



## Vertical Tube Falling Film

### Process Selection

Aqua-Chem ICD has supplied both vertical tube falling film and horizontal Spray-Film systems for this service, as well as parallel flow and counterflow five-effect arrangements. The selection of evaporator type and flow arrangement is dependent upon the likelihood of sodium sulfate and/or acrylonitrile being present in the solution to be evaporated and the customer's preference.

If acrylonitrile is in the feed to Effect #1, where the temperature is about 130°C, it will polymerize in the vapor phase and the polymer will deposit on all the surfaces the vapor comes in contact with. This polymerization reaction does not occur if the feed is introduced into Effects #4 or #5, where the vapor temperatures are 40-80°C lower. Therefore, if there is a possibility of acrylonitrile in the feed, Aqua-Chem recommends the counterflow arrangement. In this arrangement, the solution flows through the evaporator system counter to the vapor flow. This means that the feed enters Effect #5, which is the coldest effect. Any acrylonitrile in the feed will volatilize, and will flow to the condenser and out through the vacuum pump. Since the vapor temperature is around 50°C, the polymerization reaction will not occur. The concentrate exits from Effect #1, which is the hottest effect. The solution is flashed down in a series of flash tanks connected to the evaporator effects to cool it and recover the vapor to improve the thermal economy of the plant.

If sodium sulfate is present in the feed solution, its solubility limit will be exceeded in the highest concentration liquor effect. In the parallel flow arrangement, this would be Effect #5; in the counterflow arrangement, Effect #1. Sodium sulfate is inversely soluble; that is, its solubility decreases with increasing temperature. However, the temperature-solubility dependence is not strong enough to make much difference in the selection of parallel or counterflow arrangements -- sodium sulfate's solubility is exceeded at both temperature extremes at the desired NaSCN concentration. The rate of sodium sulfate precipitation is somewhat more in the counterflow arrangement, due to the higher temperatures. Since product flash tanks are used, the sodium sulfate will also precipitate in them. The net result is that more vessels must be washed more frequently in the counterflow arrangement than in the parallel flow arrangement. In general, therefore, the parallel flow arrangement is preferable when sodium sulfate is present. However, if both acrylonitrile and sodium sulfate are present, the counterflow arrangement must be used, due to the polymerization problem described above.

Sodium sulfate will precipitate, and due to its inverse solubility, will precipitate preferentially on the heat transfer tubes, since they are the hottest. This problem occurs regardless of the flow arrangement used, if Na<sub>2</sub>SO<sub>4</sub> is present in the feed. Previous designs have attempted to "seed" the solution with suspended Na<sub>2</sub>SO<sub>4</sub> crystals to serve as nucleation sites, so that the Na<sub>2</sub>SO<sub>4</sub> in the solution precipitates preferentially on the seed crystals, rather than on the tubes. Our experience has been that for a variety of chemical and physical reasons, such preferential crystallization does not occur completely in this service, and all evaporator types including vertical, horizontal, and forced circulation configurations, build up a layer of sodium sulfate scale on the tubes over time. The scale buildup over time impedes heat transfer and eventually reduces the evaporation capacity, requiring a shutdown of the system every couple of weeks to boil out the accumulated sodium sulfate scale on the tubes.

For a five-effect vertical tube falling film evaporation system in the parallel arrangement. Some key features of our system design include:

- ? A maximum solution temperature of 130°C to avoid degradation and discoloration of the solution above that temperature.



- ? Heat recovery has been maximized wherever possible with consideration given to keeping capital equipment costs reasonable. Heat recovery equipment is described below.
- ? High efficiency wire mesh pad mist eliminators are installed in the vapor separators in each effect. The process is designed to produce a distillate stream with a maximum of 2 ppm NaSCN, measured as oven dried solid.
- ? Process heat recovery is accomplished with the following equipment (parallel flow):
  - ? A shell and tube heat exchanger using effect 5 vapor to preheat the feed.
  - ? A plate heat exchanger using distillate to preheat the feed.
  - ? A shell and tube heat exchanger for each of effects 2, 3, 4, and 5 taking steam from the each effect's steam chest to preheat the feed.