation
- Polymerisation
- Hydrotreating
Petroleum Flow Chart from the Well through the Refinery

(Courtesy of Humble Oil & Refining Co., Esso Standard, Eastern Region.)
Desalting and Dewatering

► Crude oil is recovered from the reservoir mixed with a variety of substances: gases water and dirt (minerals). Desalting is a water – washing operation performed at the production field and at the refinery site for additional crude oil cleanup. If the petroleum from the separators contains water and dirt, water washing can remove much of the water – soluble minerals and entrained solids. If these crude oil contaminants are not removed, they can cause operating problems during refinery processing, such as equipment plugging and corrosion as well as catalyst deactivation.
Distillation

- The first and the most fundamental step in the refining process (after the crude oil has been cleaned and any remnants of brine removed) is distillation, which is often referred to as the primary refining process. Distillation involves the separation of the different hydrocarbon compounds that occur naturally in a crude oil into a number of different fractions (a fraction is often referred to as a cut). In the atmospheric distillation process (Fig.), heated crude oil is separated in a distillation column (distillation tower, fractionating tower, atmospheric pipe still) into streams that are then purified, transformed, adapted, and treated in a number of subsequent refining processes, into products for the refinery’s market. The lighter, more volatile, products separate out higher up the column, whereas the heavier, less volatile, products settle out toward the bottom of the distillation column. The fractions produced in this manner are known as straight run fractions ranging from (atmospheric tower) gas, gasoline, and naphtha, to kerosene, gas oils, and light diesel, and to (vacuum tower) lubricating oil and residuum.
The feed to a distillation tower is heated by flow through pipes arranged within a large furnace. The heating unit is known as a pipe still heater or pipe still furnace, and the heating unit and the fractional distillation tower make up the essential parts of a distillation unit or pipe still. The pipe still furnace heats the feed to a predetermined temperature—usually a temperature at which a predetermined portion of the feed will change into vapor. The vapor is held under pressure in the pipe in the furnace until it discharges as a foaming stream into the fractional distillation tower. Here the unvaporized or liquid portion of the feed descends to the bottom of the tower to be pumped away as a bottom nonvolatile product, whereas the vapors pass up the tower to be fractionated into gas oils, kerosene, and naphtha.
Reforming is a process which uses heat, pressure and a catalyst (usually containing platinum) to bring about chemical reactions which upgrade naphthas into high octane petrol and petrochemical feedstock.
Cracking processes break down heavier hydrocarbon molecules (high boiling point oils) into lighter products such as petrol and diesel. These processes include:

1. catalytic cracking
2. thermal cracking
3. hydrocracking
Alkylation

Alkylation refers to the chemical bonding of these light molecules with isobutane to form larger branched-chain molecules (isoparaffins) that make high octane petrol.
Isomerisation

Isomerisation refers to chemical rearrangement of straight-chain hydrocarbons (paraffins), so that they contain branches attached to the main chain (isoparaffins).
Polymerisation

- Under pressure and temperature, over an acidic catalyst, light unsaturated hydrocarbon molecules react and combine with each other to form larger hydrocarbon molecules. Such process can be used to react butenes (olefin molecules with four carbon atoms) with iso-butane (branched paraffin molecules, or isoparaffins, with four carbon atoms) to obtain a high octane olefinic petrol blending component called polymer gasoline.
Hydrotreating

- Hydrotreating is one way of removing many of the contaminants from many of the intermediate or final products. In the hydrotreating process, the entering feedstock is mixed with hydrogen and heated to 300 - 380°C. The oil combined with the hydrogen then enters a reactor loaded with a catalyst which promotes several reactions: hydrogen combines with sulphur to form hydrogen sulphide (H2S).
Petroleum Products

- Aviation Gasoline
- Gas Diesel Oil/(Distillate Fuel Oil)
- Heavy Fuel Oil Residual
- Kerosene
- Jet Fuel
- LPG
- Motor Gasoline
- Naphtha
- Petroleum Coke
- Refinery Gas
Products Made From Oil

- Ink
- Toys
- Dolls
- Tires
- Tents
- Shoes
- Glue
- Skis
- Dyes
- Cameras
- Combs
- Di
- Ice
- Mops
- Purses
- Dresses
- Pajamas
- Pillows
- Candles
- Boats
- Crayons
- Caulking
- Balloons
- Curtains
- Milk jugs
- Putty
- Tool racks
- Slacks
- Yarn
- Roofing
- Luggage
- Fan belts
- Carpeting
- Lipstick
- Aspirin
- Dishwashing liquids
- Unbreakable dishes
- Car sound insulation
- Motorcycle helmets
- Refrigerator linings
- Electrician's tape
- Roller-skate wheels
- Permanent press clothes
- Soft contact lenses
- Food preservatives
- Transparent tape
- Disposable diapers
- Sports car bodies
- Electric blankets
- Car battery cases
- Synthetic rubber
- Vitamin capsules
- Rubbing alcohol
- Ice cube trays
- Insect repellent
- Roofing shingles
- Shower curtains
- Plywood adhesive
- Beach umbrellas
- Faucet washers
- Antihistamines
- Drinking cups
- Petroleum jelly
- Tennis rackets
- Wire insulation
- Ballpoint pens
- Artificial turf
- Artificial limbs
- Shaving cream
Paint brushes  Telephones  Insecticides  Antiseptics  Fishing lures  Deodorant  Linoleum  Sweaters  Paint rollers  Floor wax  Plastic  wood  Model cars  Trash bags  Soap  dishes  Hand lotion  Clothesline  Shampoo  Panty  hose  Fishing rods  Oil filters  Anesthetics  Upholstery  TV cabinets  Cassettes  Salad bowls  House paint  Awnings  Ammonia  Safety glass  Hair curlers  VCR tapes  Eyeglasses  Movie film  Ice chests  Speakers  Ice buckets  Credit cards  Fertilizers  Water pipes  Toilet seats  Fishing boots  Life jackets  Garden hose  Golf balls  Umbrellas  Detergents  Rubber cement  Sun glasses  Cold cream  Bandages  Hair coloring  Nail polish  Guitar strings  False teeth  Toothpaste  Golf bags  Toothbrushes  Perfume  Folding doors  Shoe polish  Shower doors  Cortisone  Heart valves  LP records  Hearing aids  Vaporizers  Wading pools  Parachutes
Oil and The Environment

- Air
- Water
- Land
Air

Preserving air quality around a refinery involves controlling the following emissions:

- sulphur oxides
- hydrocarbon vapours
- smoke
- smells
Water

The majority of the water discharged from the refinery has been used for cooling the various process streams. The cooling water does not actually come into contact with the process material and so has very little contamination.
Rainwater falling on the refinery site must be treated before discharge to ensure no oily material washed off process equipment leaves the refinery.

Process water has actually come into contact with the process streams and so can contain significant contamination.
Land

- The refinery safeguards the land environment by ensuring the appropriate disposal of all wastes.
- Within the refinery, all hydrocarbon wastes are recycled through the refinery slops system. This system consists of a network of collection pipes and a series of dewatering tanks. The recovered hydrocarbon is reprocessed through the distillation units.