# Trends in Engineering and Technology Development in Pulp and Paper Industry

## Evaporator Designs Reduce Energy Demands

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Ever since the first evaporator was built and put into operation, designers have put forth a wide variety of arrangemements for accomplishing a relatively simple operation; namely, the removal of a solvent. More than one design might be suitable for any given application with the final selection being based on initial cost, operating cost, adaptability to space requirements, etc. As far as the paper industry is concerned, at one time or another all of the following types have been used :

(a) LTV—Long-Tube-Vertical
(b) FC —Forced-Circulation
(c) FF —Falling Film
(d) STV —Short-Tube - Vertical or Calendria
(e) HT —Horizontal Tube

Over the past forty years for concentrating kraft and soda liquors, the majority of installations have consisted of the LTV type. For handling NSSC and sulphite liquors, the forced-circulation evaporator has usually been used although there are installations using the falling-film, horizontal-tube (Lillie or Spray-Film), and recirculating LTV.

Cost of energy for generating steam of electric power is an increasingly important factor today. As a heat sourse (usually steam) is required for the evaporator, then the amount required will be a function of (a) number of effects, (b) feed temperature, and (c) liquor flow sequence. Other factors such as the use of liquor flash tanks, steam condensate flash tanks, and internal heaters will have some effect on the steam requirements.

Assume as a start that an evaporator is required to concentrate a kraft black liquor at 180°F from 15% to 50% total solids. Also assume that pre-heaters are used in effects for one case and after-heaters in the other case. Table 1 gives information on number of effects vs. economy for both cases.

TABLE NO. 1

| *No. of Effects* | *No Heaters* | *After-Heaters* |
|---|---|---|
| 4 | 3.50 | 3.82 |
| 5 | 4.30 | 4.62 |
| 6 | 5.07 | 5.37 |
| 7 | 5.82 | 6.10 |

In addition to steam requirements, there will also be change in cooling water usage. Here for our purposes assume water in at 85°F and out at 110°F. Then, Table 2 gives the comparison based on number of effects vz. GPM/1,000 lb. evaporation.

TABLE NO. 2

| *No. of Effects* | *No Heaters* | *After-Heaters* |
|---|---|---|
| 4 | 24.38 | 22.54 |
| 5 | 19.74 | 18.44 |
| 6 | 16.67 | 15.70 |
| 7 | 14.57 | 13.85 |

By comparing the steam and water requirements for an evaporator with and without after-heaters, it is apparent that the operating costs with after-heaters will be the lowest.

The information in Tables 1 and 2 was all based on a feed temperature of 180°F. Should the feed temperature drop to 140°F., then the amount of the steam will go up and GPM of water will go down.

TABLE NO. 3

| *No. of Effects* | *Lbs.Vapor/ Lbs. Steam* | *GPM/1,000 lb. Evap'n.* |
|---|---|---|
| 4 | 3.51 | 20.61 |
| 5 | 4.25 | 16.07 |
| 6 | 4.97 | 12.92 |
| 7 | 5.64 | 10.93 |

At most mills, the weak liquor temperature seldom drops this low. This information points out the desirability of keeping the temperature at a higher level. Handling of steam condensate has varied depending on

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the design of the boiler feed water system. All data given in the tables was based on a two-stage steam condensate flash system. Eliminating this and returning the condensate direct to the feed water system without flashing will decrease the evaporation/pound of steam from 5.37 to 5.08 for our base sextuple arrangement.

Up to this point, all comparisons have been based on a conventional arrangement; i.e. straight multiple effect with 50% total solids discharge concentration. For those mills where the direct-contact evaporator is eliminated, heavy liquor at greater than 62% total solids must be discharged from the multiple effect evaporator. Most installations now consist of either single or double effect concentrating bodies operating in parrallel with one of the effects of the multiple effect on the vapor side. For example, the second effect of the double effect would operate at the same pressure as the third effect of a sextuple. Table 4 illustrates overall conditions for several arrangements with double-effect concentrating bodies.

TABLE NO. 4

| *No. of Effects* | *Lb. Evap'n./ Lb. Steam* | *GPM/ 1,000 Lb. Evap'n.* | *Vapor To* |
|---|---|---|---|
| 4 | 3.35 | 24.17 | 2 Vapor Hd. |
| 5 | 4.05 | 19.60 | 2 Vapor Hd. |
| 6 | 4.53 | 17.81 | 3 Vapor Hd. |
| 7 | 5.14 | 16.30 | 4 Vapor Hd. |

The information in Tables 4 and 5 is based on steam condensate flash and also on flashing the 50% liquor with an intermediate storage tank between the multiple effect and the concentrating effect(s). Where possible to do so, the preferred method is to go directly from the multiple effect to the concentrating effect(s) without flashing. This eliminates the heating of relatively cold 50% liquor and also gives a nominal increase in economy 4.41 vs. 4.39 for a quintuple with double-effect finishing effect.

All calculations would be more or less applicable to an installation consisting of any of the several evaporater types listed in a previous paragraph. The LTV is by far the most widely used throughout the world. It requires less power than most other types and is usually the least expensive both in first and total installed cost. Turndown can be a problem with five, six, or seven effect installations as liquor flow has conventionally been single pass; however, this can be overcome by providing recirculation as has been done in other applications. Installations have ranged from as little as 1 to greater than 600 tons per hour evaporation.

The falling-film and forced-circulation evaporators have the capability of operating stably over a rather wide range of capacity. Both require more power and are more expensive. Depending on actual type used there, the installation cost could possibly be greater than for the usual LTV of same capacity. Other types such as the calandria and old style horizontal tube are infrequently used. A modification of the Lillie evaporator has found favor in a number of cases due to unit construction, power and cost. Some of the inherent disadvantages of the old horizontal tube still exist with respect to cleaning of the tubes. Conventional Pulp Mills evaporators are 5, 6 and 7 effects. In saline water application they are up to 30 effects.

Vapor recompression is a way to meet expanded evaporation requirements; however, it does have certain limitations. Vapor compression can be accomplished by mechanical means or by the use of steam boosters. Both types have been used in other fields; however, the mechanical compressor has been used for virtually all installations for kraft, NSSC and sulphite liquors. As the pressure rise across any given compressor is limited, this means that if the boiling point elevation of the liquor becomes significant that the amount of heating surface will increase even though the unit is divided into a multiplicity of sections. Ideally, the evaporator runs at or near atmospheric pressure. If the incoming feed is below the body temperature, then heat exchangers are provided to heat the feed liquor using the product liquor and/or the heating element condensate. Depending on temperature conditions, make-up steam might be required. The data in Table 6 gives an example of what could be done through the installation of a vapor recompression evaporator on weak liquor.

TABLE NO. 5

| | Base multiple effect | Vapor Recompression Evaporator | Multiple effect Evaporator |
|---|---|---|---|
| Feed | 500,000 lbs/hr | 700,000 lbs/hr | 525,000 lbs/hr |
| % TDS | 15—50 | 15—20 | 20—50 |
| Evaporation | 350,000 lbs/hr | 175,000 lbs/hr | 315,000 lbs/hr |

TABLE NO. 6

| Case | A | B | C |
|---|---|---|---|
| Steam Temperature °F | 223 | 227 | 231 |
| Delta T, °F | 7 | 11 | 15 |
| Liquor Temperature, °F | 216 | 216 | 216 |
| BPE, °F | 4 | 4 | 4 |
| Vapor Temperature, °F | 212 | 212 | 212 |
| Feed Temperature | 180 | 180 | 180 |
| HP/1,000 Lb. Evap'n. | 8.49 | 11.11 | 15.30 |
| Make-Up Steam-lb/ 1,000 lb. Evap'n. | 33.0 | 30.1 | 23.8 |

With a fixed evaporation rate and heat input, the above table shows that for Case A over twice as much beating surface will be required along with just under 40% more make-up steam; but on the other hand, only 55% as much power will be needed. The final decision will depend on the differential between utility and equipment costs. These must be determined for each individual application.

By installing the Vapor Recompression Evaporator ahead of a conventional evaporator the total capacity would be increased and even through the basic capacity of the multiple effect might drop some due to a higher input concentration, the overall system capacity represents an increase of about 40%.

Heat can also be recovered from the hot water accumulator tank on batch digester blow heat condensing system. One or more effects can be used in series depending on the available water temperature which more or less sets the overall available $\triangle T$ as the last effect temperature usually is set at 125—130°F as a practical minimum. The heat from the accumulator is recovered by circulating the hot water through a flash tank(s) or a heat exchanger (which could be the 1st effect).

Continuous digesters usually have one or more flash tanks to reduce the effluent liquor to less than atmospheric boiling point. The first stage vapor normally goes to the chip steamer. However, the liquor leaving this flash tank would go to one or more flash tanks incorporated with a multiple effect evaporator system for concentrating from 15—50% TS. Another source of heat that may become more important with time is geothermal steam. As this is a low level source it would be best used for a pre-evaporator like the blow heat application. Availability would dictate when this will be used.

As for equipment to be used, any of the types previously listed would be suitable and have been used.