Energy Efficiency of Evaporation Plants

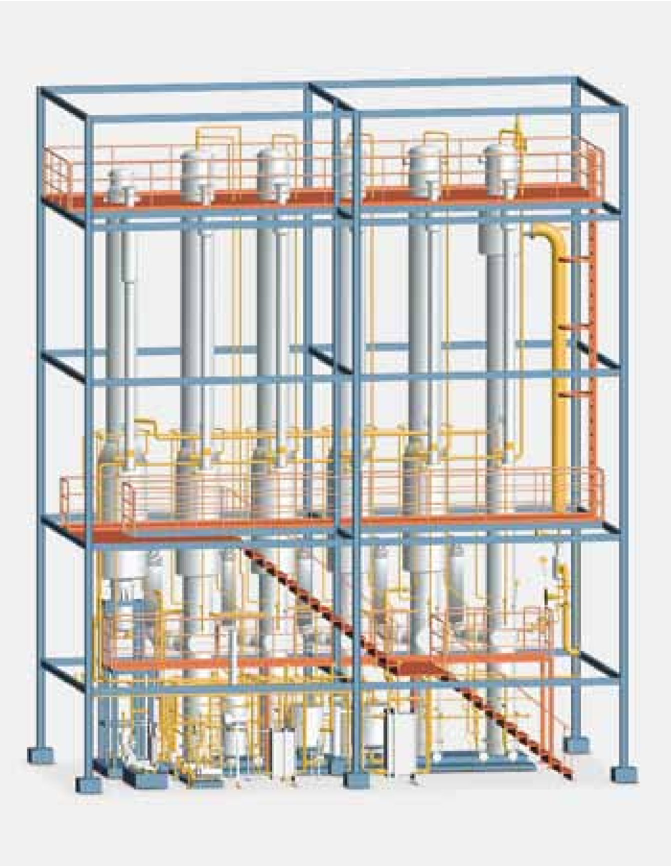
The operating costs of an evaporation plant are largely determined by the energy consumption.
Under steady-state conditions there must be a balance between the energy entering and leaving the system.

The energy consumption of the system can be tailored to meet the customer's individual requirements by intelligent thermal configurations of the evaporation plant.

There are three basic possibilities to save energy:

- Multiple-effect evaporation
- Thermal vapour recompression
- Mechanical vapour recompression

Application of one of these techniques will considerably decrease the energy consumption. Often it is feasible to combine two of these possibilities to minimise capital and operating costs. In highly sophisticated evaporation plants all three techniques may be applied.



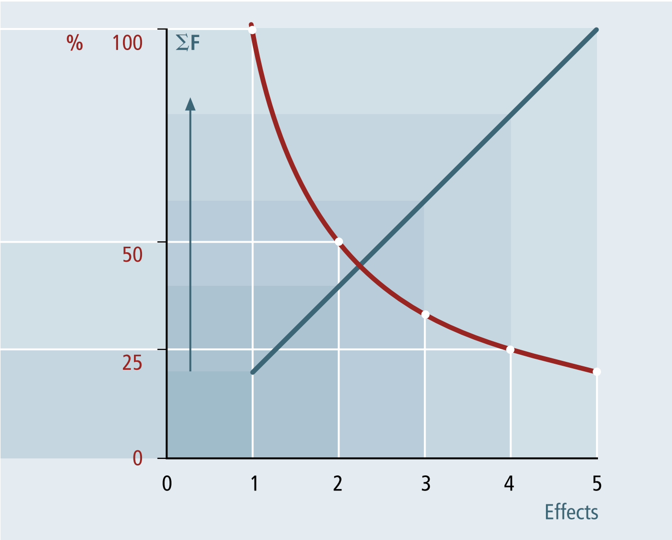
5-effect falling film evaporation plant for apple juice concentrate, directly heated, with aroma recovery. Evaporation rate: 12,000 kg/hr

Multiple-effect evaporation

If we consider the heat balance of a single-effect evaporator we find that the heat content (enthalpy) of the evaporated vapour is approximately equal to the heat input on the heating side. In the common case of water evaporation, about 1 kg/hr of vapour will be produced by 1 kg/hr of live steam, as the specific evaporation heat values on the heating and product sides are about the same.
If the amount of vapour produced by primary energy is used as heating steam in a second effect, the energy consumption of the overall system is reduced by about 50 %. This principle can be continued over further effects to save even more energy.

	Live steam	Vapour	Specif. steam consumption
1-effect-plant	1 kg/h	1 kg/h	100 %
3-effect-plant	1 kg/h	3 kg/h	33 %

The maximum allowable heating temperature of the first effect and the lowest boiling temperature of the final effect form an overall temperature difference which can be divided among the individual effects. Consequently, the temperature difference per effect decreases with an increasing number of effects. For this reason, the heating surfaces of the individual effects must be dimensioned accordingly larger to achieve the required evaporation rate, but with a lower temperature difference (Δ t).
A first approximation shows that the total heating surface of all effects increases proportionally to the number of effects. Consequently, the investment costs rise considerably whereas the amount of energy saved becomes increasingly lower.



Decrease of the specific steam consumption in % and increase of the approximate total heating surface ΣF in relation to the number of effects

Energy Efficiency of Evaporation Plants

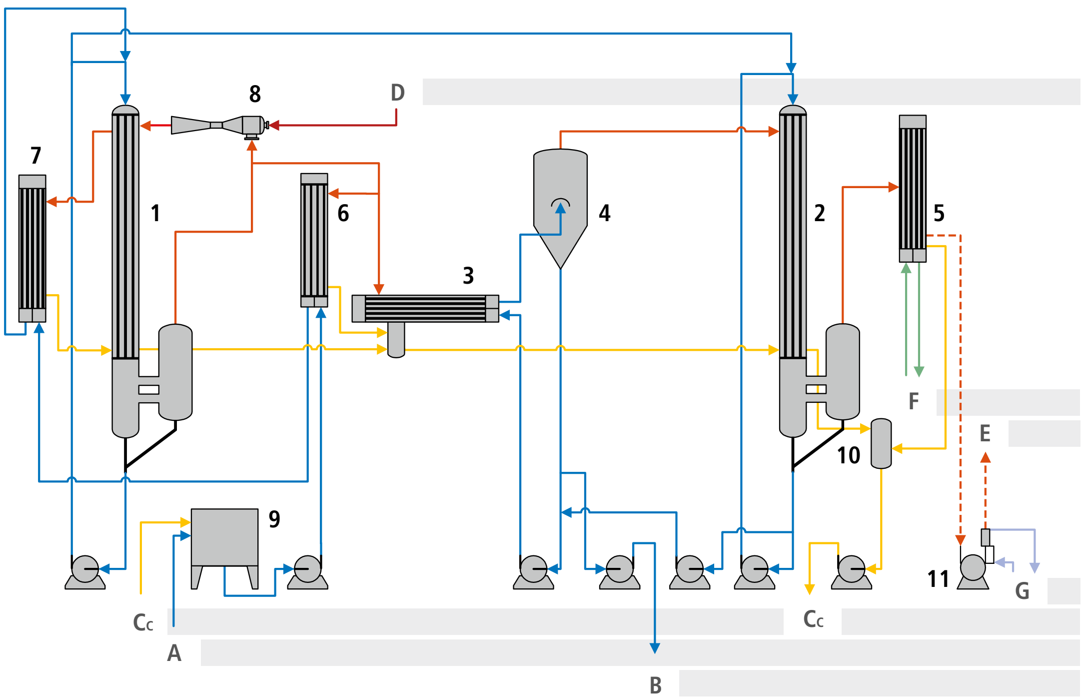
Thermal vapour recompression

During thermal vapour recompression, vapour from a boiling chamber is recompressed to the higher pressure of a heating chamber in accordance with the heat pump principle. The saturated steam temperature corresponding to the heating chamber pressure is higher so that the vapour can be reused for heating.
To this end, steam jet vapour recompressors are used. They operate according to the steam jet pump principle. They have no moving parts and are therefore not subject to wear and tear. This ensures maximum operational reliability.

The use of a thermal vapour recompressor gives the same steam/ energy saving as an additional evaporation effect.

A certain steam quantity, the so-called motive steam, is required for operation of a thermal vapour recompressor. This motive steam portion is transferred as excess vapour to the next effect or to the condenser. The energy of the excess vapours approximates the energy of the motive steam quantity used.

3-effect falling film forced circulation evaporation plant heated by thermal vapour recompressor for waste water from sodium glutamate production. Evaporation rate: 50 t/hr



Heating steam

- **1, 2** *Falling film evaporators*
- **3, 4** *Forced circulation evap.*
- **5** *Condenser*
- **6, 7** *Preheaters*
- **8** *Thermal vapour recomp.*
- **9** *Feed tank*
- **10** *Condensate collection tank*
- **11** *Vacuum pump*

Cooling water
Deaeration

Service water
Vapour condensate
Product
Concentrate

Mechanical vapour recompression

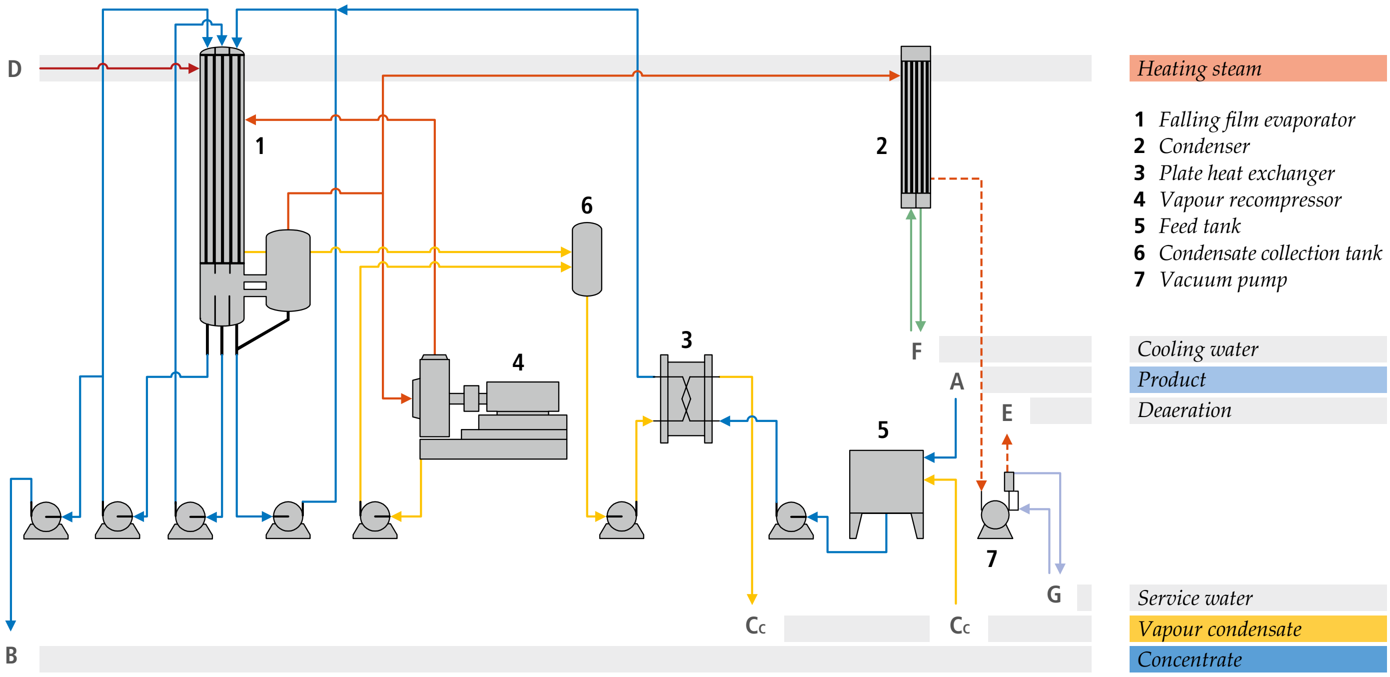
Evaporation plants heated by mechanical vapour recompressors require particularly low amounts of energy.

Whereas steam jet compressors only compress part of the vapour, mechanical vapour recompressors recycle all of the vapour leaving the evaporator. The vapour is recompressed to the pressure of the corresponding heating steam temperature of the evaporator, using a mere fraction of electrical energy relative to the enthalpy recovered in the vapour. The operating principle is similar to that of a heat pump. The energy of the vapour condensate is frequently utilized for the preheating of the product feed. The amounts of heat to be dissipated are considerably reduced, with the evaporator itself re-utilizing the energy normally dissipated through the condenser cooling water. Depending on the operating conditions of the plant, a small quantity of additional steam, or the condensation of a small quantity of excess vapour may be required to maintain the overall evaporator heat balance and to ensure stable operating conditions.

Due to their simplicity and maintenance friendly design, single stage centrifugal fans are used in evaporation plants. These units are supplied as high pressure fans or turbo-compressors. They operate at high flow velocities and are therefore suited for large and very large flow rates at vapour compression ratios of 1:1.2 to 1:2. Rational speeds typically are 3,000 up to 18,000 rpm. For high pressure increases, multiple-stage compressors can be used.

(See our special brochure “Evaporation Technology using Mechanical Vapour Recompression”).

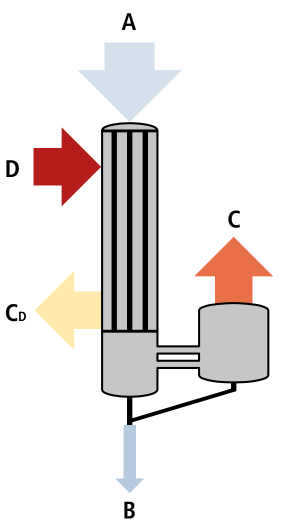
1-effect falling film evaporation plant heated by mechanical vapour recompression for wheat starch effluent. Evaporation rate: 17,000 kg/hr

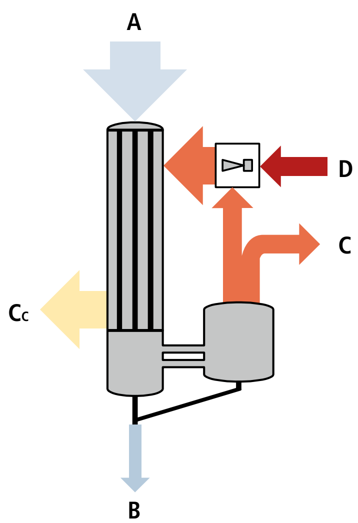


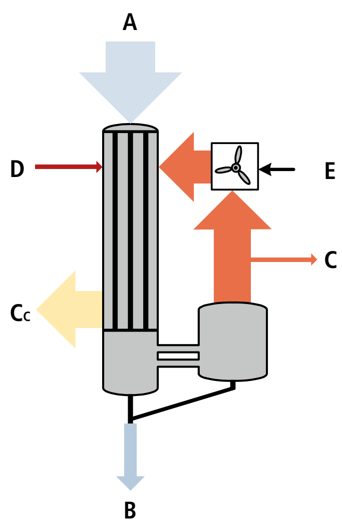
Energy Efficiency of Evaporation Plants

Mass/energy flow diagrams of an evaporator with different types of heating

Directly heated	Thermal vapour recompression	Mechanical vapour recompression







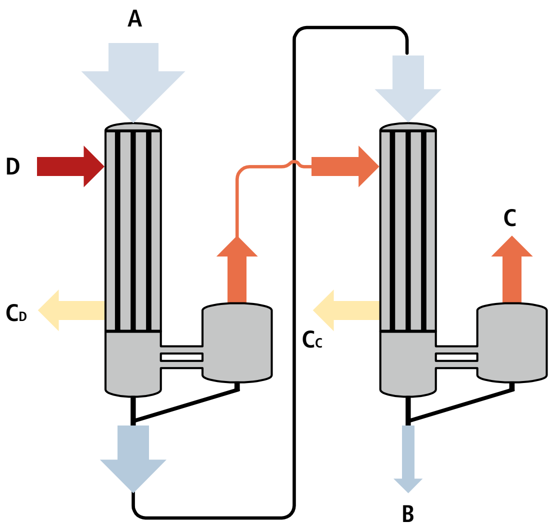
If we consider the heat balance of a single-effect evaporator we find that the heat content (enthalpy) of the evaporated vapour (C) is approximately equal to the heat input (D) on the heating side. In the common case of water evaporation, about 1 kg/hr of vapour will be produced by 1 kg/hr of live steam, as the specific evaporation heat values on the heating and product sides are about the same.

A certain quantity of live steam, the so-called motive steam, is required for the operation of a thermal vapour recompressor. This motive steam quantity must be transferred to the next effect or to the condenser as surplus residual vapour. The surplus energy contained in the residual vapour approximately corresponds to the amount of energy supplied in the motive steam.

The operation of evaporation plants heated by mechanical vapour recompressors requires a particularly low amount of energy. The operating principle of a mechanical vapour recompressor is similar to that of a heat pump. Almost the entire vapour quantity is compressed and recycled by means of electrical energy. Only minimum quantities of live steam are required, generally just during start-up. The quantities of residual "waste" heat to be dissipated are considerably reduced.

2-effect design

If the amount of vapour produced by primary energy is used as heating steam in a second effect, the energy consumption of the overall system is reduced by about 50 %. This principle is repeated over further effects to save even more energy.



A *Product*
B *Concentrate*
C *Condensate*
C_C *Vapour condensate*
C_D *Heating steam condensate*
D *Heating steam*
E *Electrical energy*