Cost Minimisation in Evaporation of Black Liquor A Case for Forced Circulation

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Conservation of energy is the prime moto behind entire process industry today. Energy need to be managed better, when price of fuel is skyrocketing. There has been a four fold increase in price of furnace oil thereby increasing steam production cost enormously. In this situation forced circulation evaporators for black liquor concentration in pulp industry deserves attention.

Till now long tube vertical evaporators are used in B.L. evaporation. Though these evaporators are designed for steam economy of 4.5 lbs per lb. of steam in a normal six effect backward feed evaporators, due to hard scaling on tube side, reduces this to three lbs of water/lb of steam, thereby increasing steam requirement. In India normally eucalyptus and bamboo are used for pulping. These have higher inorganic salts. An experiment[1] shows that scales in evaporator contains as much as 10 to 62% inorganic salts. So to improve steam economy, scaling must be reduced.

In long tube natural circulation system the overall heat transfer coefficient vary from 100 BTU/hr. sq. ft °F at the concentrated end to 200 BTU/hr sq. ft °F at the weak end,[2] but by using forced

TABLE * I *

Effect	Conc. B. L. out	Evap. lb/hr.	Temp. V °F.	Temp. L °F.	(u C_p.)	($\triangle$T.°F.)	U BTU/Hr	$\triangle$ sq. ft.
1	50%	37,879.	245.65	255.65	36.4	42	342	2502
2	34.1	37255	213.65	219.65	6	26	582	2403
3	25.97	36484	188.15	192.65	2.5	21	740	2339
4	21.06	36336	164.65	168.65	1.8	19.5	809	2304
5	17.73	36266	143.15	146.15	1.5	18.5	852	2308
6	15.31	35377	125.15	125.15	1.3	18	885	2282

Capacity of the pump = 30.7166 Cu. ft./Sec.
Total Head = 14.32 (including frictional losses)
H. P. of each pump = 54.86
H. P. of motor = 75. (Assuming for 85% efficiency of pump & 85% efficiency of motor).
Steam in first effect at 50 psig, amount of steam in 40,000. lbs./hr.
Vaccum in last effect 26″ Hg., BL into last effect 290160 lbs./hr. at 13.515%.
BL out from first effect = 81240 lb./hr. at 50%.
Area in each effect = 2375 Sq. ft.
Tube length = 8 ft. O. D.=2″ I.D.=1.75″ Triangular Pitch=2½″.
No. of tubes=605. Double pass exchanger shell dia. = 6 ft.
Dia of evaporator body = 8 ft. dia of connecting pipes = 12″.
Velocity through tubes = 6 ft./Sec. Length of tubes = 8 ft.

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TABLE "2"

ITEM	Forced Circulation.	Natural Circulation LTV.
Area of each evaporator.	2375 ft².	7000 ft².
Cost of 6 Evaporators	364000 Dollars.	600,000/ = Dollars.
Cost of 6 Pumps.	24,000/ ,,	.....
Cost of 6 Motors.	12,000/ ,,	.....
Total Cost.	400,000/ ,,	600,000/ ,,
Installed Cost = 1.5 Total cost.	600,000/ ,,	900,000/ ,,
Steam consumed	40,000 lb/hr.	69,972 lb/hr.
Cost of steam @ $4/10⁶ B.T.U.	1,152,677. $/yr.	2,014,99/ $ /yr.
Maintenance @ 10%	60,000 $/yr.	90,000 $/yr.
Depriciation @ 10%	60,000 $/yr.	90.000 $/yr.
Cost of Electricity @ $ 0.02/Kwh.	53,174 $/yr.	....
Total operating cost	1.325,851 $	2,194,992 $.

NETT GAIN=869,000/= $ per year.

circulation, U can be increased to 300 to 800 BTU/hr sq. ft °F. Frgen and Badger[3] has shown that when liquid does not boil inside tubes, for a forced circulation evaporator,

$$U = \frac{2020\ D^{0.57}\ Vs^{3.6/L}}{u^{0.25}\ \Delta T^{0.1}}$$

An evaporator system has been designed with the use of these ideas and results are tabulated in Table No. 1. For a conventional evaporator (L.T.V) the design shows that for evaporation of black liquor from a 200 tons/day pulp plant the heat transfer area is 7000 Sq. ft/effect. An economic balance has been shown in Table No. 2 for these two systems, Depreciation and maintenance is taken as 10% each of the installed cost.

Conclusions

The economic balance for a 200 tons/day pulp plant is provided in table 2. Though the cost data is with reference to the American operating conditions in U.S. dollars, it can be easily seen that the investment is much less in case of forced circulation evaporators. It can be seen that the replacement of natural circulation evaporators by forced circulation is highly economical as the savings in the steam and other costs are substantial. Besides forced circulation reduces scaling to minimum, system with heat exchanger outside the evaporator body greatly facilitates maintenance.

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Nomenclature.

A=Heat transfer area in sq. ft.

D=Diameter of tubes in ft.

U=Overall heat transfer coefficient in BTU/hr sq.ft °F

μ=Viscosity in lb/hr ft.

ΔT=Temperature in °F

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