# Heat Balance calculations of the Evaporator Unit at the West Coast Paper Mills Limited, Dandeli

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#### SUMMARY

The West Coast Paper Mills has stepped up production of paper since the start of the mill. The Evaporator Unit in the Chemical Recovery Plant has proved to be a bottle-neck while handling the black liquor for the increased production of pulp in the Pulp Mill. To be more specific, the capacity as well as the efficiency of this unit has progressively dropped with the use of increased amount of black liquor. Therefore, it was decided to improve the efficiency of Evaporators to increase the capacity of the unit to keep up with the production of pulp. Moreover, it was intended not to make any capital investment for the present. The heat balance calculations were, therefore, carried out in a detailed fashion. The data so collected during the investigation and the figure of heat transfer obtained revealed very useful information. The heat transfer efficiency of the surface condenser, the 4th, 3rd and 2nd effects, have dropped to a very low value on account of excessive scaling on the vapour side of the tubes. The sequence of operation in our quadruple evaporator unit is 3-4-1-2. It is noted that about 16% of the total heat transferred in the first effect is utilised in increasing the sensible heat of the liquor obtained from the 4th effect.

Based on the data on our investigation, the following conclusions are arrived at:

- 1. It was felt necessary to change the tubes in the 4th effect as well as the Surface Condenser.
- 2. A new installation of a Liquor Heater between the 4th effect and the lst effect was felt necessary to increase the overall capacity.
- 3. It was also concluded that re-circulation of outgoing black liquor from the 2nd effect with the evaporator feed will increase the overall heat transfer co-efficient.

Therefore, as a follow up, during our annual shut down the tubes of the surface condenser and 4th effect were changed.

#### Introduction and Experimental details

As outlined above, the West Coast Paper Mills' Recovery Unit has a quadruple effect evaporator with the liquor flow sequence 3-4-1-2. (Diagram 1). The evaporators

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have natural circulation system, the surface condenser and steam ejectors. Live steam is supplied at 40 psi to 1st effect. The spent liquor from the Pulp Mill is received at 14-16% total solids. The final concentration of the outgoing liquor from the evaporator unit has a solid content of 54-56%.

During the 4 years running of the evaporator unit, both the efficiency and the capacity have considerably dropped. In addition, the tubes in the 4th effect and the surface condenser have completely corroded.

Observations were made sometime in April to check up the efficiency of the evaporator unit. Liquor samples were drawn from all the effects at the intervals of 30 minutes and total solid content was found out. Pressures and temperatures of the individual effects were also recorded. The average readings are given in Table 1.

Heat balance calculations and heat transfer co-efficient of the individual effects and surface condenser were calculated and compared with design figures (Table II). Comparative figures are given in Table III.

#### CONCLUSIONS

The low efficiency of the surface condenser indicates the heavy scaling of the condenser on the vapour side, as the water side of the tubes were periodically cleaned. This low heat transfer efficiency resulted in only partial condensation of final effect vapours and thus low vacuum in the fourth effect. Total available temperature differential was reduced, thereby decreasing the efficiency and capacity.

Heat transfer co-efficient was also quite low in the second, third and fourth effects due to fouling of fourth effect calendria on the vapour side. and high liquor concentration in second effect.

It is observed that 16% of the total heat transfer in the 1st effect is utilised as a sensible heat to heat up the 1st effect feed liquor. We are planning to install the locally fabricated Heat Exchanger between the 4th effect and the 1st effect. This will result in heating the liquor coming from 4th effect to the boiling point and then fed to the 1st effect. The condensate from the digester pre-heaters along with the make up steam will be used as a heating medium in the Heat Exchanger. As this will be used in the system immediately before the 1st effect, we will be getting the advantage of steam economy of multi-effect. This will amount to virtually increasing the heating surface of the 1st effect.

Recirculation of outgoing black liquor from second effect to the third effect may be beneficial in the same, that concentration distribution will be more evenly divided in all the effects. Due to increased velocity of liquor through the effects, overall heat transfer co-efficient will also increase.

It is now felt by us that periodical heat balance calculations of the Evaporator Unit will reveal the true efficiency of the unit and will guide us in future planning of the black liquor evaporation for raised capacity of the pulp production.



#### TABLE I

## EVAPORATOR TEST DATA

Readings were taken every half an hour

Date: 21st April, 1964

and average readings were recorded :

Time : 9.00 to 11.00 A.M.

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	First Effect	Second Effect	Third Effect	Fourth Effect
<ol> <li>Calendria pressure/ Saturation Temp.</li> </ol>	35.0 psig/280.7°F	23.3 psig/264.5°F	3.8″ Hg Vac/205°F	15.6″ Hg Vac/
2. Vapour Space Pres- sure/Saturation	23.3 psig/264.5°F	3.8″ Ho/205°F	15.6" Hg Vac/	77.4°F 20.5″ Hg Vac/
3. Liquor Tempera- ture	267°F (131°C)	219°F (104°C)	177.4°F 181°F (83°C)	159°F 161°F (71.5°C)
4. Black Liquor In- coming	.×			
(a) °Tw/Temp.	30°Tw/56.5°C	37°Tw/87°C	17.0°Tw/71°C	24°Tw/52°C
(b) % Total Solids	29.0 %	37.8 %	18.5 %	22.8 %
(c) Flow $M_3/hr$	_	-aurorated	34.5 $M_3/hr$ .	_
(d) Temp. of liquor			165°F (74°C)	
5. Black Liquor Out- going :				
(a) °Tw/Temp.	37°Tw/87°C	60.5/93°C	24/52°C	30°Tw/56.5°C
(b) % Total Solids	37.8 %	56.5 %	22.8 %	29.0 %
(c) Flow $M_3/hr$ .	_	9.4 m <sub>3</sub> /hr.	_	
(d) Temperature of liquor		219°C (104°C)		

TABLE I—contd.

5.	Live Steam condi- tions:				
	(a) Pressure			_	41.0 psi
	(b) Steam Tem- perature		—		150°C (302°F)
	(c) Flow				8.0 T/hr.
7.	First Effect Con- densate :				
	(a) Flow				10 M <sub>3</sub> /hr.
	(b) Temperature	<u></u>			95°C (203°F)
8.	Contaminated Condensate from 2nd, 3rd and 4th Effect :				
	(a) Flow				19 m <sub>3</sub> /hr.
	(b) Temperature			_	75°C (169°F)
9.	Surface Conden- ser :				
	(a) Cooling water supply pressure				27 psig.
	(b) Cooling water inlet tempera- ture		_	·	34°C (94°F)
	(c) Cooling water outlet tempera- ture	_	_		44.5°C (112°F)
	(d) Cooling water flow $M_3/hr$ .		_		370 m <sub>3</sub> /Hr.
	(e) Surface Con- denser & con- densate Temp.	_	autor		63°C (145.5°F)
10.	Elevation in Boil- ing Point (2nd effect)	_		_	10°C (18°F)

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### TABLE II

#### DESIGN DATA

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		First	Second	Third	Fourth	Surface condenser
1.	Steam or Vapour input	12955 kg	8687 kg	8966 kg	7855 kg	9491 kg
2.	Condensate outgoing	12955 kg	8687 kg	17653 kg	25508 kg	9491 kg
3.	Liquor input	30481 kg	21794 kg	47827 kg	39972 kg	
4.	Liquor output	21794 kg	12828 kg	39972 kg	30481 kg	
5.	Feed liquor temp.			60°C		
6.	Calendria pressure	4 atm. abs.	1.96	0.785	0.355 atm.	
7.	Calendria temp.	143.56 °C	120.44	93	73.22	
8.	Liquor Temp.	124.33	100°C	74.89	54°C	
9.	Vapour Pressure	1.96 atm.abs.	0.785 atm.abs.	0.355 atm.abs.	0.132 atm.abs.	
10.	Corresponding saturation temp.	120.44°C	93°C	73.22°C	51.78	
11.	Elevation in Boiling Point	3.89°C	70°C	1.67°C	2.22°C	
12.	Temp. defferential across the effect	19.23°C	20.44°C	18.11°C	19.23°C	
13.	Heating surface	5850 sq. ft.	5850 sq. ft.	5850 sq. ft.	5850 sq. ft.	2810
14.	Heat Transfer Co-efficient	128 k. Cal/hr. °F. Sq. ft.	86.0	105.0	94	
15.	% Total solids	33%	· <b>56</b> %	18%	23.5 %	
16.	Cooling water inlet °C			·		30°C
17.	Cooling water outlet °C		_	_	_	46°C
18.	Surface Condenser Conden- sate temp.		—		—	38°C
19.	Cooling Water Quantity		_			343000 kg

### TABLE III

#### SUMMARY OF TEST DATA

# $U = \frac{O}{A \times T}$

		Design	Date &	Heat	'n	·····	Actu	al Pe	rforman	ce			Heat transfer
		Transfe K.Cal/ Hr.°C /Ft. <sup>2</sup>	er Co-effi K.Cal/ Hr./°C. /m <sup>2</sup>	ciency Btu/Hr °F/Ft <sup>2</sup>	Heat Btu/Hr.	(O) K.Cal/Hr.	Temp ⁰F	∩Diff. °C	A. H Surf Sq. Ft.	eating face. Sq. M.	Heat 7 co-eff Btu/ Hr./ °F/Ft <sup>2</sup>	Transfer iciency K.Cal/ Hr./°C. /M <sup>2</sup>	co-efficiency with respect to design value %
1.	First Effect	128.0	1380.0	283.0	7400x2200	4100x10 <b>3</b>	13.7	7.7	5850.0	540.0	204.0	955.0	72.0 %
2.	Second Effect	86.0	925.0	190.0	5730x2200	3180x103	45.0	25.6	5850.0	540.0	47.0	229.0	24.7 %
3.	Third Effect	105.0	1137.0	232.0	6320x2200	3500x103	24.0	13.5	<b>5</b> 850.0	540.0	100.0	487.0	44. %
4.	Fourth Effect	<b>94</b> .0	1024.0	210.0	7140 <b>x220</b> 0	3960x103	26.6	14.8	5850.0	540.0	101.0	493.0	48.0 %
5.	Surface Condenser	<b>304</b> .0	3262	670.0	6700x2200	3710x103	42.5	23.5	2810.0	260.0	123.0	600.0	18.4 %

# DETAILS OF CALCULATIONS EVAPORATOR MASS BALANCE BASIS ONE HOUR

		M³	Metric Tons
(1)	Weak Black Liquor consumed	14.5	37.20
(2)	Power House Condensate which include First Effect Condensate, Air Heater Condensate, Less Flash Vapoured	10.0	10.00
(3)	Contaminated, Condensate, which includes Flash Vessel, and condensates from Second, Third, Fourth Effect Calendrias	19.0	19.0
(4)	Black liquor solids calculated on the basis of W. B. L. flow & % solids		6.9
(5)	Semi-concentrated black liquor produced (Appendix III)	9.4	12.20
(6)	Total Water Evaporated (1) - (5)		25.0
(7)	Flash vapour from Flash vessel to Second Effect		
	= (3) $\div$ Evaporation in 4th Effect – (6)		0.6
(8)	Air Heater Condensate		2.6
	<ul> <li>Power House Condensate</li> <li>Flash Vapours</li> <li>Flash Effect Condensate</li> <li>10-06-80</li> </ul>		

#### HEAT BALANCE

#### Detum Level — $32^{\circ}F$ .

# OVERALL HEAT BALANCE FOR EVAPORATORS INCLUDING FLASH VESSEL :

	Input		B. T. U.	Kg. Cal.
(1)	L. P. Steam (8.0 x 22 00) x 1176.8		9400 x 2200	5208 x 10 <sup>3</sup>
(2)	Air Heater condensate (1.3 x 2200 x 249.8÷1.3x2200x338.6)		765x2200	424 x 10 <sup>3</sup>
(3)	Heat in Weak Black Liquor (37.2 x 2200) x 0.9x (165.0-32.0)		4500x2200	2393x10 <sup>3</sup>
		TOTAL	14665x2200	8025x10 <sup>3</sup>

	Output	Btu	Kg. Cal.
(1)	SCBL outgoing (12.2 x 2200) x 0.69 x (219-32)	1570 x 2200	870 x 10 <sup>3</sup>
(2)	Contaminated condensate (19.0x2200) x 1 x (169.0-32)	2600 x 2200	1440 x 10 <sup>3</sup>
(3)	Heat extracted by warm water (370x2200) x 1 x (112.093.0)	6650 x 2200	3684 x 10 <sup>3</sup>
(4)	Surface condenser condensate $(6.6 \times 2200) \times (145.5-32)$	750 x 2200	$416 \times 10^3$
(5)	Power House Condensate (10x2200) x (203.0-32)	1730 x 2200 13300 x 2200	$\frac{958 \times 10^3}{7368 \times 10^3}$
(6)	Radiation and unaccounted losses (by difference)	1365 x 2200 14665 x 2200	$\frac{657 \times 10^3}{8025 \times 10^3}$
	Overall Thermal Efficiency	7368 8025 x 100	
		= 92 %	

#### HEAT BALANCE FOR FIRST EFFECT

	Heat Input	<u>B.</u> T. U.	K. Cal.
(1)	L. P. steam	9400 x 2200	5210 x 10 <sup>3</sup>
(2)	Liquor from fourth effect (23.70 x 2200) x $0.84$ x (161.0-32)	2400 x 2200 11800 x 2200	$\frac{1328 \times 10^3}{6520 \times 10^3}$
	Heat Output		
(1)	Heat in 1st effect condensate (8.0 x 2200) x 249.8	2000 x 2200	1108 x 10 <sup>3</sup>
(2)	Liquor to second effect (18.2 x 2200) x 0.8 x (268.8-32)	3400 x 2200	1880 x 10 <sup>3</sup>
(3)	Water evaporated in first effect (5.5 x 2200 x 1169.5)	6400 x 2200	3550 x 10 <sup>3</sup>
	TOTAL :	11800 x 2200	6538 x 10 <sup>3</sup>

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	Btu.	K. Cal.
Heat transferred across the tubes $Q_{12} = (9400 \times 2200) = 200 \times 2200)$	7400 x 2200	4100 x 10 <sup>3</sup>
$Q = (9400 \times 2200 = 200 \times 2200)$ Heating Surface A = 5850 sq. ft. Temperature Differential = (280.7-	7400 x 2200	100 / 10
$U_{\text{overall heat transfer co-efficient}}$ $= \frac{Q}{A. t.} = \frac{7400 \text{ x } 2200 \text{ Btu}}{5850 \text{ x } 13.7 \text{ h. sq. ft. °F}}$	= 204  Btu/hr. Ft. <sup>2°</sup> F.	995 K. Cal. hr./m <sup>2</sup> °C.
Design heat transfer co-efficient = 128 K. Cal./Hr. Ft <sup>2</sup> .°C. = 128 x 2.205 Btu/hr. ft. <sup>2°</sup> F.	= 283  Btu/hr. Ft. <sup>2°</sup> F	1380 K. Cal/ hr./m <sup>2°</sup> C.
Efficiency of the 1st effect on the basis of design heat transfer co-efficient.	995 x 100 1380	=72%

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# HEAT BALANCE FOR SECOND EFFECT

	Heat Input		Btu.	K. Cal.
(1)	Vapour from first effect		6450 x 2200	3580 x 10 <sup>3</sup>
(2)	Liquor from first effect		3400 x 2200	1890 x 10 <sup>3</sup>
(3)	Flash vapour 0.6 x 2200 x 1169.5		700 x 2200	388 x 10 <sup>3</sup>
		Total	10550 x 2200	5858 x 10 <sup>3</sup>

## Heat output

(1)	Semi concentrated black liquor	1570 x 2200	870 x 10 <sup>3</sup>
(2)	Evaporation in 2nd effect 6.1 x 2200 x 1148.2	7000 x 2200	3880 x 10 <sup>3</sup>
(3)	Condensate to 3rd effect ( $0.6 \div 5.5$ ) x 2200 x 233.4	1420 x 2200 9990 x 2200	788 x 10 <sup>3</sup> 5538 x 10 <sup>3</sup>
(4)	Unaccountable & radiation losses	560 x 2200 10550 x 2200	$\frac{320 \times 10^3}{5858 \times 10^3}$

Heat Transfer across tubes (O)	Btu.	$\underline{K. Cal}$
$= (450 \div 700 - 1420) \times 2200$	5730 x 2200	3180 x 10 <sup>3</sup>
Heating surface $A = 5850$ ft. <sup>3</sup> t = (264.5 - 219.0) = 45.0°F.		
Overall heat transfer co-efficient		
$U = Q = 5730 \times 2200$ A. t 5850 x 45.0	47.0 Btu/ hr. ft. <sup>2°</sup> F.	229 K. Cal/ Hr. m <sup>2°</sup> C.
Design Heat Transfer co-efficient	= 86 K. Cal/ Hr. $ft.^{20}F.$	
	$= \begin{array}{c} 86 \text{ x } 2.205 \\ \text{Btu/hr. } \text{ft}^{2\circ}\text{F.} \end{array}$	
·	$= 190 \frac{Btu/hr}{ft.^{2\circ}F}$	925 K. Cal/ hr. m <sup>2</sup> .°C.
Efficiency = $\frac{47}{190}$ x 100	= 24.7%	

# HEAT BALANCE FOR THIRD EFFECT

	Heat input	Btu.	K. Cal.
(1)	Vapours from 2nd effect	7000 x 2200	<b>3</b> 880 x 10 <sup>3</sup>
(2)	Condensate from 2nd effect	1420 x 2200	787 x 10 <sup>3</sup>
(3)	Liquor from WBL Storage	4500 x 2200	2500 x 10 <sup>3</sup>
	Total :	12920 x 2200	7167 x 10 <sup>3</sup>

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	Output	<u>Btu.</u>	K. Cal.
(1)	Liquor feed to 4th effect (30.3x2200) x 0.86 x (181.0x32)	3900 x 2200	2160 x 10 <sup>3</sup>
(2)	Evaporation in 3rd effect (6.9x2200) x 1137.5	7800 x 2203	4320 x 10 <sup>3</sup>
(3)	Condensate to 4th effect ( $0.6 \div 5.5 \div 6.1$ ) x 2200 x 172.9	2100 x 2200 13800 x 2200	$\frac{1160 \times 10^3}{764 \times 10^3}$
	Difference	900 x 2200	-4/3 X 10 <sup>3</sup>
	heating surface = $(7000 \div 1420 - 2100)$ 2200	=6320 x 2200	3500 x 10 <sup>3</sup>
	Heating surface 5850 ft <sup>2</sup>		
	A.t = $(205.0 - 181^{\circ}F) - 24$		
	$\mathbf{U} = \frac{0}{\mathbf{A}. \mathbf{t}} = \frac{6320 \mathbf{x} \ 2200}{5850 \mathbf{x} \ 24^{\circ} \mathbf{F}}$	$= 100 \text{ Btu/} \\ \text{Hr. ft}^{2\circ}\text{F.}$	488 K. Cal/ hr. m <sup>2</sup> °C.
	Design Heat transfer co-efficient	105 K/Cal./hr. Ft <sup>2</sup> °C.	
		==232 Btu/hr. ft <sup>2°</sup> F.	1137 K. Cal/ Hr. m <sup>2°</sup> C.

Efficiency =  $\frac{103}{232} \times 100 = 44\%$ 

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# HEAT BALANCE OF FOURTH EFFECT

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	Heat Input	Btu	K. Cal
(1)	Vapour from 3rd effect	7800 x 2200	4340 x 10 <sup>3</sup>
(2)	Condensate from 3rd effect ( $0.6 \div 5.5 \div 6.1$ ) 2200 x 172.9	2100 x 2200	1170 x 10 <sup>3</sup>
(3)	Liquor from 3rd effect	3900 x 2200	2160 x 10 <sup>3</sup>
	Total	13800 x 2200	7670 x 10 <sup>3</sup>
	Heat Output		
(1)	Evaporation in fourth effect 6.6 x 2200 x 1128.7	7450 x 2200	4120 x 10 <sup>3</sup>
(2)	Liquor to first effect	2400 x 2200	1320 x 10 <sup>3</sup>
(3)	Condensate to contaminated hot water tank - ( $0.6 \div 5.5 \div 6.1 \div 6.9$ ) x 2200 x 145.3	2760 x 2200	1530 x 10 <sup>3</sup>
	Total	12610 x 2200	6960 x 10 <sup>3</sup>
	Unaccounted and radiation losses ( by difference )	<u>1190 x 2200</u>	710 x 10 <sup>3</sup>
	Heat transfer across heating surface $Q = (7800 \div 2100 - 2760) 2200$	7140 x 2200	3960 x 10 <sup>3</sup>
	A = 5850  sq. ft.		
	t = (177.4 - 151) - 264		
	$U = O_{A. t.} = \frac{7140 \times 2200}{5850 \times 26.4}$	$= 101 \text{ Btu/hr.} \\ \text{Ft}^2 ^{\circ}\text{F.}$	493 K. Cal/ hr. m <sup>2</sup> °C.
	Design Heat transfer co-efficient	= 94 K. Cal/ hr. ft <sup>2</sup> °C.	
		= 210  Htu/hr. °F. ft <sup>2</sup>	1024 K/Cal. hr. m <sup>2</sup> °F
	Efficiency	$= \frac{101}{210} \times 100$	
		= 48 %	

## HEAT BALANCE FOR SURFACE CONDENSER

Input		Btu	K. Cal.
1) Vapour from 4th effect		7450 x 2200	4140 x 10 <sup>3</sup>
2) Cooling water (370 x 2200) x1x (94.0-32)		23000 x 2200	12740 x 10 <sup>3</sup>
	Total	30450 x 2200	16880 x 10 <sup>3</sup>
Output			
1) Warm water to Pulp Mill (370 x 2200) x 1x (112.0-32)		29600 x 2200	16400 x 10 <sup>3</sup>
2) Surface condensate		750 x 2200 30350 x 2200	416 x 10 <sup>3</sup> 16816 x 10 <sup>3</sup>
Unaccounted and radiation	losses		
(by difference)		100 x 2200 30450 x 2200	$\frac{64 \times 10^3}{16880 \times 10^3}$
Heat transfer across the tub = $(7450 - 750) \times 2200$	Des	6700 x 2200	3710 x 10 <sup>3</sup>

Area = A = 2810 sq. ft.

At : :-

	Inlet	Outlet
Vapour side	145.5	145.5
Water side	94.0	112.0
Difference	51.5	33.5
At =	$\frac{51.5\div 33}{2}$	$\frac{.5}{}$ = 42.5
U =	$\frac{0}{A. At.} = -$	6700 x 2200

0700	Y	2200	
2810	х	42.5	

 $= \frac{123 \text{ Btu/hr}}{\text{Ft }^{2^{\circ}}\text{F.}}$ 

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600 K. Cal/ Hr. M<sup>2</sup> °C.

# DESIGN HEAT TRANSFER CO-EFFICIENCY FOR SURFACE CONDENSER :

			British unit	Metric unit.
(1)	Vapours from 4th effe	ct	9.491 x 2200. lb.	9491 Kg.
(2)	Vapour pressure		1.94 psig	0.132 atm. abs.
(3)	Saturation Temp		125.6°F	51 <b>.78°C</b> .
(4)	Total Heat		1116.0 Btu/lb.	630 K. Cal/Kg.
(5)	Total Heat in vapours 9.491 x 2200 x 1116	_	10500 x 2200 Btu.	5800 x 10 <sup>3</sup> K. Cal.
(6)	Heat transferred acros tube (10500-650) x 2	s 2200 Btu ==	9850 x 2200 Btu.	5450 x 10 <sup>3</sup> K. Cal.
		Inlet	Outlet	
	Vapour side	51.78°C(125.6°F)	38°C (100.40F)	
	Water Side	46°C(114.8°F)	30°C (86°F)	
	Difference	5.78°C(10.8°F)	8°C (14.4°F)	
	At = $\frac{10.8 \div 14.4}{2}$	= 12.6°F.	12.6°F.	6.9°C
	$U = \frac{O}{A. t.} =$	9850 x 2200 2810 x 12.6 Btu/hr/°F.sq.ft.	670 Btu/hr °F/sq.ft.	3262 K. Cal/ hr. m <sup>2°</sup> C.
	Efficiency =	$\frac{123}{6700}$ × 100 =	18.4%	

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	Gauge Pressure psig or inches Hg. Vac,	Absolute pressure psig.	Satura— tion Temp. °F.	Sensi– ble heat Btu.	Latent Heat Btu	Total Heat Btu
Live steam	41.0 psig	55.7	287.9	257.3	919.5	1176.8
First Effect Calendria	35.0 "	49.7	280.7	249.8	924.9	1174.7
First Effect Vapour space & Second Effect Calendria	23.3 ,,	38.0	264.5	233.4	936.2	1169.5
Second Effect Vapour Space & Third Effect Calendria	3.8 Hg	13.1	205.0	172.9	975.3	1148.2
Third Effect Vapour space & Fourth Effect Calendria	15.6 Hg	7.2	177.4	145.3	992.3	1137.5
Fourth Effect Vapour space	20.5 Hg	4.3	159.2	127.1	100.5	1128.7

	%T.S. by Wt. (O.D.)	Specific Gravity	Specific Heat Cal- culated by Wt. average.
Weak Black Liquor	18.5	1.08	0.90
Third Effect Liquor from Fourth Effect Liquor from First Effect Liquor from Second Effect Water Black Liquor Solids	22.8 29.0 37.8 56.5	1.12 1.15 1.19 1.30 1.00	0.86 0.84 0.80 0.69 1.00 0.45

# PHYSICAL PROPERTIES OF BLACK LIQUOR

## TABLE VI

# WATER EVAPORATION IN DIFFERENT EFFECTS CALCUTTA TED ON THE BASIS OF CONCENTRATION.

	% Total solids	Lb. water per lb. B.L.S.	Solids through- put per hour	Water evapa- rated per hr.
Weak Black Liquor	1850	4.40	6.9	6.9 x (4.40-3.40) = 6.9 (III Effect) 6.9 x (3.40-2.45)
Liquor from IV Effect Liquor from I Effect Liquor from II Effect	29.00 37.8 56.5	2.45 1.65 0.77	6.9 6.9 6.9	= 6.6 (IV Effect) $6.9 \times (2.45-1.65)$ = 5.5 (I Effect) $6.9 \times (1.69-0.77)$ = 6.1 (II Effect)
Weak Black Liquor		34.5 m <sup>3</sup>		
Solids/Hr. = $37.20 \times 0.1850$ S.C.B.L. Output = $\frac{6.9 \text{ Tons}}{1.2 \times 0.565}$		34.5 x 1.08 37.20 Tons 6.9 Tons/Hr. 9.4 m <sup>3</sup>		
1.3x0.365	=	12.20 Tons.		

#### TABLE NO. VII

	Tons	
Weak Black Liquor feed	37.20	0
Evaporation in III Effect	6.90	
Input Black liquor to IV Effect	30.30	
Evaporation in IV Effect	6.60	*
Input to First Effect	23.70	
Evaporation in I Effect	5.50	
Input to II Effect	18.20	
Evaporation in II Effect	6.10	
S. C. B. L. Produced	12.10	

#### TABLE VIII

#### TO CALCULATE FLASH VAPOURS

Air Heater Condensate			2.6 Tons
M. P. Condensate (Assumed)			1.3 Tons
L. P. Condensate ( ,, )			1.3 Tons
L. P. Steam Condensate			8.0 Tons
L. P. Pressure	35.0	) psig	
M. P. Pressure	150	psig	
Second effect calendria 23 psig.			
% Flash Vapours (35.0 to 23 psig)	= 2.1	5	
% Flash Vapours (150.0 to 23 psig)	= 11.78	3	
			(Table IV Efficient use
			of steam page 838).
Total Flash Vapours			

 $(8 \div 1.3) \times 0.0215 \div 1.3 \times 0.1178$ 

Flash Vapours by difference = 0.6 Tons.

 $0.20 \div 0.16 - 0.36$ 

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