Vapor Recompression: Distillation without Steam

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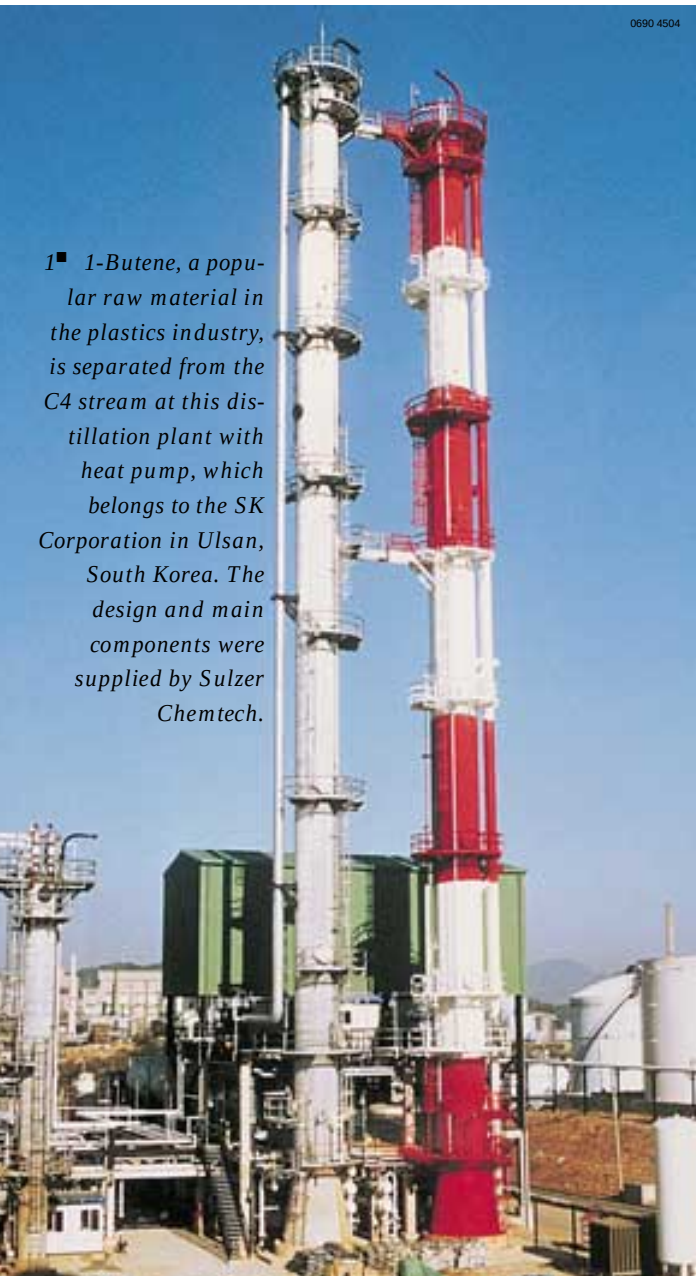
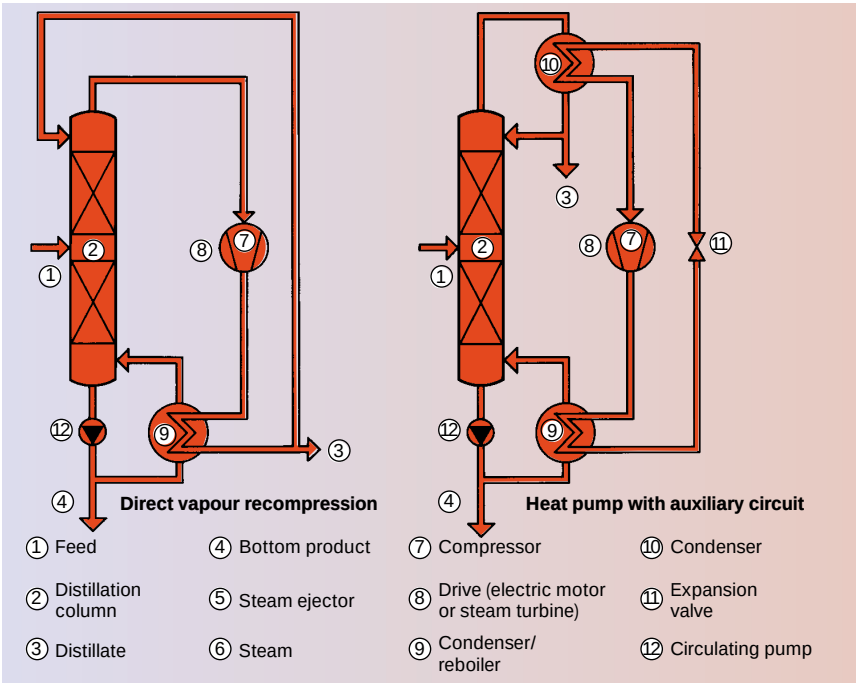
Distillation is not only the most frequently employed separation technique in the chemical and petrochemical industry, distillation plants are also the largest consumers of energy in many installations. This large consumption of energy is not necessary. Heat pumps "recycle" a major part of the energy input and thus spare the environment and the purse.



1■ *1-Butene, a popular raw material in the plastics industry, is separated from the C4 stream at this distillation plant with heat pump, which belongs to the SK Corporation in Ulsan, South Korea. The design and main components were supplied by Sulzer Chemtech.*

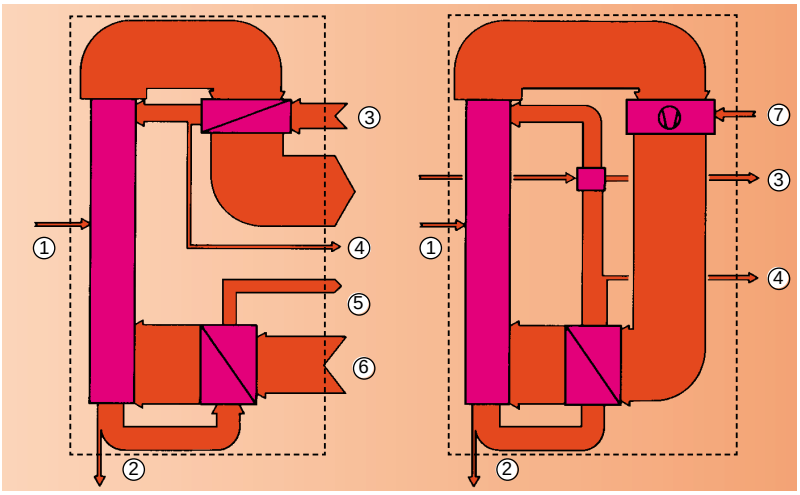
Energy saving is one of the most important measures for controlling global environmental problems such as the greenhouse effect. The saving of energy, however, is also worthwhile financially. In addition to the benefit realized through the lower consumption of energy, environment-friendly technologies are being supported more and more through national or EU subsidies.

The employment of heat pumps is one of the best possibilities for drastic reduction of the energy demand. The principle of a heat pump consists in boosting the non-recyclable thermal energy from a low temperature level to a higher one, at which it can be employed in a beneficial manner. In the industrial field, distillation is by far the most frequently applied process for the separation of mixtures



(Fig. 1■). An estimated 300 million liters of oil are used worldwide for distillation every day. The energy saving potential is correspondingly large.

① Feed
② Bottom product
③ Cooling water
④ Distillate
⑤ Condensate
⑥ Heating steam
⑦ Compressor drive power



2■ In a conventional plant (left), large quantities of energy pass through the system limit. In a plant with heat pump (right), only small energy flows are supplied or dissipated. The greater part of the energy remains in the system.

MAKING ENERGY REUTILIZABLE

Figure 2■ compares the advantages of a distillation plant with heat pump to a conventional unit. In the case of the latter, energy is fed into the system via the reboiler in order to create the gas load needed in the column for the separation process. The vapors from the column are liquefied in the water-cooled reboiler. About 95% of the energy needed for the reboiler leaves the system without being used any further.

In a distillation plant with a heat pump, the reboiler and the condenser are linked together. The heat pump increases the existing energy in the column head, which is normally dissipated, and transfers it into the reboiler, where the vapor is condensed. In comparison with conventional distillation units, this process only requires a fraction of the thermal energy. Furthermore, it does not need any heating steam or large quantities of cooling water. Various heat pump systems are available (see box, "The most important heat pump systems").

REPEATEDLY SUCCESSFUL TECHNIQUE

Heat pump technnology has already been applied successfully in distillation plants on numerous occasions. Sulzer was and is still playing a decisive role in the development in this area. The first Sulzer vapor compressor in an industrial separation process was installed some 120 years ago. In the meantime, the systems have been continuously developed and improved.

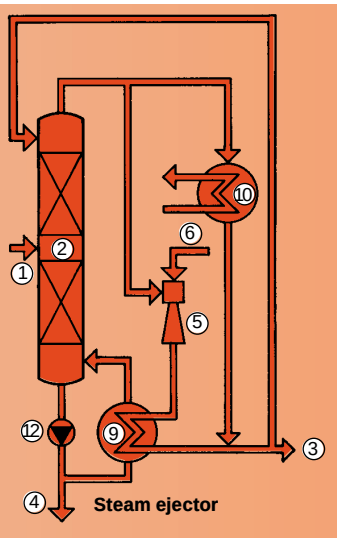
THE MOST IMPORTANT HEAT PUMP SYSTEMS

Direct vapor recompression, heat pumps with auxiliary circuits and steam ejectors are the most frequently employed heat pump systems in distillation plants. The direct vapor recompression saves the most energy, while the steam ejector entails the lowest investment costs.

With direct vapor recompression, the vapors from the column head are compressed to such an extent that the resultant temperature is sufficient to heat the reboiler.

If the head product is not suitable for compression, e.g. by the styrene finishing column, heat pump systems with an auxiliary circuit are employed. A condenser liquefies the top product and reboils the auxiliary medium with the released energy. This is compressed to the necessary pressure by means of the heat pump and then condensed in the reboiler itself, whereby the bottom product is caused to reboil at the same time.

The steam ejector, driven by medium-pressure steam or product vapors, compresses a part of the head vapors from the column to the pressure necessary for heating the reboiler. The vapor mixture is condensed in the reboiler itself and the bottom product reboiled with the released energy. An auxiliary condenser liquefies the residual head vapors.



3■ This single-stage radial turbocompressor from Sulzer is suitable for the compression of 1-butene or isobutane, for example.

The important thing is that the individual components of the system are tuned to each other, since it is not the sum of the individual equipment designs, but their perfect interplay that determines the magnitude of the energy savings. They are certainly impressive. With direct vapor recompression, the consumption of energy can be reduced by up to 80%. In large plants, it can mean financial savings amounting to several million USD per year. The investment for a heat pump system is paid back after just a few years, in many cases within a period of one year.

TYPICAL APPLICATIONS

Heat pumps have already been employed successfully with:

- 1-Butene
- Chlorobenzene
- Dichloroethylene
- Dimethyl formamide
- Ethanol
- Ethylene glycol
- Isobutane
- Isopropanol
- Propylene
- Silane
- Styrene
- Hydrogen peroxide

Further applications:

- Butanol
- Chloronitrobenzene
- Cumene
- Cyclohexan
- Acetic acid
- Methanol
- Methylphenol (Cresol)
- Phenol
- Xylene and others

COMPRESSOR: RELIABLE AND LONG LASTING

The heart of the heat pump system is the compressor. Depending on the separation task and the capacity of the plant compressors such as, turboblowers, radial turbo compressors, screw-type or axial compressors are employed for this (Fig. 3■). The choice of the column filling has a major influence on the selection of the compressor. Appropriate internals, e.g. structured packings, random packings or, in some cases, also suitable trays, reduce the pressure drop in the column and thus permit the employment of single- or two-stage radial compressors.

Experience shows that compressors operate very reliably and only require a minimum of maintenance. The addition of a heat pump makes the distillation plant even more reliable. In contrast to a conventional unit, it makes no difference whether the correct steam capacity or cooling water temperature is assured at all times (see box, "Fields of application and selection criteria").

Heat pump systems can be designed for new installations and also for retrofitting in existing plants. They can be employed almost anywhere (see box, "Typical applications"). Sulzer Chemtech has many years' experience in the engineering, supply and commissioning of new as well as the retrofitting of existing installations. Ω

FOR MORE DETAILS

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FIELDS OF APPLICATION AND SELECTION CRITERIA

The following circumstances or requirements speak for the application of Sulzer heat pump technology:

- energy-saving solution for new and existing plants
- the lack or insufficiency of steam or cooling water capacity
- high cooling water temperatures
- reliability
- CO_2 taxes and environmental management systems, e.g. ISO 14 000

Heat pumps are economical for plants with:

- thermal energy requirement of more than 2 MW
- temperature differences of less than 40 °C between head and bottom products