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Distillation of alcohol fuels

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Quick Facts

- Distillation separates mixtures on the basis of different boiling points.
- The main types of distillation systems are batch distillation, batch rectification and continuous distillation.
- Many types of vapor-liquid contacting devices are available for distillation; sieve plates or packing may be the best choices.
- Protein deposits within distillation columns must be removed from time to time.
- A number of alternatives to azeotropic distillation for final dehydration of 95 percent alcohol are under development.
- This is the fourth in a series of five information sheets on alcohol fuels; other sheets discuss the basics of alcohol fuel production, raw materials for alcohol fuels, use of alcohol fuel by-products, and the economics of alcohol fuel production.

Distillation is the process that separates a mixture of compounds on the basis of different boiling points among the compounds. Vapors coming off a boiling liquid mixture will have a higher concentration of the more volatile component than the original solution. Alcohol is more volatile than water and can be separated in this manner. However, it is impossible to get a complete separation in one-stage vaporization. The three main types of distillation system are batch (pot) distillation, batch rectification and continuous distillation. These three types are shown schematically in Figure 1.

Batch Distillation

In a batch distillation system, an alcohol-water mixture is boiled in a closed pot, the vapors driven off are condensed in a heat exchange unit and the condensed liquid is collected. The disadvantages of this technique are that a single distillation step will produce only a low-proof product and double or triple distilling consumes a great deal of energy. Furthermore, each distillation results in some loss of alcohol in the pot.

Batch Rectification

The batch rectifier permits a higher-proof product. Vapors from a boiling mixture pass through a series of plates (trays) in a rectifying column. Each tray becomes a small boiling vessel that produces a higher-proof vapor. The enriched vapors are condensed at the top of the column. Since this is a batch operation, conditions are changing continuously with time and careful operation is required to attain the potential alcohol concentrations.

Continuous Distillation

The most efficient type of distillation is the continuous stripped-rectifier method in which a vertical column containing 40 or more plates (or trays) is used. The near boiling alcohol-water mixture is fed continuously near the center of the column. Above the feed point, the vapors become enriched in alcohol — up to 95 percent alcohol (190 proof) — at the top of the column. This is the maximum alcohol concentration possible under ordinary distillation conditions. A portion of the alcohol-rich stream at the top must be condensed and returned to the column. Below the feed point, the alcohol content decreases until little or no alcohol remains.

Plate Types and Column Dimensions

Three major types of plates or trays may be used for vapor-liquid contact in batch or continuous distillation. The most common is the so-called sieve tray or perforated plate. This is a tray that directs liquid across its surfaces where vapors rising from the tray below pass through the perforations and bubble through the down-flowing liquid layer. Another type of tray is the bubble-cap tray where the vapor is forced to bubble out under the liquid by inverted caps submerged in the liquid. This type of tray should not be used when the feed contains large solids. The third vapor-liquid contacting device is the packed column that uses a variety of packing materials in many shapes. Here there are no distinct fractionating stages but rather a height of packing equivalent to a stage.

The alcohol-water mixture contains considerable protein that tends to accumulate on the column internals. The sieve trays and packings are relatively easy to remove and clean; the bubble cap trays are not. Alternatively, the column internals may be cleaned by pumping hot caustic through the column.

The height of a distillation column is determined by the number of stages, which, in turn, is determined by the alcohol concentration desired. For a 40-plate column to produce 95 percent ethanol, normally a 30- to 40-foot (9- to 12-meter) column would be used. One large column can be split into two smaller columns if necessary by using ap-

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propriate piping to move gas and liquid between the columns. Column diameter is determined by the alcohol production rate desired. A 1-foot (.3-m) diameter column will produce 20 to 25 gallons (76 to 95 liters) per hour, a 6-inch (15-centimeter) column will produce one-fourth this amount or 5 to 6 gallons (19 to 23 liters) per hour, and a 2-foot (.6-m) column will produce four times this amount or 80 to 100 gallons (303 to 379 liters) per hour.

Column Operation

The alcohol-water feed to the distillation column (the beer) should be preheated by the hot stillage from the bottom of the column. Stillage is acidic and hot, so it may be wise to use copper or stainless steel to minimize corrosion. All equipment that contacts the stillage must be accessible for cleaning because of the problems with protein buildup noted earlier. Introducing live steam into the bottom of the beer column rather than condensing steam in an indirect heat exchanger in the base of the column is a common practice. This improves heat transfer efficiency and eliminates heating coils and their associated scale but does increase the total volume of water in the stillage. All equipment and lines that are at high temperatures should be insulated for safety and to conserve energy, especially in smaller alcohol plants.

Azeotropic Distillation and Alternatives

Removing the final 5 percent of water from 95 percent alcohol usually is accomplished by special techniques known as azeotropic distillation in which a third organic compound (benzene, cyclohexane, pentane, etc.) is added to the 95 percent alcohol-water mixture. This mixture then is distilled in a separate column with the alcohol exiting at the bottom of the column. A three-component mixture exits the top, requiring further separation and purification. Other alcohol dehydration techniques are being developed but currently are not in commercial use. Some of these techniques are described briefly below.

Vacuum distillation offers the potential of producing nearly anhydrous alcohol in the distillation column. Energy requirements and cost impacts are not yet completely determined. Molecular sieves to separate alcohol from water are being used in several plants and the results should be available soon. This technique has good potential for economical use in both small- and large-sized plants. Several solvent extraction techniques for alcohol dehydration also are under development using such solvents as gasoline or carbon dioxide at its critical pressure. Such drying agents as silica gel, starch and even corn stalks appear also to offer some potential in alcohol dehydration. One technique that bypasses the dehydration step involves converting ethanol into valuable ethylene gas via certain acid catalysts. The ethylene gas bubbles off from the mixture in a purified form that is easily salable. The ethylene is no longer a liquid fuel but has many important uses in the petrochemical industry. Other such alcohol dehydration techniques as ion-exchange and crystallization extractions also are currently under development.

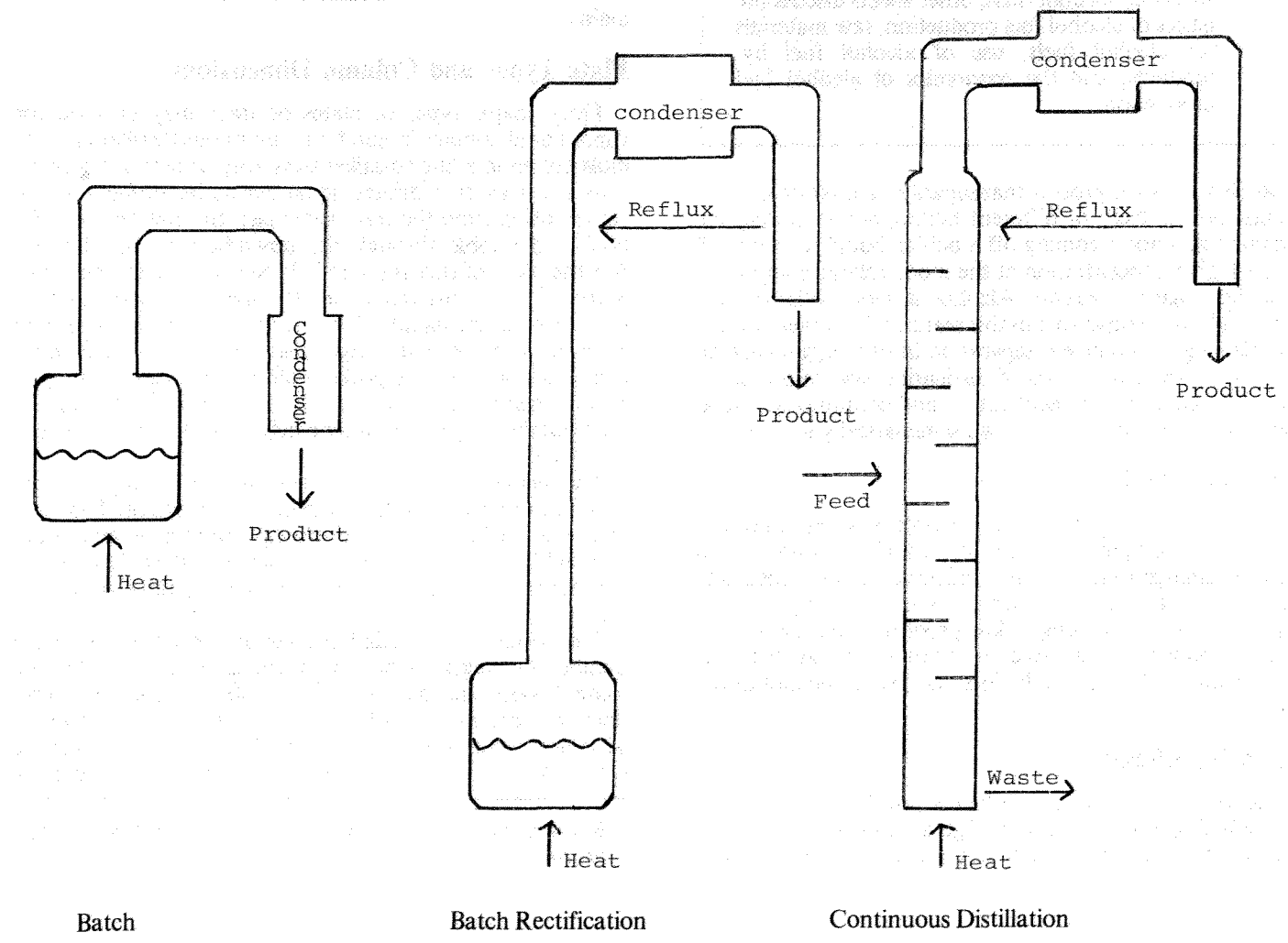

Figure 1: Types of distillation systems.