Three Effect Vertical Tube Falling Film

Overview

This describes a three effect vertical tube falling film system designed to concentrate a 32 wt% caustic soda solution to 50%. Some of the factors which were considered in the process selection and equipment design include:

- Utilizing partial recirculation to minimize capital and operating costs and allow for maximum turndown capability (to 415 tons/day as 100% NaOH).
- Maximizing heat recovery from the product and condensate streams to minimize steam consumption.
- Minimizing material cost and corrosion by the flow sequence and the distribution of the differential temperature (delta-T).
- Selecting a control scheme for ease of operation.
- Selecting equipment to minimize maintenance requirements.

Vertical Tube Falling Film Evaporation

In falling film vertical tube evaporators liquid is distributed evenly over the top tube sheet and falls in a thin film down the inside of the tubes. Some of the water evaporates from this film as the liquid absorbs heat from condensing steam on the outside of the tubes. For every kilogram of steam that condenses, approximately one kilogram of water is evaporated from the liquid film. The driving force for this heat transfer is the delta-T, the difference between the boiling liquid temperature and the condensing steam temperature.

The steam is mostly water vapor but also contains air and other noncondensables. These noncondensables will stay in the vicinity of the tube walls and impede heat transfer unless swept away by sufficiently high vapor velocities and proper venting. A vent on the evaporator body continuously removes the noncondensables to maintain high heat transfer coefficients.

Process Flows - NaOH

The 32% NaOH enters the system in the third effect where it is concentrated to 36%. The 36% NaOH is pumped to the second effect where it is concentrated to 41%, then to the first effect where it is concentrated to the desired 50%. All concentrations are presented in weight percent (wt%).

Because the operating temperature in the third effect is only 73°C, 304L stainless steel can be used. The corrosion rate is less than 0.025 mm/year. The other two effects must be nickel because they operate above 93°C.

The 304L SST surface area in effect 3 is greater than the nickel surface area in effects 1 and 2 to reduce system cost. There is a fixed differential temperature available for heat transfer. By increasing the heat transfer surface in effect 3, the surface in effects 1 and 2 can be reduced. All three effects use partial recirculation to achieve a sufficiently high wetting rate to keep the tubes evenly wetted during turndown conditions. At full capacity, however, a once-through flow sequence is used to maximize the available heat transfer driving force (delta-T).

Process Flows - Vapor

The boiler steam entering the system condenses in the first effect tube bundle. This steam flow is regulated to maintain the final concentration at 50%. Water vaporized in the first effect serves as heating steam in the second effect. Water vaporized in the second effect serves as heating steam in the third effect, and the vapor generated in the third effect condenses in a surface condenser.

Aquatech International Corporation
One-Four Coins Drive; Canonsburg, PA 15317 USA t) 724 746 5300 f) 724 746 5359

The pressures vary from about 10.8 bar (abs.) in the shell of the first effect to almost a full vacuum in the condenser. The pressure difference is what allows the steam produced in one effect to generate more steam in the subsequent effect. Noncondensables vent from effect to effect to the final condenser and are removed from the condenser by a liquid ring vacuum pump.

Process Flows - Condensate and Distillate

The condensate from the first effect flows through two of the intereffect preheaters, transferring heat to the feed to Effects 1 and 2, and leaves the system. The distillate from the second effect combines with distillate from the third effect and from the final condenser in the distillate level tank. A pump discharges the distillate from the system.

Preheating

Two plate heat exchangers are provided which cool the 50% caustic soda by heating the feed to the first and second effects. Two additional plate heat exchangers cool the condensate leaving the first effect by heating the caustic soda solution going to the first and second effects.

Controls

Feed into the system is flow controlled. Differential pressure type level controls regulate the flow of caustic entering each effect. Product concentration is maintained by adjusting the steam flow to boil off the correct amount of water. The concentration is inferred by measuring the boiling point rise of the concentrate. To change capacity, the feed flow is changed and all other controls adjust to maintain proper level and concentration.