280.371
Evaporator Equipment

Based on material by
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System components

Generation of vacuum

Preheating of feed

Vapour and product separated

Calindria (Heat Exchanger

Movement of concentrated product

Heating Medium

To vacuum pump

Pre -heater

Feed

Vapour

Steam

Separator
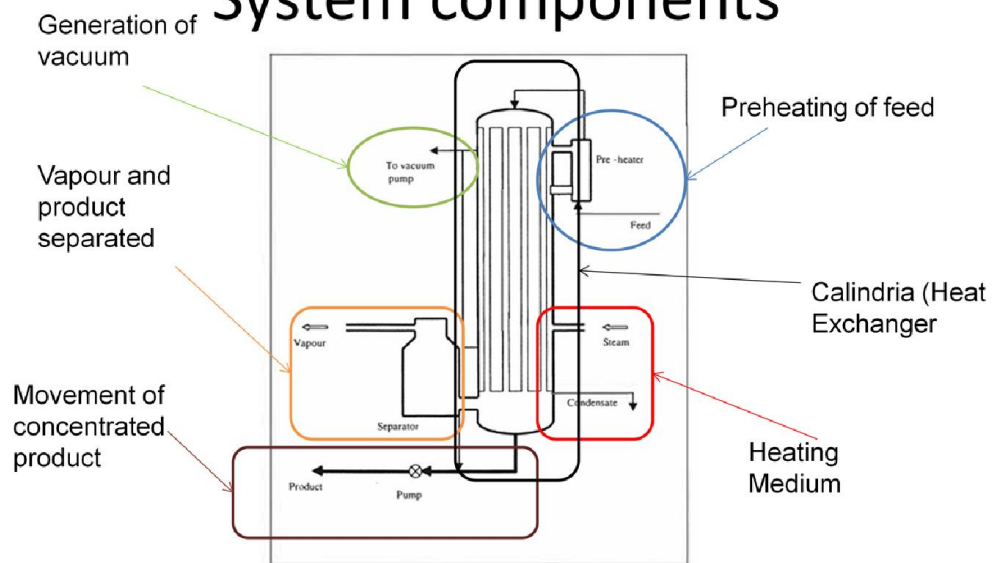
Condensate

Product

Pump

Figure 2.17: Single effect falling-film evaporator

References

- Geankoplis, C.J. (2003), *Transport Processes and Separation Process Principles,* p588-594.

- Paramalingam, S. (2004), Ph.D. thesis

- Russel, N.T. (1997), Ph.D. thesis

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Liquid flow

- Single pass or recirculating
  - Single pass → short residence time → thermally sensitive products
  - Recirculating → long residence time → high turbulence → fouling or crystallising products

Vapour-Liquid (V-L) separator

- Two options
  - Gravity separation – mesh, impingement baffle
  - Centrifugal – cyclone or centrifuge

- Cyclones
  - More effective separation
  - Greater pressure drop → lower overall $\Delta\theta$

Condenser

- ## Indirect
    - Typically external Shell & Tube HE
    - Reduced risk of product contamination
    - Lower pumping duty
    - Recovery of volatile flavours aromas

- ## Direct
    - Vapour condensed in cold water spray
    - Lower capital costs
    - Greater pumping costs
    - Lower θcond possible $\rightarrow$ higher overall $\Delta\theta$

Vacuum production

- Condensation process
- Mechanical pump
- Steam jet injector system

Preheaters

- Small heat exchangers
  - Direct contact (Steam injection)
  - Indirect
- Feed enters at boiling point
  - Improved efficiency
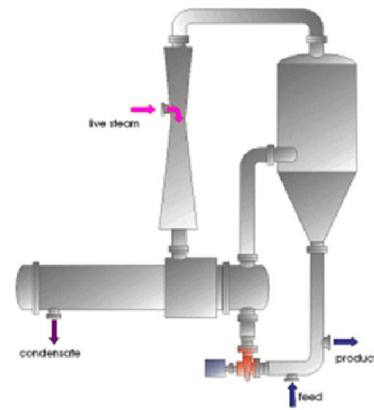 - or above bpt.= flashing

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Vapour recompression

- Can increase steam pressure prior to reuse to recover latent heat
- Two options for vapour recompression
  - Thermal (TVR) - using a steam ejector (venturi)
  - Mechanical (MVR) - using a compressor
- Demand for fresh steam is reduced
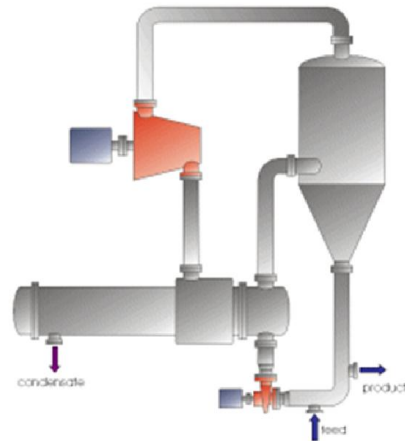- Reduced installation costs with TVR

Thermal vapour recompression – steam ejector

- Raises the pressure of the re-used vapour

- Evaporation load in the effect is effectively doubled

- *n* effect evaporator becomes an evaporator with capability of *n+1* effects – efficient use of energy in evaporator vapours.

- Widely used in multi-effect evaporators – most common

live steam

condensate

product

feed

Mechanical vapour recompression

- A compressor increases the pressure of the vapour
- Expensive
- Widespread use in the food industry
- Positive displacement compressors, axial or radial flow compressors (fan compressors)
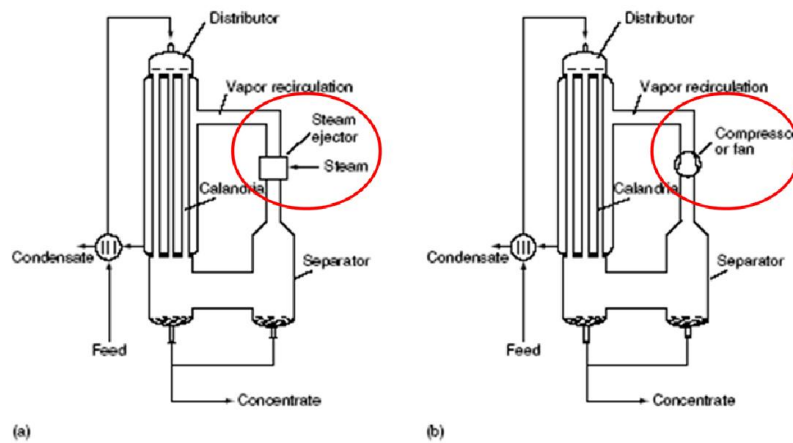
TVR / MVR – falling film

Figure 4 Main components of vapor recompression evaporators: (a) TVR and (b) MVR. Reproduced from *Evaporation: Uses in the Food Industry, Encyclopaedia of Food Science, Food Technology and Nutrition*, Macrae R, Robinson RK and Sadler MJ (eds), 1993, Academic Press.

Design components

- Process Variables
- Single or Multi-stage
- ΔT limitations
- Heat Exchanger Capacity
- Batch or Continuous
- Use (and disposal) of vapours

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Many things must be considered when an evaporator is to be designed. There are many designs of evaporators, as we will see. In almost all situations the ultimate solution will have to compromise on other issues. For example, the heat sensitivity of a product will dictate the operating pressures and temperatures.

However, the same basic issues are present in each case – how can we effectively and efficiently transfer heat to the solution to increase it's solids concentration to the target amount (maintaining an economic cost).

Liquid circulation

- Forced or natural
- Natural
  - Driven by density difference
  - Lower circulation velocity, less control
  - Lower costs
- Forced = external pump
  - Constant circulation → good heat transfer
  - Useful for viscous or crystallising solutions