SURVEY OF WATER UTILIZATION AND WASTE CONTROL PRACTICES IN THE SOUTHERN PULP AND PAPER INDUSTRY

by

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ABSTRACT

The state of water usage and water pollution abatement in the Southern Pulp and Paper Industry was studied by surveying forty-six mills which produce about 60% of the total pulp and paper output of this region.

The study covered use and treatment of fresh water, reuse of water in the mills, the amount of waste water and pollutants, waste treatments, and sludge disposal.

The amount of waste water from the surveyed mills amounted to about 1,200 million gallons per day containing about 2.5 million pounds of BOD which was reduced to about 1.3 million pounds after treatment.

Six areas of research are recommended.

Survey of Water Utilization and Waste Control Practices in the Southern Pulp and Paper Industry

I. INTRODUCTION

The objectives of this investigation were to find the present status of water usage and water pollution abatement in the Southern pulp and paper industry and to define research needs. Principals of the leading companies were invited to participate in a survey of water usage and pollution practices in the Southern mills. The response was almost unanimously positive. During May and June of 1968, copies of the comprehensive questionnaire, which is shown in the Appendix, were submitted to 60 pulp and paper mills. The return of the questionnaires proceeded relatively slowly, mainly due to lack of manpower for gathering the information requested. By the end of 1969, 46 questionnaires had been returned. Most were only partially completed. In order to get additional information and to clarify some of the information provided in the returned questionnaires, visits were made to 36 mills by one of the investigators.

The questionnaires returned covered 60.5% of the pulp production and 61% of the paper products in the South.

Forty-two of the mills were integrated pulp and paper or board mills, two were board mills, and two mills were producing high quality bleached pulps. The types and quantity of the pulps produced in the surveyed mills are given in Table 1.

About 85% of all pulps produced in the South are Kraft pulps. This explains why most of the surveyed mills are Kraft mills. Currently the pulp and paper industry in the South comprises 84 integrated pulp and

Table 1. Types and quantity of pulps produced in the surveyed mills

Types of Pulp	Number of Mills	Tons per Day	Percent of Production in the South (1969)
Kraft, total	43	41,915	about 70
Kraft, bleached	22	14,300	" 54
Groundwood	5	2,530	" 49
NSSC	9	1,740	" 46
Soda	1	180	" (100)
Pulp from Waste Paper	3	730	Not Available

paper mills, 11 pulp mills, and 70 paper board and felt mills (1). The daily production capacity in the South for 1970 is about 79,000 tons of pulp and 77,500 tons of paper and board. This is about 62% of the pulp production and 46.5% of the paper production in the U.S.A. (1).

For an effective comparison of the data compiled from the questionnaires, it was necessary to separate the mills into several groups. The classification of the mills is given in Table 2.

II. DISCUSSION OF RESULTS

1. Fresh Water Use and Treatment

The amount of fresh water used for production of 1 ton of product varied considerably. It was very dependent on the type of product, the availability of water, the types of unit operations, and the degree of water reuse. The fresh water demand for the different categories of surveyed mills is shown in Table 3.

Table 2. Classification of the surveyed mills

Group of Mills	Type of Product	No. of Mills	Size of Mills, Tons of Product per Day
A	Unbleached Kraft pulp & paper	15	250 - 1870
B	Bleached Kraft pulp & paper	5	700 - 1400
C	Unbleached and bleached Kraft pulp & paper	7	160 - 1100
C-g	Unbleached and bleached Kraft and groundwood pulp & paper	5	590 - 1465
D	NSSC & waste-based pulp & paper	1	800
E	Unbleached Kraft & NSSC pulp & paper	5	725 - 2500
F	Bleached Kraft & NSSC pulp & paper	1	1250
G	Unbleached and bleached Kraft & NSSC pulp & paper	2	1300 - 1450
H	Unbleached Kraft pulp & paper (10%)	1	860
I	Bleached pulp (highly purified)	2	570 - 1100
J	Board from waste paper	2	110 - 120

Table 3. Fresh water demand in pulp and/or paper mills, producing different kinds of products

Group of Mills[a]	No. of Mills	Average Water Demand gal/ton Product	Range of Water Demand gal/ton Product
A	13	24,000	14,000 - 36,000
B	5	46,000	34,000 - 65,000
C	6	35,000	25,500 - 42,500
C-g	5	31,000	23,000 - 51,000
D	1	29,600	(29,600)
E	5	23,200	15,000 - 40,000
F	1	28,300	(28,300)
G	2	25,900	21,800 - 30,000
H	1	13,400	(13,400)
I	2	65,400	52,500 - 88,000
J	2	2,150	1,200 - 3,100

[a]The classification of the mills is given in Table 2.

The total fresh water demand of the surveyed mills amounted to about 1,425.4 MGD, of which 981.6 MGD (69%) was river water and 443.8 MGD (31%) was well water. Twenty-two of the mills obtained their water from rivers, 12 mills used only well water, and 11 mills took their water both from wells and rivers.

Sixty-two and one-half percent or 891 MGD, of the fresh water was treated for removal of colloidal dispersed matter. The types and costs of water treatment in the surveyed mills are shown in Table 4.

The cost of the raw river water was about 0.5¢/1000 gallons. For well water it varied from about 0.5¢ to 4.5¢/1000 gallons. The major expense for raw water was pumping cost. The cost of treatment of process water varied from about 1-4¢ per 1000 gallons, depending on the types of treatment and amounts of impurities in the raw water.

Typical investment for treatment of process water was about $25 per 1000 gallon daily capacity.

The purity requirements for boiler feed water are very high, so demineralized water must be used. Typical cost figures were 6.5¢-10¢/1000 gallons. However, a few mills paid up to $.50 per 1000 gallons. The investment for demineralizer equipment varies from about $40 - $360 per 1000 gallon daily capacity. The consumption of makeup water for the boiler in an integrated pulp and paper mill is about 1500 gallons per ton of product.

2. <u>Water Reuse</u>

The use of effluent from one unit operation as process water for another unit operation, or the reuse of discharged water in the same

Table 4. Types and costs of fresh water treatment in the surveyed mills

Group of Mills	No. of Mills with Sedimentation or Filtration Only*	Cost of Water (¢/1000 gal)	No. of Mills With Flocculation and Sedimentation*	Cost of Water (¢/1000 gal)	No. of Mills With Hardness Removal, Flocculation & Sedimentation	Cost of Water (¢/1000 gal)
A	7	0.5-2.0	6	2.2-2.9	2	about 4.5
B	2	about 3.2	3	2.1-5.0	-	-
C	2	-	4	2.7-4.3	1	" 3.5
C-g	2	about 2.0	2	2.5-2.7	1	" 3.5
E	1	-	2	-	1	" 3.5
F	1	1.6				
G	1	1.2	1	2.2		
H	1	5.5**				
I	-	-	-	-	2	-
J	2	-				

*With or without chlorination.

**Well water.

unit operation after treatment, will be characterized as true water reuse.

Extensive reuse of water can lead to substantial savings in fresh water. The survey of the Southern pulp and paper industry revealed that a high degree of water reuse is practiced in the pulping and recovery departments in the majority of the mills. Table 5 demonstrates how the different types of effluents are reused.

The condensate and the cooling water from the blow gas condensers is mainly used for washing of the unbleached pulps. Most of the mills use direct contact condensers. The water from these is contaminated with the odorous organic sulfur compounds, hydrogen sulfide, the turpentine compounds, methanol and acetone. The carry-over of obnoxious odor and also of oxygen-demanding substances to the effluents of the following unit operations are disadvantages of using the direct condensate as process water. The cooling water from the turpentine or blow gas surface condensers is usually hot and clean and can be utilized as process water any place in the mill. The effluents from the indirect blow gas condensers, as well as from the turpentine decanters, are highly contaminated and commonly discharged to the sewer. Steam or air stripping of these relatively low volume streams, followed by burning of the volatile compounds, will reduce both air and water pollution and make these effluents more suitable for reuse in the pulp mill or recovery.

The condensate from the evaporators is frequently used as process water in the pulp mill as well as in the chemical recovery operations. The condensate contains the volatile components of the spent cooking liquor, previously referred to, including a substantial amount of hydrogen sulfide. It has a high oxygen demand and will be a major pollution source

Table 5. Reuse of effluent from different unit operations in the surveyed mills

Type of Effluent	Amount of Effluent* (gal/ton)	Place of reuse	No. of Mills Reporting
Blow gas condensate, direct	1500-5900 Average: about 2000	1. Brown stock washing	16
		2. Screen room or decker operation	1
		3. Hot water supply	1
		4. Mud washing	1
		5. Dissolving of additives	1
Blow gas condensate, indirect	350-400	(1. Sewer)	
Cooling-water for blow-gas condenser, indirect	1500-5900 Average: about 2000	1. Hot water supply	2
		2. Brown stock washing	3
		3. Bleached stock washing	1
		4. Screen room or decker operation	1
Turpentine-decanter	10-165 Average: 50	(1. Sewer)	(12)
		2. Showers on knotter	1
		3. Showers on brown-stock washers	3
Cooling water for turpentine condenser	650-2400	1. Hot water supply	1
		2. Screen room	1
		3. Boiler make-up water	1
		4. Direct blow-heat condenser	1
Evaporator condensate	675-2800 Average: About 1500-2000	1. Brown stock washing	9
		2. Lime kiln scrubber	4
		3. Cooking liquor preparation	10
		4. Mud-washing or dreg washing	6
		5. Woodyard	1
		6. Wash-ups	3
		(7. Sewer)	1
		8. Boiler make-up water	1
Evaporator barometric effluent	8000-15000	(1. Sewer)	6
		2. Transport of bark-boiler fly ash	1
		3. Recycled through cooling-tower	2

(continued)

Table 5. (Continued)

Type of Effluent	Amount of Effluent* (gal/ton)	Place of reuse	No. of Mills Reporting
Cooling water for evaporator surface condensers		1. Hot water supply 2. Machine showers in paper mill	
Evaporator seal pit, discharge from surface condensers	400-1550	(1. Sewer) 2. Brown stock washing	
Effluent from mud washers	475-1640 Average: 800-1100	1. Melt dissolving tank 2. Lime kiln scrubber	25 1
Discharge from screen room (decker)	710-10500	(1. Sewer) 2. Brown stock washing 3. Barometric evaporator condensers 4. Dilution of high density stock 5. Repulper 6. Centricleaners 7. Wash-ups 8. Woodyard 9. Cowan screen (showers) 10. Log washing (woodyard)	
Bleach Plant Seal Pits			
Chlorination stage	(10500)	(1. Sewer) 2. Consistency regulation of brown stock to chlorination tower 3. pH control of brown stock 4. Screen room (dillution water)	10 1 1

(continued)

Table 5 (Continued)

Type of Effluent	Amount of Effluent* (gal/ton)	Place of reuse	No. of Mills Reporting
1st Caustic extraction	(4250)	(1. Sewer) 2. Showers on chlorination-stage washer 3. Consistency regulation of stock to caustic extraction tower 4. Woodyard (flumes)	10
1st Hypo-chlorite stage	(920)	(1. Sewer) 2. Showers on caustic extraction-stage washers 3. Consistency regulation of stock to hypo-stage tower	
2nd Caustic stage		(1. Sewer) 2. Showers on 1st hypo-stage washers 3. Consistency regulators	
2nd Hypo-chlorite stage	(2500)	(1. Sewer) 2. Showers on 2nd caustic-stage washers 3. Consistency regulators	
Chlorine Dioxide stage		(1. Sewer) 2. Showers on other bleaching stage washers 3. Consistency regulators 4. Screen room dilution water 5. Centricleaners	
Hydrogen Peroxide stage		1. Showers on chlorine dioxide stage washers (pH control)	
Paper or Board Mill			

(continued)

Table 5 (Continued)

Type of Effluent	Amount of Effluent* (gal/ton)	Place of reuse	No. of Mills Reporting
Savealls	2450-6100	1. Machine showers	15
		2. Pulp mill	13
		3. Recovery	1
		4. Wash-ups	2
		5. Vacuum pumps	4
		6. Centricleaning	1
		7. Consistency regular	2
		8. Barometric evaporator condensers	1
		9. Repulping of broke	1
		10. Bleach plant	1
Vacuum pumps		1. Recycled to vacuum pumps	5
		2. Pulp mill (dilution)	1
		3. Hot water supply	1
Paper or board mill waste water		1. Pulp mill or waste paper repulping	3
		2. Machine showers	2
		3. Consistency regulators	2
		4. Barometric evaporator condensers	1

*Total effluent from these operations.

if discharged to the sewer. Therefore, reuse of condensate within the mill in such places as the chemical recovery operations, where it is returned to the system, is very advantageous. The majority of mills have direct barometric condensers on their evaporator, and a large volume of water is contaminated by "dirty" condensate. Generally, this water is directly discharged to the sewer. Cooling water from the evaporator surface condenser can be used as the hot water supply for any operation in the mill.

The effluents from the surface condensers, which are evaporator condensate and ejector water, are suitable for brown stock washing, especially if it is stripped of its odorous volatile compounds.

The discharged water from the screen room, or more specifically the decker, is used in many of the unit operations in the pulp mill and woodyard as can be seen in Table 5. However, the trend is to make the water system in the screening operation as closed as possible, or perform the screening before brown stock washing where weak black liquor can be used for dilution.

In the bleach plant a lot of water is needed for dilution of the high consistency stock from the pulp mill to a consistency of 3-3.5% used in the chlorination stage. Effluent from the chlorination stage can be utilized, at least partially, for this purpose as demonstrated in two of the mills.

The use of effluent from one bleaching stage as wash water for a preceding one is practiced in a few mills. In this way a considerable amount of fresh water can be saved as one to two displacement washings are practiced after each bleaching stage. It would also cut the amount of waste water from the bleach plant tremendously. In a modern bleach plant, waste water should only be discharged from the chlorination and first alkaline extraction stages.

Application of Savealls in paper and board mills have reduced the intake of fresh water to a very high degree. The clarified white water is now widely used in paper and board machine showers, which require about 5000 - 6000 gallons of water per ton of production.

Theoretically, all dilution water and shower water could be recirculated white water in a "closed" system. The effluent white water from the paper or board mill would then be reduced to about the difference between the amount of water in the pulp transferred to the mill and the water in the fiber mat leaving the wet-end of the machine. Different inorganic and organic substances are present in the pulp and/or are added to the fiber suspension in the paper mill for improvement of certain properties. The portion of these substances which are not retained in the fiber mat would, if dissolved, be present in the recirculated white water at concentrations reciprocally proportional to the amount of effluent from the system. Some of the substances, such as sulfates, chlorides, and dissolved organics could, if present at high concentrations, adversely affect the runability of the paper or board machine, the properties of the products, and/or the corrosion of manufacturing equipment. The tolerance limit of certain chemicals in the white water system will dictate the amount of fresh water used and, thereby, the waste water load from a paper or board mill. Little definitive information is available on tolerance limits of the chemicals normally present in white water.

Closed systems with negligible discharges of waste water have been adopted in two of the surveyed board mills producing "low-grade" products from waste paper. In these mills a high concentration of impurities can be tolerated.

Clarified white water from the Savealls is further used as process, cleaning and cooling water in the bleach plant, in the pulp mill, in the recovery, and in the woodyard.

The amounts of sealing and cooling water for vacuum pumps on a paper or board machine can be substantial and amount to 6000-7000 gallons per ton of product. This water can be recycled or used as process water in many places in the mill.

Huge volumes of water, about 20,000 - 30,000 gal/ton of product, are used for cooling of the turbines in the power house. This water can be utilized as process water in the mill, returned to the water reservoir, or be recycled through a cooling tower.

3. Waste Load from Different Types of Mills before Treatment

The amount of untreated liquid effluent and the load of water pollutants from different types of pulp and/or paper mills is illustrated in Table 6 and Figure 1. It is interesting to note the differences which exist within each group of mills. This is mainly caused by variation in housekeeping practices and in water reuse and, to some degree, by the type of equipment in the different unit operations. Differences between the groups are due to variation in products. Mills making high brightness papers or boards produce about half of their waste load from the bleach plant. The chemicals added during the bleaching operations are presently not recovered, therefore, the bleach plant is the major single source of BOD, dissolved solids, and color.

Production and use of the high yield semichemical pulps or groundwood pulps in an integrated mill will, in general, reduce the pollution load per ton of total production. This is mainly due to the higher pulp yield. Typical waste loads from different production units in a modern integrated pulp and paper mill, with good housekeeping are given in Table 7. The data are based on the information given by the surveyed mills. In Figure 1 the total BOD_5-loads from the individual mills are presented as a function of the BOD_5 in their raw waste effluent in pounds per ton of product.

Table 6. Pollution load in raw waste water from the different types of surveyed mills

Group of Mills**	Amount of Waste Water (gal/ton of Product)	BOD_5 (lbs/ton of Product)	Suspended Solids (lbs/ton of Product)	Dissolved Solids (lbs/ton of Product)	Color* (lbs/ton of Product)
A	10,900-27,800 (12) Ave. 18,500	19.5-69.5 (12) Ave. 43.0	10- 99 (10) Ave. 37.5	84-200 (4)	250 (1)
B	24,400-56,000 (5) Ave. 38,000	46 - 128 (5) Ave. 78.5	93-460 (5) Ave. 205	325-540 (3)	300-290 (3)
C	31,000-90,000 (6) Ave. 37,000	54.5-84.0 (6) Ave. 67.0	61-226 (5) Ave. 100	365 (1)	435 (1)
C-g	19,000-26,000 (5) Ave. 23,200	30.1-59.0 (5) Ave. 44	90-150 Ave. 43	190-250 (3)	110-175 (2)
D	6,000 (1)	26.5 (1)	-	-	-
E	15,000-22,000 (5) Ave. 18,600	20 -47.5 (5) Ave. 35	32-49 (5) Ave. 43	28-115 (2)	160-175 (2)
F	21,600 (1)	54.0	108.0	460	375
G	21,800-28,300 (2)	30.5-50.0	73 (1)	225-235	305 (1)
H	13,400 (1)	44.0	56.0	112	-
I	52,500-79,000 (2)	108 -140	210 (1)	750-980 (2)	-
J	0- 750 (2)	0- 7.5	0- 12.5	0-14	-

( )Number of mills included.

*Based on platinum equivalents in cobalt chloroplatinate (color units), and exposed as lbs/ton.

**Classifications of the mills are given in Table 2.

Table 7. Water pollution load (untreated) from different production units in a modern Kraft pulp and paper mill with good housekeeping

Location of Effluent	BOD_5 (lbs/ton of Product)	Suspended Solids (lbs/ton of Product)	Amount of Waste Water (gal/ton of Product)	BOD_5 (ppm)
Wood preparation & pulping	2	9	950	250
Evaporation, Recovery and Liquor preparation	11	17	5000	260
Bleaching	27*	14	14000	230
Papermaking	6	36	7500	100
Whole Mill	46	76	28000	200

*For pine pulp.

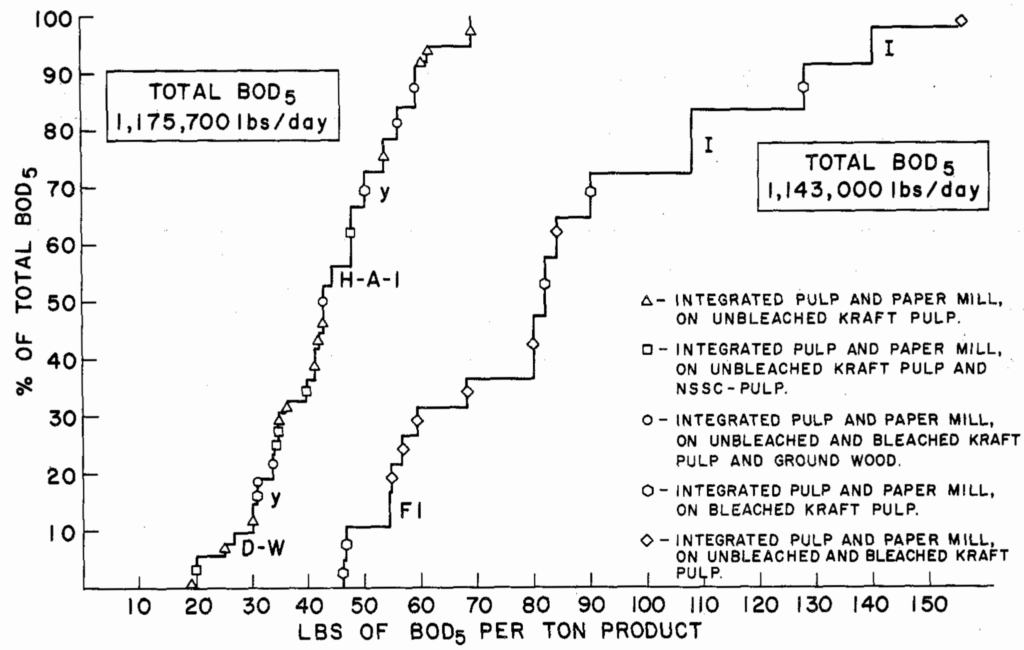

Figure 1. Summative biochemical oxygen demand in untreated waste water from the surveyed mills in relation to their pollution load per ton of product.

Left curve represents the mills producing mainly unbleached products. (Group I).

Right curve represents the mill producing mainly bleached products. (Group II).

Y: Integrated Pulp and Paper Mills, on unbleached and bleached Kraft pulp and NSSC-Pulp.

H(AI): Integrated Pulp and Paper Mill, having an output of 90% Kraft pulp and 10% Kraft paper.

DW: Integrated Pulp and Paper Mill, on NSSC-Pulp and Waste board pulp.

FI: Integrated Pulp and Paper Mill, on bleached Kraft pulp and NSSC-Pulp.

I: Pulp mills, producing highly purified pulps.

In this figure the mills are divided into two groups, depending on their pollution potential. The biochemical oxygen demand (BOD_5) in the unbleached waste water from each mill is expressed in percent of the total BOD_5 in the waste water from all the mills in the group. The left curve in Figure 1 represents the group of mills producing mainly unbleached products (Group I). The right curve represents the group of mills, producing mainly bleached products (Group II). The curves show a summative picture of the pollution loads, which means that the mills are arranged in the figure according to their BOD_5 effects per ton of product and their percent of the total BOD_5 from the corresponding group of mills. The two board mills with "closed" process water systems are not included in the figures.

The amount of raw waste water from the surveyed mills, representing about 60% of the production capacity in the pulp and paper industry in the South, is about 1,200 million gallons per day. The untreated waste water contains about 2.3 million lbs of BOD_5 which is equivalent to the biological oxygen demand of human waste in effluent water derived from a city of about 13.5 million people.

4. Waste Treatment

a. Primary treatment. Removal of suspended solids from waste water by primary treatment was performed in 37 of the surveyed mills. One mill had a primary treatment facility under construction. Twenty-six mills, discharging 710 MGD, used mechanical clarifiers. The most common sizes of clarifier were about 100-300 feet in diameter and 12-14 feet in depth. The retention times varied from about 1.5-9 hours, with an average of about 2-4 hours. Suspended solids removal of 60-95% and BOD_5-removal of 15-30% was reported by the mills. Consistency of the sludge obtained from the clarifiers varied from 0.6-3%. Eleven of the mills discharging about 300 MGD removed their suspended solids in settling ponds, which were 6-12 feet deep and 1-30 acres in area. From 55 to 98% of the suspended solids were removed by the settling pond treatment.

As shown in Table 8, seventeen of the mills using mechanical clarifiers and 10 of the mills using settling ponds reduce their suspended solid content in the final discharged waste water to less than 10 lbs per ton of production.

Table 8. Primary treatment of waste water in the surveyed mills (1968-1969)

Type of Treatment	No. of Mills With the Specific Treatment	No. of Mills with Effluent Waste Water Containing Less Than 10 lbs Supsended Solids Per Ton Production
Mechanical Clarifier	26	17
Settling Pond	11	10
No Treatment	7	--

b. Secondary treatment. Table 9 illustrates the 1968-69 status of secondary treatment of waste water by the Southern pulp and paper industry. The treatment in 15 mills (285 MGD) was performed in stabilization basins or storage lagoons, 10 mills (310 MGD) used aerated lagoons which were followed by impoundment in 5 of these mills; and 3 mills (about 100 MGD) used activated sludge treatment, and one mill disposed of its waste by irrigation.

The stabilization basins were shallow multiple basin systems 1.5-21 feet (average 4-8 ft.) deep and varied from about 25-2300 acres in total size. Average waste water retentions in the stabilization basins from 3 up to 270 days, and BOD_5 removal from 10 to 95% was reported. An advantage of large capacity stabilization basins is that all discharge of waste water can be interrupted during hot and dry summer months and when the fish are "running" in the receiving water. Only six out of the 15 stabilization basins reduced the BOD_5 content in the final discharged waste water to less than 10 lbs BOD_5 per ton of production. Some mills are forced to reduce their BOD_5 discharge

Table 9. Secondary treatment of waste water in the surveyed mills (1968-1969)

Type of Treatment	No. of Mills with the Specific Treatment	No. of Mills with Effluent Waste Water Containing less than 10 lbs BOD_5 per ton of Production
Stabilization Basin (Storage Lagoon)	15	6
Aerated Lagoon	5	3
Aerated Lagoon followed by Stabilization Basin	5	4
Activated Sludge	3	3
Irrigation	1	
No Treatment	17	-
	46	17

to less than 5 lbs BOD_5 per ton of production during the hot summer months in order to keep the dissolved oxygen level in the receiving water above the required 4 ppm.

The land requirements for natural stabilization basins are 50-90 acres per MGD of waste water.

The aerated lagoons occupied from 1.5-13.5 acres (average about 3) per MGD of waste water, and were from 4 to 12 feet in depth. The mechanical aeration applied varied from 8-50 HP (average 20-30 HP) per MGD of waste water. The retention times were from 3-25 days. A typical aerated lagoon system is illustrated in Figure 2. In the five mills where storage of the waste water in stabilization lagoons followed the aeration treatments, the retention time in the lagoons varied from 10-62 days (average about 20 days). The storage lagoon usage varied from 8-22 acres per MGD. Three of the 10 mills added nutrients. The efficiency of the BOD removal varied from 50-90% for the mills with the aerated lagoon system. Three of the mills with aerated lagoons only, and four of the mills where storage lagoons followed aerated lagoons, reduced their BOD_5 discharge to less than 10 lbs per ton of production. (Ref. Table 9). One of the mills pretreated its waste water in a PVC constructed trickling filter where nutrients were added. The BOD reduction in this unit was reported to be about 20% during the summer months and 35-40% in the winter.

Activated sludge treatment was used in three of the surveyed mills and one mill had a unit under construction. The activated sludge process is primarily used by mills which are located in an area where land is not available or is too expensive for building of an aerated lagoon system. The land requirement for the activated sludge treatments is only 0.04-0.08 acres

Figure 2. Secondary treatment in a typical aerated lagoon system.

per MGD of waste water. The time of aeration varied from 1-20 hours, and 30-70% of the sludge was said to be recirculated. Nutrients (NH_3 and P) were always added. The produced sludge is usually removed and dewatered with the sludge from the primary clarifier. The amount of sludge produced can vary from 0.2-0.6 lbs solid per lbs BOD_5 removed. The efficiency of the BOD_5 removal varied from 70-90%. All of the mills with activated sludge treatment had less than 10 lbs. BOD per ton of production in their effluent. A typical activated sludge system is shown in Figure 3.

One mill disposed of its waste water by irrigation. The land used was 29 acres per MGD and grass was used as cover crops. Spraying was performed for 18 hours and interrupted for 6 hours. No data for BOD removal were available.

The discharge of biochemical oxygen demanding matter to receiving water by the surveyed mills, representing about 60% of the production capacity in the South, is illustrated in Figures 4 and 5.

Figure 4 shows the total BOD_5 discharges from the individual mills producing products mainly from unbleached pulps (group I in Fig. 1), as a function of their BOD_5 losses in lbs per ton production.

Figure 5 shows the same thing for the mills whose products were mainly from bleached pulps (group II, in Fig. 1).

It should be noted that the one mill having an activated sludge unit under construction, expected that their BOD_5 discharge to receiving water will be reduced from about 55 lbs to less than 5 lbs per ton of production by the secondary treatments. This is indicated in Fig. 5.

For group I the average BOD_5 reduction by waste treatment was 37% compared with 50% for group II. The average BOD_5 reduction for all mills was about

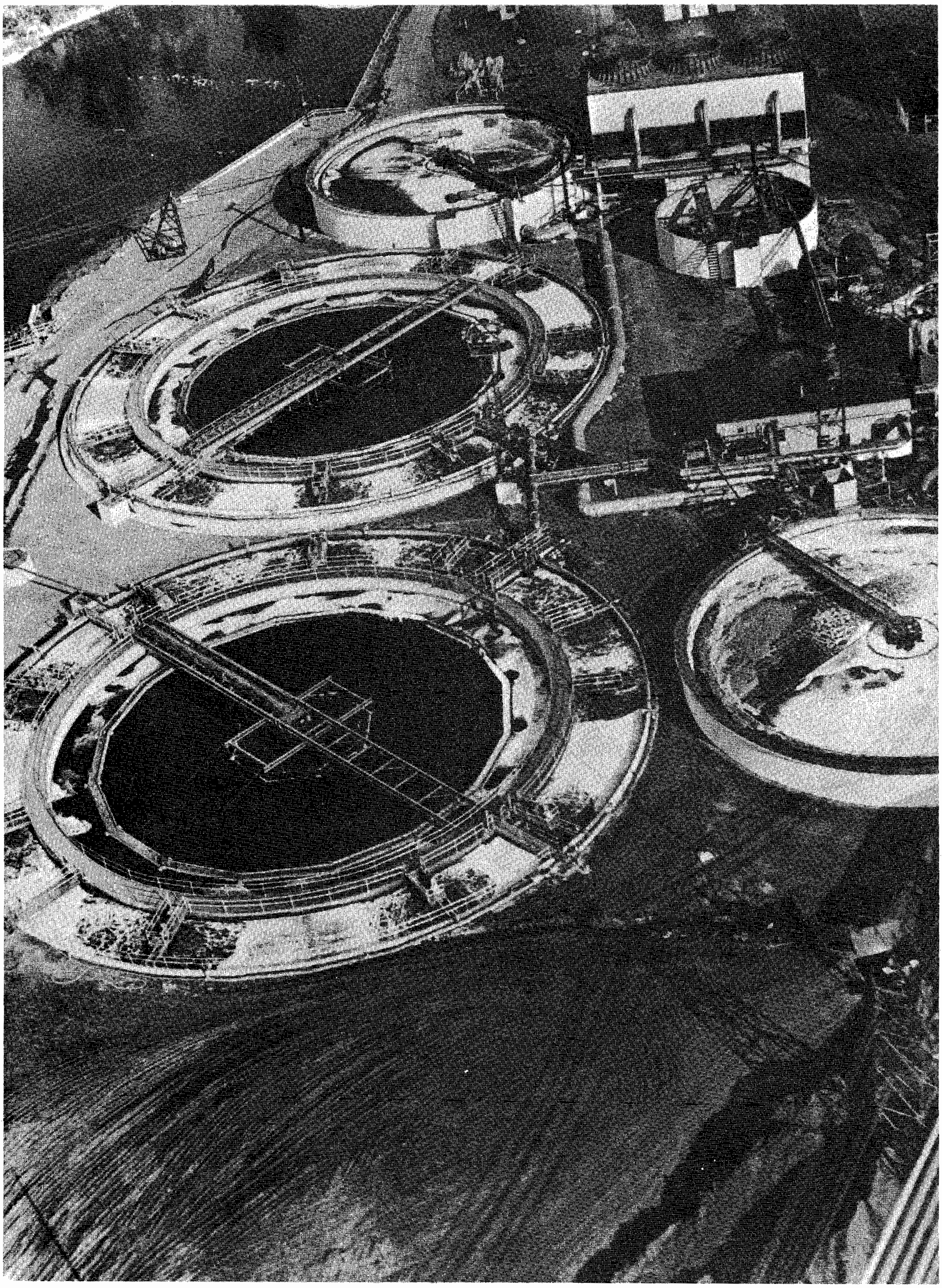

Figure 3. Secondary treatment in an activated sludge system.

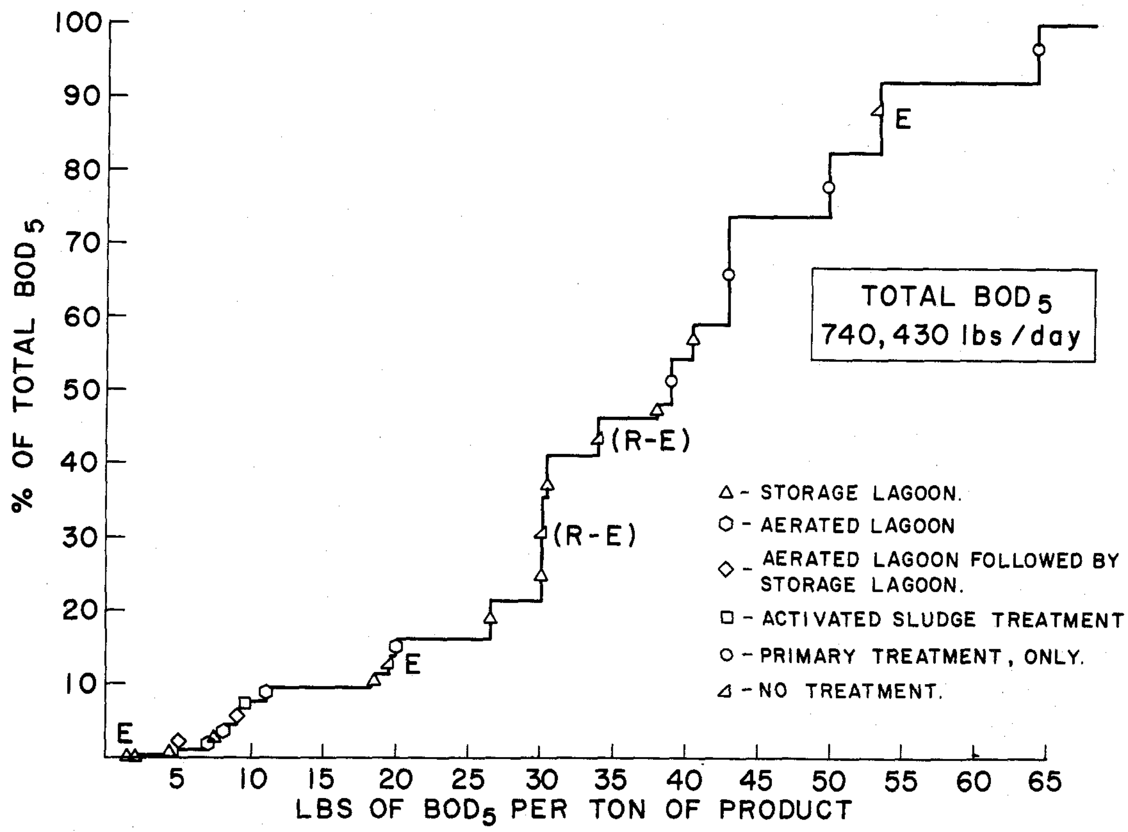

Figure 4. Summative biochemical oxygen demand in waste water discharged from the mills, producing mainly unbleached pulps, as a function of their BOD_5 losses per ton of product

E = Discharge to Estuary

R - E = Discharge to River-Estuary type basin

All others: Discharge to River

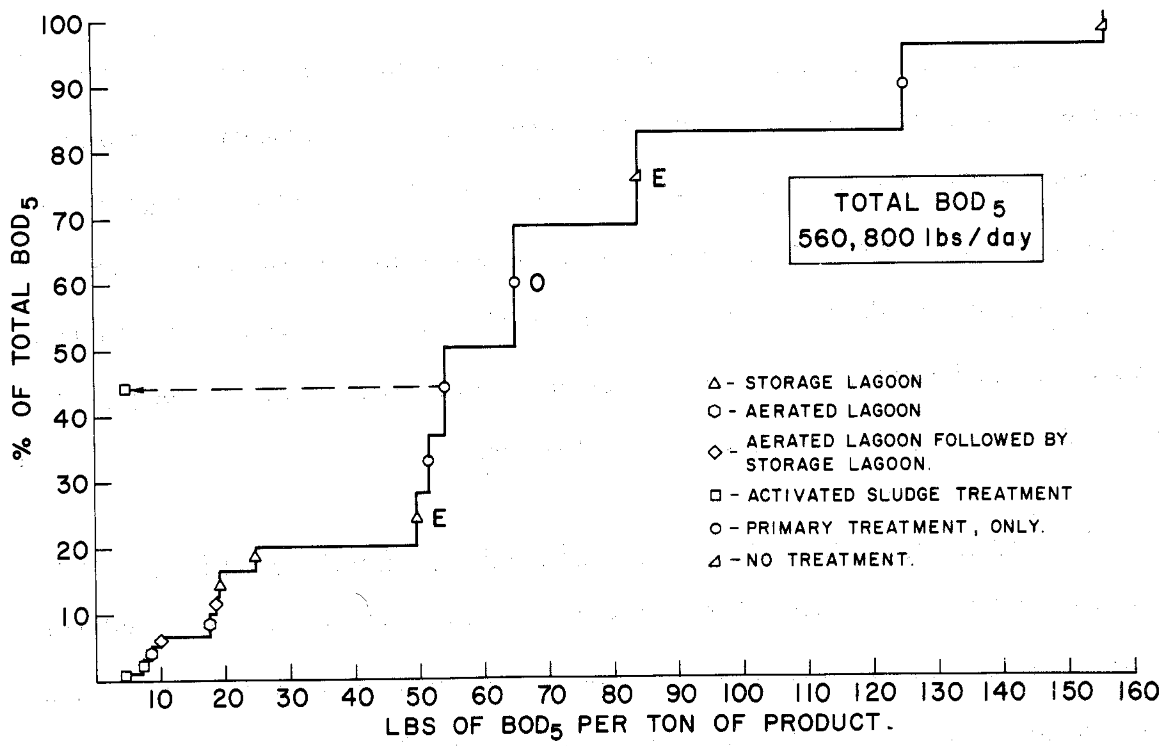

Figure 5. Summative biochemical oxygen demand in waste water discharged from the mills, producing mainly bleached products, as a function of their BOD_5 losses per ton of product

E = Discharge to Estuary

0 = Discharge to Ocean

42.5%, which means that about 1.3 million lbs of BOD_5 per day was discharged to receiving waters from the surveyed mills. This is equivalent to the waste load from 7.5 million people.

As indicated in Figures 4 and 5, most of the mills discharged their waste water into rivers. Five mills let their effluents go into estuaries; two mills discharged into river-estuary type basins, and one mill had ocean outfall.

c. Tertiary treatment. One of the surveyed mills producing unbleached Kraft pulp and linerboard carried out color removal in their combined waste water. The colored matter, which consists of degradation products from lignin, was precipitated by the addition of lime (about 190 lbs/ton of production) to the mill effluent. The used lime was not recovered, but settled and was disposed of with the primary sludge. More than 90% of the color is removed by this treatment.

d. Disposal of sludge from primary and secondary treatment. The principal problem of waste treatment is the disposal of the settled suspended solids, namely the sludge. The old method is to pump the sludge leaving the clarifier (at a consistency of 0.6-3%) to storage lagoons. The lagoons were usually abandoned when they were filled. Twenty-three of the surveyed mills disposed of their sludge by lagooning (see Table 10). The mills which did not have land available for lagoons, or were afraid of the odor problem it might create, disposed of their sludge by trucking it away for land fill or by burning. In both cases the solid content had to be increased considerably, which is done by the use of vacuum filters, by centrifuges, or presses. Pressing, combined with filtering or centrifugation, may be necessary for an economical incineration process.

Six of the mills used centrifuges, two mills filter, and one mill presses for dewatering. The sludge from secondary treatment is usually mixed with the primary sludge in order to enhance its ability to lose water.

Eight of the surveyed mills disposed of their sludge by land filling, three mills used incineration, and two mills returned the sludge to their board making process. One mill reported that it recovered the long fiber fraction from the waste water and sold it.

e. Cost of waste treatment. The cost of different types of waste treatment in the surveyed mills is illustrated in Table 11.

The figures are based only on information from the mills which provided a treatment good enough to reduce the BOD_5 and suspended solid content in their effluent waste water to less than 10 lbs per ton of production. The investment cost for primary and secondary treatment was highest for mechanical clarification followed by activated sludge treatment. An investment of $1930-2900 per daily ton of production and operating costs varying from $0.82-1.60 per ton of product was reported for this type of treatment.

Mechanical clarification followed by aerated lagoons required an investment of about $1120-1930 per daily ton of production capacity, and $0.80-0.90 per ton of product in operational cost. Using settling basins instead of mechanical clarifier reduces somewhat the average investment, and amounts to only $0.30-0.35 per ton of product in operating cost for primary and secondary treatment combined. Incorporating of color removal in the waste treatment considerably increased the investment as well as the operating cost. Treatment of waste water in settling basins followed by long retention stabilization basins is by far the lowest cost treatment if inexpensive land is available.

Table 10. Disposal of primary and secondary sludge in the surveyed mills

Type of Sludge	Amount of Ovendry Sludge (lbs/ton Production)	Method of Increasing the Solid Content	Solid Content of the Sludge (%)	Method of Disposal
Primary	12-240	a. None (24) b. Filter (1) c. Centrifuge (5) d. Presses (1)	0.6-3 20 17.5-30 35-40	a. Lagooning (3) b. Landfill (6) c. Incineration (3) d. Reuse (2 + 1)
Primary and sludge from color removal	-	a. None (1)	2.75	a. Lagooning (1)
Primary and Secondary	91-110	a. None (1) b. Filter (1) c. Centrifuge (1)	1.5 22 22	a. Lagooning (1) b. Landfill (2)

( ) Indicate the number of surveyed mills which have given the specific information.

Table 11. Cost of waste water treatment in the surveyed mills

Type of Treatment	Investment Cost: $ per 1000 Gal. Daily Capacity	Investment Cost: $ per Ton of Daily Production	Operating Cost: ¢ per 1000 of Gal. Treated Waste	Operating Cost: $ per Ton of Production
Mechanical Clarifier/ Activated Sludge	47-135	1930-2900	2.3 - 7.4	0.82 - 1.60
Mechanical Clarifier/ Aerated Lagoon	46- 84	1120-1930	2.3 - 3.8	0.80 - 0.90
Settling Ponds/ Aerated Lagoon	50- 64	1270-1380	1.1 - 1.3	0.30 - 0.35
Mechanical Clarifier/ Stabilization Basins	360*	6400*	12.5*	2.20*
Settling Pond/ Stabilization Basins	(5.0)	(75)	-	-

*Cost given includes removal of color by precipiation with lime, without lime recovery.

III. RESEARCH NEEDS

Based on the information in the questionnaires returned and on a recent literature survey (2, 3), the following research needs have been established.

1. Waste Management

   a. Develop systems analysis procedures for determining the optimum economical balance between in-plant pollution abatement methods and treatment of the waste.

2. In-plant Abatement

   a. Investigate the tolerance limits for the different chemicals which are present in the process water for the various unit operations applied in the pulp and paper industry. The objective is to determine optimum reuse of water.

   b. Develop new economical pulping and bleaching processes which will be free from the air-polluting sulfur components from Kraft mills and free from water pollution resulting from the bleaching of pulps. Delignification of cellulosic materials with oxygen and alkali is a potential "nonpolluting" bleaching and pulping process, and a basic investigation of this process is recommended.

   c. Research should be intensified in the area of improving strength, brightness, and brightness-stability of high yield pulps. Partial replacement of bleached chemical pulps by surface bleached high yield pulps in high brightness paper and board products can greatly reduce the waste load from an integrated pulp and paper mill.

3. Waste Treatment

a. Develop effective and economical technologies for removal of color, turbidity, suspended solids, and dissolved solids from pulp and/or paper mill effluents. The goal should be to obtain economically closed water systems.

b. Investigate improvements in clarification of waste water and in dewatering and disposal of the sludge. The use of different types of coagulation aids for improved clarification of waste water should be further investigated. Fundamental hydrogel studies will enhance the discovery of new economical methods for thickening and dewatering of sludges suitable for incineration. Optimal procedures for landfill disposal of sludges, as an alternative to incineration, should be developed.

c. Develop techniques for recovery of valuable substances, such as fibers and paper additives (e.g., titanium dioxide) direct from mill effluents or from primary or secondary settled sludges. Attention should also be given to the possibility of separation and utilization of lignin and carbohydrates in the brine from reverse osmosis units operating on waste water from a pulp mill. Utilization of the high-protein containing sludge from secondary treatment for various uses such as fish food are projects worth investigating.

d. Research should be directed towards improvement of existing biological treatments of waste water and also towards irrigation disposal of pulp and paper waste.

4. Recovery of Cellulosic Fibers from Solid Waste

Intensive research should be conducted for developing non-polluting and economical recovery processes of fibers from waste-paper and board. Emphasis should be put on collection of the waste fibers and separation of the cellulosic fibers from other types of waste materials.

IV. SUMMARY

The objective of this study was to find the state of water usage and water pollution abatement in the Southern pulp and paper industry and to define research needs.

Our findings are based on questionnaires returned from 46 different mills, which were comprised of 42 integrated pulp and paper mills, 2 board mills and 2 pulp mills. About 60% of the pulp and paper production in the South is represented in the survey (1968-1969). Forty-three of the mills produced Kraft pulps, reflecting the paramount position of Kraft pulping in the nation and especially in the South.

The total fresh water demand in the surveyed mills added up to about 1,425 MGD, of which 69% was taken from rivers and 31% from wells. Sixty-five percent of the water was treated before use. The cost of raw water varied from about 0.5¢ for river water up to 4.5¢ per 1,000 gallons for well water. A cost of 1¢ - 4¢ per 1,000 gallons was reported for water treatment prior to process usage in the plants.

The average water usage per ton of product was dependent on the grade of products and varied from 2,150 to 46,000 gallons, and most mills ranged from about 20,000 - 30,000 gallons for unbleached and from about 35,000 - 50,000 gallons for bleached products.

A high degree of water reuse was practiced in the pulping, recovery, and papermaking departments in many of the mills. Condensates were used for washing of pulps, for preparation of pulping liquor, and for general use in the woodyard and recovery departments. Cooling water was most often used as process water. Clarification of white water in the paper mill (by Savealls) and reuse of this water in machine showers and in the pulp mill were practiced in at least one-third of the mills. Generally, the reuse of water in the bleach plants was limited and can be considerably increased. Two board mills producing low-grade products from waste paper used closed systems with practically no discharge of waste water.

The amount of waste water from the integrated Kraft pulp and paper mills producing unbleached and bleached products varied from 10,900 - 27,800 gals per ton and 24,400 - 56,000 gallons per ton, respectively. The untreated waste waters contained 19.5 - 69.5 lbs and 46 - 128 lbs of BOD_5, 84 - 200 lbs and 325 - 540 lbs of dissolved solids per ton of unbleached and bleached products, respectively. The amount of waste water from the surveyed mills added up to about 1,200 million gallons per day and contained about 2.5 million lbs of BOD_5.

Primary treatment of waste water was performed in 37 of the mills. Twenty-six mills used mechanical clarifiers and 11 had settling ponds. The removal of suspended solids varied from 55 - 98%.

Twenty-nine of the mills had secondary treatment which was performed in storage lagoons in 15 mills. Ten mills used aerated lagoons which were followed by impondment by 5 of these mills. Activated sludge treatment was used in 3 mills, and 1 mill disposed of the water by irrigation. The BOD_5 reduction was dependent on the type of treatment and the retention times. About 35% of the mills reduced the BOD_5 load in their effluent waste water to less than 10 lbs per ton of production. This was done in stabilization basins by 6 mills, in aerated lagoons, often followed by impondment, by 7 mills and in the 3 mills with the activated sludge treatment.

The overall BOD_5 reduction for the surveyed mills was about 42.5% which means that about 1.3 million lbs of BOD_5 were discharged to receiving water each day.

Color removal from waste water was performed in one mill. The color-bodies were precipiated with lime, which was not recovered. More than 90% of the color was removed by this treatment.

One of the main problems of waste treatment is to dispose of the sludge. Thirty-three of the surveyed mills disposed of the sludge by lagooning, 8 mills used land fill, and 3 mills incineration. Six mills used centrifuges, 2 mills filters, and 1 mill presses for the dewatering of the sludge.

The investment cost of primary and secondary treatment to meet government regulations varied from about \$1,390-\$2,900 per daily ton of production capacity for activated sludge to about \$1,120-\$1,930 per ton in the aerated lagoon systems. The operational cost varied from \$0.82-\$1.60 per ton of product to about \$0.80-\$0.90 per ton, respectively, for the two types of treatments.

Treatment of waste water in settling basins followed by storage in stabilization basins is by far the lowest cost treatment if inexpensive land is available.

Based on the information provided by the survey and recent literature studies by one of the authors, the following research goals have been established:

1. Optimization of waste management.
2. Optimum reuse of process water.
3. Development of economical and nonpolluting pulping and bleaching processes.
4. Obtaining completely closed water systems in pulp and paper mills.
5. Improvement of the present primary, secondary, and tertiary waste treatment processes, and the utilization of the products from these processes.
6. Developing nonpollutant and economically feasible recovery processes for fibers from waste paper and board.

V. LITERATURE CITED

1. Slatin, B. "Paper in the South moves strongly forward," Southern Paper Manufacturers 32 (10):17 (1969).

2. Kleppe, P. J. "The contribution of inplant controls and process modification to pollution abatement in the pulping industry," Proceeding of the 18th Southern Water Resources and Pollution Control Conference, Raleigh, North Carolina, 1969.

3. Kleppe, P. J. "Kraft pulping." Tappi 53(1):35 (1970).

APPENDICES

APPENDIX A. Letters to participating mills

Dear

For some time, we at N. C. State University have been preparing to develop research and training programs insofar as they relate to the problems of effluent treatment faced by the pulp and paper industry. We are aware that the costs of effluent treatment and control are rising and that there is need for additional trained manpower with competence in the effluent treatment field.

At the present time, a significant percentage of our pulp and paper graduate students are also electing to take minors in the field of effluent control. In the last few months we have prepared and transmitted a proposal to the Federal Water Pollution Control Board for support to develop a training program at N. C. State. Additionally, we recently received a research grant from the same agency to undertake research on Kraft liquor filtration. Also, a federally supported research project on lignin is in progress from which we hope benefits to reduce pulp and paper mill effluent will follow.

As an aid to developing the soundest possible approach in our program, we would like to survey and evaluate methods of effluent improvement for various types of paper and board mills in the South in a preliminary manner. From such an evaluation we plan to also identify specific problem areas for subsequent research in depth.

We plan to survey the following systems:

A. "Closing" the mill system (the re-circulation of the product laden waters) to prevent, or materially reduce losses, and to lower the amount of effluent to be subsequently treated.

B. Methods of effluent improvement (treatment) after the system has been "closed."

Factors to be studied in this investigation are (i) Methods, (ii) Problems, (iii) Effectiveness, (iv) Cost, and (v) Savings.

So that the results of this survey and evaluation will be of maximum value to the industry, we are requesting the assistance of each of the principal mills in the South in obtaining the above information through questionnaires and/or visits.

We assure you that the information and/or its source will be held in confidence if so requested.

Assuming that you would be willing to assist us in this project, please advise us as to whom future inquiries should be addressed. Possibly, because of divisions in your operations, inquiries should be addressed to more than one individual. If this is the case, please identify the area of each individual's interests.

If you have any comments or suggestions to make about this proposed study, they would be also appreciated.

Sincerely,

Charles N. Rogers
Associate Professor
Pulp and Paper Engineering

CNR/ch

Dear

The response to my letters regarding our proposed survey of effluent improvement methods used by the various southern mills has been so good that we are going ahead with the project.

Questionnaires will be prepared that will be applicable to the various type mills and will be forwarded to the individuals you suggested with the requested copies.

Because of the exceptional response to our inquiry, we are reconsidering the value of this study and the format of the questionnaires. Consequently, it will be some time before they will be sent out.

We certainly appreciate your willingness to assist us in this endeavor.

Sincerely,

Charles N. Rogers
Associate Professor
Pulp and Paper Engineering

CNR/ch

Dear

The attached questionnaire is the one which I referred to in my letter to your company last October. As you will note, it is prepared to cover our industry in general, rather than having one specifically for each mill.

Please have it filled in as completely as your sources of information will enable, and add additional information which you consider may be helpful in making our survey as complete and useful as possible. Undoubtedly, we have not requested all of the information which you as an individual plant has that will be valuable to us.

As stated in my previous letter, we will hold in confidence any information that you suggest we handle in that manner.

Should your units of measure be different than these we specify, please state yours.

We would especially appreciate additional information or comments that would assist us in becoming familiar with areas in which you think additional research "in depth" may be warranted or desired. As was pointed out in my initial letter, we have facilities at N. C. State University to do such research and would like to be guided by the needs of our industry.

You, that operate pulp plants, can be of help to us by giving as much quantitative and qualitative analysis of materials, both liquids and solids, at as many locations within your pulping, washing, and bleaching operations as possible.

This information will assist us in also evaluating areas wherein additional research may be most fruitful.

You, who have a waste paper operation, can be of special help by giving as much information in as much detail as is available regarding the source, use (recirculation), treatment, and disposal in your systems wastes paralleling as much as possible the information requested of those having pulp plants.

After we are able to evaluate the results of this questionnaire, we will write or call you regarding our progress results and may plant a visit with you, after May 27th, to discuss this subject.

Please provide us with as complete information and comments as you have and at your earliest convenience. If additional copies of the questionnaire would be helpful, please let us know how many, and we will forward them to you immediately.

Thank you for your interest in this project as it is only with the cooperation you have given us, such as this, that we have been able to be of service to the industry.

Sincerely,

Charles N. Rogers
Associate Professor
Pulp and Paper Engineering

CNR/ch

Enclosure

P. S. Should you have flow sheets, drawings, or reprints of articles covering your systems or plant, they would also be helpful.

APPENDIX B. Copy of questionnaire

SOUTHERN PULP PAPER AND BOARD WATER SURVEY

Date ______________

COMPANY:

MILL LOCATION:

DATE OF FIRST PRODUCTION:

(Use back of page or extra sheets for any additional space needed for more complete information and comments.)

I. PULP PRODUCED (TONS PER DAY) — I-A PULPWOOD & CHIPS (TONS PER DAY)

		HARDWOOD	PINE
Kraft Unbleached	:-	-	-
Kraft Bleached	:-	-	-
NSSC	:-	-	-
Dissolving	:-	-	-
Sulfite	:-	-	-
Groundwood	:-	-	-
Waste Paper	:-	-	-

Other & Type	:-	-	-
None	:-	-	-

II. PAPER & BOARD (TONS PER DAY)

Paper & Board :-

% Coated :-

Building Board :-

% Coated :-

None :-

III. FRESH WATER SOURCE (GPD & COST PER MIL. GALS.)

River (Name) :-

Well :-

Municipal (Name) :-

Other :-

IV. FRESH WATER TREATMENT

Total GPD :-

Type Treatment :-

Equip. Installed Cost (If various dates, identify and give costs of each) :-

Chemical Cost/Day :-

Power (Pumping, etc.) Cost/Day :-

Labor Cost/Day :-

Supervision & Tech. Cost/Day :-

Maintenance Cost/yr. :-

Other & Type Costs/ Yr. :-

V. TREATED FRESH WATER USED (GAL. PER DAY)

Pulp Plant :-

Paper & Board Mill :-

For Cooling Only :-

Other :-

V-A. BOILER FEEDWATER

Type Treatment :-

VI. RAW FRESH WATER USES (GPD)

Pulp Plant :-

Paper Mill :-

For Cooling Only :-

Other :-

VII. IN PLANT PROCESS WATER TREATMENT COST

Type Systems :-

Installed Cost :-

Chemical Cost/Day :-

Power Cost/Day :-

Labor Cost/Day :-

Maintenance Cost/ yr. :-

Supervisory & Technical Cost/Day :-

Other & Type Costs :-

VIII. OUT PLANT EFFLUENT TREATMENT COST

Type Systems :-

Installed Cost :-

Chemical Cost/Day :-

Power Cost/Day :-

Labor Cost/Day :-

Maintenance Cost/yr.:-

Supervisory & Technical cost/day :-

Other & Type Costs/ yr. :-

IX. WATER REUSE - PULP MILL

SOURCE	GPD	ANALYSIS
Bleach Plant Seal Pits		
_Seal pit	___	pH ________
		Temperature (^{o}F) ________
		Residual GPL ______ as ______
		Dissolved Solids (PPM) ________
		Color (PPM) ________
		Fiber (PPM) ________

Used-where & GPD ____________________

SOURCE	GPD	ANALYSIS
_Seal pit	___	pH ________
		Temperature (^{o}F) ________
		Residual GPL ______ as ______
		Dissolved Solids (PPM) ________
		Color (PPM) ________
		Fiber (PPM) ________

Used-where & GPD ____________________

_Seal pit ____ pH ____________________

Temperature (^{o}F) ____________________

Residual GPL __________ as __________

Dissolved Solids (PPM) ____________________

Color (PPM) ____________________

Fiber (PPM) ____________________

Used-where & GPD ____________________

IX. WATER REUSE - PULP MILL (CONT'D)

_Seal pit ____ pH ____________________

Temperature (^{o}F) ____________________

Residual GPL __________ as __________

Dissolved Solids (PPM) ____________________

Color (PPM) ____________________

Fiber (PPM) ____________________

Used-where & GPD ____________________

_Seal pit ____ Ph ____________________

Temperature (^{o}F) ____________________

Residual GPL __________ as __________

Dissolved Solids (PPM) ____________________

Color (PPM) ____________________

Fiber (PPM) ____________________

Used-where & GPD ____________________

IX. WATER REUSE - PULP MILL (CONT'D)

SOURCE GPD ANALYSIS

Screen Room ___ Ph ______

Temperature (°F) ______

Fiber (PPM) ______

Dissolved Solids (PPM) ______

Color (PPM) ______

Used-where & GPD ______

Blow Heat Recovery

Direct GPD ______ Ph ______

Temperature (°F) ______

Fiber (PPM) ______

Dissolved Solids (PPM) ______

Color (PPM) ______

Used-where & GPD ______

Indirect GPD ______ Used-where ______

Turpentine Decanter

GPD ______ Used-where ______

Causticizing Weak Wash

Overflow GPD ______ pH ______ Used-where ______

Lime Kiln Scrubber

GPD ______ pH ______ Solids % ______

Used-where ______

Evaporator combined

Condensate GPD ______ pH ______ Used-where ______________

Evaporator Seal pit

GPD ______ pH ______ Used-where ______________

Others GPD ______ Ph ______ Used-where ______________

IX. WATER REUSE - PULP MILL (CONT'D)

SOURCE

Where	GPD	Where		GPD
______________	____	Machine showers	:	____
______________	____	Vacuum Pumps	:	____
______________	____	Pulp plant	:	____
______________	____	Other	:	____
______________	____	______________	:	____
______________	____	______________	:	____

SOURCE	GPD	ANALYSIS
Outfall Sewer		
	____	pH ______________
		BOD (PPM) ______________
		Suspended Solids (PPM) ______________
		Dissolved Solids (PPM) ______________
		Color (PPM) ______________

Used-where & GPD ________________________________

X. WATER REUSE - PAPER OR BOARD MILL

SOURCE

Where	GPD	Where		GPD
______	___	Machine showers	:	___
______	___	Vacuum Pumps	:	___
______	___	Pulp plant	:	___
______	___	Other	:	___
______	___	______	:	___
______	___	______	:	___

SOURCE	GPD
Outfall Sewer	___

ANALYSIS

pH ______

BOD (PPM) ______

Suspended Solids (PPM) ______

Dissolved Solids (PPM) ______

Color (PPM) ______

Used-where & GPD ______

XI. OTHER WATER USES

Location:	Source:	Goes to:	GPD
Boiler Fly Ash:-			
Wood Flume :-			
Woodroom Overflow :-			
Cooling Water :-			
1. T. G. Condenser			

2.

3.

Other :-

XII. **MILL EFFLUENT** (Total outfall sewer; if more than one, give information for each and identify

SOURCE	GPD	ANALYSIS
Outfall Sewer		
	___	pH ______________
		BOD (PPM) ______________
		Suspended Solids (PPM) ________
		Dissolved Solids (PPM) ________
		Color (PPM) ______________
		Temp.(^{o}F) - Summer _____ Winter ___

XIII. PRIMARY TREATMENT

Type Equipment :-

Number & Size :-

Installation Cost :-

Operating Cost per year :-

Input	Color (PPM)	pH	GPD	BOD(PPM)	Solids (PPM) Suspended	Solids (PPM) Dissolved

Total Clarified Water

1. Total:

2. Reused:

(a) Where:

(b) Other:

3. Lagooned Natural:

4. Lagooned Aereated:

5. Lagooned Combination (Nat. & Aer.):

6. Activated Sludge:

7. Trickling or Roughing Filter:

8. Pyrolysis:

9. Irrigation:

10. Dialysis:

11. Coagulation:

12. Other:

Sludge or Cake

	(OD) Tons/Day	% OD
1. Total		
2. Reused in Product :-		
Where: ______________________		
3. Incinerated :-		
4. Used in Boiler :-		
5. Lagooned :-		
6. Land Fill :-		
7. Other :-		

XIV. SECONDARY TREATMENT

A. Natural Lagoons:

Input per day:

Gal.:

#BOD:

#Solids:

Suspended:

Dissolved:

Nutrients Added:

Ammonia #/Day:

Phosphorous #/Day:

Others #/Day:

pH to Units:

Is sanitary sewage included?:

Number of Ponds:

Number of Acres:

Average Depth (Ft.):

Retention Time (Days):

% BOD Reduction, Odor Present:

Summer:

Winter:

Comments, Problems, etc.:

B. Aerated Lagoons

Input Per Day:

Gal.:

BOD:

Solids:

Suspended:

Dissolved:

Nutrients added:

Ammonia #/Day:

Phosphorous #/Day:

Others #/Day:

pH to Units:

Sanitary Sewage included?:

Number of Ponds:

Number of Acres:

Average Depth (Ft.):

Retention Time (Days):

% BOD Reduction, Odor Present:

Summer:

Winter:

Aerators

Installed Cost:

Number:

Horsepower:

Type:

% Running Time
Summer
Winter

Maintenance Cost per year:

Comments:

C. IMPOUNDING

Input per day:

Gal:

BOD:

Solids:

Nutrients added:

Ammonia #/Day:

Phosphorous #/Day:

Others #/Day:

pH to Units:

Sanitary Sewage Included?:

Number of Ponds:

Number of Acres:

Average Depth (Ft.):

Retention Time (Days)

% BOD Reduction, Odor Present:

Summer:

Winter:

Maximum Storage Time:

What Governs Effluent Release:

Oxygen Level in Stream:

BOD/Day

% Stream Flow:

Others:

Comments, Problems, etc.:

D. ACTIVATED SLUDGE:

Input per day:

Gal.:

BOD:

Solids:

Nutrients Added

Ammonia #/Day:

Phosphorous #/Day:

Others #/Day:

pH to Units:

Sanitary Sewage Included?:

Units

Number:

Sizes:

Costs:

Air Used (CFM):

% Recirculation:

Operators Per Shift:

Maintenance Cost per year:

Sludge:

Tons O.D. Per Day:

% O. D. :

Disposal:

Reused:

Burned:

Land Fill:

Lagooned:

Other:

Effluent

% BOD Reduction, Odor Present:

Summer:

Winter:

Average Retention Time:

Disposal (GPD):

Use - Where:

Ponds - Type:

River:

Other:

Comments, Problems, etc.:

E. TRICKLING OR ROUGHING FILTER

Input Per Day:

Gal.:

BOD:

Solids:

Suspended:

Dissolved:

Nutrients Added:

Ammonia #/Day:

Phosphorous #/Day:

Others #/Day:

pH to Units:

Sanitary sewage included?:

Cost of Units:

Annual Operating Cost:

Type of Packing:

Height of Packing:

Gal. per Sq. Ft.:

% BOD Reduction, Odor Present:

Summer:

Winter:

Comments and Problems:

F. PYROLYSIS

Type Unit Used:

Cost Installed:

Annual Operating Cost:

Supplemental Fuel:

Type:

Cost/Day:

Input per day:

Gal.:

pH:

#Solids, % Solids:

BTU Value per pound solids:

Steam Recovered

Pounds/Hr; Psig.:

Sulfur Gas Recovered:

#/Day: %:

Ash Recovered:

Amount? ______________ Analysis? _____________ Where Used? ___________

Comments and Problems:

G. IRRIGATION

Flow (GPD):

BOD Per Day:

Acres:

Schedule:

Hours Irrigate: Hours Rest:

Cost of Installation:

Operating Cost/Day:

Supervisory & Technical:

Operators Per Day:

Cover Crop:

Planted: Species:

Natural: Species:

Crops Marketed:

Type: Value:

Comments and Problems:

H. OTHER SYSTEMS AND VALUABLE INFORMATION:

APPENDIX C. Flow sheets and brief descriptions of the different manufacturing practices

Kraft Pulping and Chemical Recovery

The production steps involved in making Kraft pulps are shown in Figure 1. The figure demonstrates the processes and materials balance involved in producing pulp for manufacture of one ton of brightness paper or board from southern pine wood. The process starts in the wood-yard, where the wood is stored, debarked, cleaned and made into small chips. The wood logs are often transported from the storage area to the debarkers by the use of long ditches filled with water. This transportation is called flume and the water is very often recycled.

The logs are debarked by tumbling in huge horizontal cylinders, barking drums, with coarse slots to allow bark to pass out. The bark is disposed of by burning in a special furnace for production of steam. The ash from the bark boilers is collected in special precipitators, and transported by water in a suspended stage of storage lagoons (ash ponds).

The debarked logs are made into chips by multiple knife chippers. During the chipping operation 1-3% of the wood is turned into fine sawdust, which is removed in the screening operations. The sawdust is usually burned together with the bark in the bark boiler.

The screened chips are transported pneumatically or by belt conveyors to batch or continuous digesters. The chips are there delignified by cooking at about 175°C with an alkaline solution containing sodium hydroxide and sodium sulfide as the active chemicals. The cooking liquor contains also some sodium carbonate, and small amounts of sulfites and thiosulfates. The total amount of sodium and sulfur compounds, which are present in the added cooking liquor (white liquor) are expressed as lbs of NaOH and lbs of elementary sulfur. Spent liquor, called the black liquor from a previous cook is often added to the digesters, in order to increase the liquid to wood ratio. The turpentine fraction of the wood is released from the digester during the cook and recovered by condensation. Total cooking time varies for about 2.5 - 4 hours. The batch digesters are then blown from full pressure into a blow tank.

Less severe cooking is practiced in the continuous digester, as compared to the batch digester where the chips first are steamed and then heated in the cooking liquor to a maximum temperature of approximately 170°C during a period of 90-100 minutes. The cooking is usually intercepted by cooling with a "wash water," which is forced countercurrent to the down-flowing "delignified" chips. Prewashing for a period of approximately 90-120 minutes is often practiced in continuous digesters, before the wood residue is discharged to a blow tank at low temperature (100-110°C).

The force of blowing is usually sufficient to fiberize the cooked chips to a reject level of about 1-3%, if most of the lignin in wood has been removed. Wood residues of higher lignin content are passed through a fiberizer and often through hot stock refiners. The pulp is then hot-stock screened and washed. The rejects are returned to the blow tank or the digesters.

The washing is done countercurrent in three or four stages on drum rotary washers, if the cooking is carried out in batch digesters. Countercurrent washing means that fresh water is only added at the last stage and the effluent from this stage is then used as wash water for the previous stage and so on. Pulps for continuous digesters with prewashing are washed only in one stage, and the effluent is then injected into the bottom of the digester for diffusion washing. The collected spent liquor (black liquor) from the washing operation contains, by proper washing, about 96-98% of the dissolved wood constituents and 96-98% of the used pulping chemicals.

The Kraft pulping process is not selective in delignification, and an equivalent amount of carbohydrates is simultaneously degraded and dissolved in the cooking liquor.

The black liquor is evaporated in multiple effect evaporators to increase the solid content, which is about 14%, to about 50%. The condensate from evaporation contains from 10-20 lbs. of BOD_5 per ton of pulp. Oxidation of evaporated spent liquor, before further concentration in a direct contact evaporator by combustion gases from the recovery unit, is widely practiced in the South. This considerably reduces the air pollution, especially by losses of hydrogen sulfide.

In the recovery furnace the dissolved organic wood constituents are burned for production of steam and the cooking chemicals are converted to sodium carbonate and sodium sulfide. The cooking chemicals, leaving the furnace as a hot melt, are dissolved in water in a tank, the dissolving tank. The liquor from the dissolving tank, the green liquor, is clarified, and the undissolved inert materials, call dregs, are disposed of after washing.

In order to convert the sodium carbonate in the green liquor to sodium hydroxide, the liquor is heated with calcium oxide in a unit operation, called causticizing. The unreactive materials which are characterized as grits, are removed mechanically and disposed of as solid waste. The causticized green liquor is called white liquor, and this liquor is ready to be used as cooking liquor after clarification.

The calcium oxide changes, during the causticizing to calcium carbonate, which is characterized as lime mud. It is removed mechanically from the bottom of the white liquor clarification tank to a washing filter. The residual white liquor in the lime mud is washed out by displacement by water, and the effluent, the weak liquor, is used for dissolving the melt from the recovery furnace. The washed mud is then converted to calcium oxide in the lime kiln, which is heated directly by burning of oil or neutral gas.

Screening and Bleaching of Pulp (Figure 2)

The pulp leaving the brown stock washer, is in many mills, cleaned by removing of the wood knots in a deknotter, and the fiber bundles in a "fine" screening operation. These operations are performed at a very high water to fiber ratio, and much water is added for dilution. The dilution water is afterwards removed for the fibers by passing the vat over a screen covered rotating drum, called a decker. The decker is also often used as a final washing stage, and water corresponding to about one displacement of the liquor in the vat is often added. Most of the effluent for the decker is recycled for dilution water. The excess water, is discharged to the sewer. The pulp vat leaving the decker at a relatively high solid content is routed to a storage tank.

The bleaching operation illustrated in Figure 2 is a CEHD sequence, which means that the pulp is treated successively with a chlorine, a sodium hydroxide, a sodium hypochlorite and a chlorine dioxide solution. The chlorination is done at a high water to fiber ratio, and water has, therefore, to be added to the pulp coming from the storage tank. Washing is performed between the bleaching stages on rotary drums, and an amount of water corresponding to 1 - 2 displacements of the liquor in the pulp-vat is added. The pulp coming from the bleaching towers is usually diluted with water to very low solid content before washing. The needed water is recycled effluent from the washers.

The waste water from the bleach plant, containing the degraded residual lignin in the unbleached pulp, some degraded carbohydrates and most of the added bleaching chemicals in a modified form, is directed to the sewer. The high brightness and totally delignified fibers are stored at a relatively high consistency for use on the paper machine.

Paper Making (Figure 3)

The stored pulp is diluted with recirculated water from the paper machine to a consistency of about 3.5% and directed to a holding tank, called stock chest. The pulp is then passed through refiners to give the fibers bonding ability and flexibility on formation of paper or board of the desired strength. The refined pulp is further diluted to a consistency of about 2.5% with recirculated water and directed to another holding tank, called the machine chest. The formation of the fiber mat (wet web) is done at a water to fiber ratio of about 200:1 or sometimes even higher. The pulp coming from the machine chest is therefore further diluted to a consistency of about 0.5% by recirculated water from the paper machine. The diluted pulp stock is taken through a cleaning operation, where fiber bundles and dirt are removed by centrifugal screens or vortex cleaners. The cleaned stock is directed to the headbox, from where it is sprayed on a revolving continuous wire, to form a sheet. Most of the water and some of the fibers drain through the wire and into a holding silo called the wire pit. The water, which passes through the wire is called white water, and most of this water is recirculated for dilution of the stock. In order to remove as much water as possible from the wet sheet, vacuum boxes are placed under the wire to suck out water. The wet sheet (about 20% moisture) leaving the wire at the couch roll, is passed through presses for further removal of water. The sheet leaving the wet end of the paper machine at a consistency of about 35-40% is then dried on steam heated cylinders to give the final paper or board product.

Different inorganic and organic substances such as aluminum sulfate, clay and starch are added to the pulp stock for enhancement of certain paper or board properties. These substances are only partially retained in the sheet and will be present in the white water. (Additives are not included in the system, shown in Figure 3).

A substantial amount of water is used for cleaning the revolving wire and also for preventing foam formation in the headbox or on the wire. This water is applied through sprays or showers, and is characterized as shower water. The water used here is fresh water and/or clarified white water.

The equipment used for clarification of white water, which means removal of suspended solids, is called the Saveall. The most used Savealls are rotating wire covered drums or disc screens, but Savealls based on the air flotation principle are also applied in the industry. Long fibered virgin pulp is often added to the "screen" savealls, as a "sweetener", to improve the removal of fine suspended solids. The solid fractions from the saveall are mostly reused for papermaking, and the filtered white water is reused in the mill or directed to the sewer.

Materials Balance for Production of 1100 Tons of Linerboard in an Integrated Pulp and Paper Kraft Mill

Figure 4 shows an approximate materials balance for an integrated pulp and paper mill producing 1100 tons per day of Kraft linerboard. The amount of wood, pulping chemicals, reaction products and final products are given in tons per day. All sodium and sulfur components, which are present in the different process-streams are expressed as tons of NaOH and tons of elementary sulfur per day.

Neutral Sulfite Semichemical (NSSC) Pulping

Figure 5 shows the different process steps in production of neutral sulphite semi-chemical pulps.

The process involves cooking of chips (hardwood) for 10-20 minutes at temperatures of 175-185°C with an aqueous solution of sodium sulfite and sodium carbonate. The amount of pulping chemicals required is about 9-16% Na_2CO_3 and 4 - 7% SO_2 per ton of dried wood. The pulp yield is about 75 - 80%, based on dried wood. The pulp is defiberized mechanically in disc refiners and washed by a countercurrent method on rotary drums.

The spent liquor, leaving the washers, is evaporated in multi-effect evaporators and usually burned together with the spent liquor from Kraft cooks. The sodium and sulfur content of the NSSC-Spent liquor as thus used as a make-up chemicals, to compensate for the chemical losses by the Kraft process. The combined burning of Kraft and NSSC-spent liquor, is characterized as cross recovery of chemicals.

Mechanical Pulping and Papermaking

Mechanical pulping is illustrated in Figure 6. The basic operation consists in forcing a log of debarked wood against a grindstone in presence of water. The abrasive surface of the revolving stone reduces the wood to fiber fractions. The water keeps the stone cool, cleans and lubricates the stone surface, and carries away the fiber fragments of the pulp. The pulps are then screened, and the rejected oversized matters are reduced to acceptable pulp by refining in disc refiners. The screened pulp is cleaned for dirt particles by centrifugal cleaners.

The grinding,as well as the purification operation, is performed at very high water to fiber ratio. The excess water is separated from the cleaned pulp by moving the pulp over a rotating drum screen, the decker. The clarified water is directed to a holding tank, from where it is reused for dilution or discharged to the sewer.

The groundwood pulp leaving the decker at a consistency of about 8 - 10% is directed to a storage tank. The pulp is usually bleached by adding small amounts of sodium peroxide and/or hydrosulfite. The semibleached pulp is then directed to the paper mill where it is mostly used for production of newsprint on a Fourdrinier paper machine (see Figure 3). Excess white water from the paper mill is clarified by use of a saveall system. The clarifier water can be used as shower water on the paper machine and/or as dilution water in the pulp mill, or it is discharged to the sewer.

Production of Paper and Board from Secondary Fiber (Waste Paper).

The most used process for reclaiming secondary fibers is as follows:

The collected waste is brought to the mills usually from metropolitan areas and, if not previously done, it is separated into grades for storage or use.

Often the first piece of equipment is a pulper where the bales of waste may be dumped and water, mainly recycled process water, is added. The pulper may be operated continuously or by batch. In any event the pulp slurry results from the mechanical and hydraulic action on the fiber bundles. This action continues until the degree of pulping sufficient for the next step in the process.

Connected to the lower part of the pulper is usually a Junker. The Junker, through centrifugal action in the pulper collects heavy items such as paper clips, extraneous solid impurities, as well as wet strength papers and other items not satisfactory for use. These impurities are worked clean of fibers in the Junker by the addition of water and removed from the process.

After the pulper, the stock usually goes to a cleaning device (at .5 - 1.5% consistency) of some type often of the centrifugal type where fiber bundles and other undesirable products are rejected and are sent back to the pulper for reprocessing.

The selected fibers from the cleaners go to some type of thickening equipment usually of cylinder or hillside type to drain off a large amount of the water that has been used to transport and process the fibers. This water is returned to the pulper to be used again.

The concentrated fibers from the thickener (at 3-4% consistency) are now ready for further processing in a refiner of some type usually of the conical (Jordan) or disc type. This refining reduces the fiber bundles further as well as shortening and brushing out the fibers so as to improve the sheet formation and strength.

After this step in the process,the stock is pumped to the stuff box where the proper amount is metered for the paper machine.

If the machine is a multi-cylinder type, different grades of pulp and amounts may be supplied to the various cylinders thereby forming a sheet of many layers of different grades. In this way the center of the sheet may consist of lower grades and off color pulp. This incidentally provides an excellent place to use the dirtiest of the waste waters, thereby, closing the white water systems relatively completely. Each cylinder and vat system may have its own water system to facilitate the optimum reuse of water.

After the stuff box the stock goes to a screen, frequently the flat plate type, where it is diluted to .5% consistency for screening. The rejects from the screen go back to the pulper or ahead of the refiners for further processing.

The selected stock flows to the mixing box where additional water is added to produce .3 - .5% consistency. This water, and that added ahead of the screen, usually is returned from the same vat where this specific stock is going to be used.

In the vat, a revolving cylinder with a fine mesh wire forms the mat of fibers by allowing the water to strain through (5% consistency). This mat then is deposited on the traveling felt (13% consistency) and becomes the sheet of paper subsequently going through press rolls to be further dewatered (38% consistency) prior to reaching the drying section of the machine where it is dried to 94% consistency or 6% moisture.

Needless to say, there are many modifications of this system. Some are very sophisticated such as those used for deinking and asphalt dispersion.

A Suggestion for Reuse of Water in an Integrated Kraft Pulp and Paper Mill.

A possible suggestion for extensive reuse of water is illustrated in Figure 8. The numbers represent gallons of water per ton of final product.

The cooling water for surface condensing the turpentine and blow gases from the digester and the vapor from the spent liquor evaporators, can be used as fresh process water supply for the whole mill. The condensate from the blow gases and the evaporators can, after air or steam stripping, be used partly for making up the pulping liquor, and partly for washing of the unbleached pulps.

Dilution of the pulp for the chlorination stage can probably be done completely by the use of recycled effluent from the chlorination stage. Clarified white water from the paper machine can probably be used as wash water for some of the bleaching stages.

The white water can be widely reused as dilution water and shower water in the paper mill.

The sealing water for the vacuum system on the paper machine can possibly be almost closed, with only small amount of cold fresh water addition to keep down the temperature. The cooling water needed for the power turbines, as well as other excess cooking water, can be returned to the water reservoir.

The system given in Figure 8, will have a waste water discharge of only about 10,000 gallons per ton of bleached product, of which about 8,000 gallons will be discharged from the bleach plant. If the suspended solid content in the effluent for the bleached plant is low, this effluent would only have to be treated for BOD and probably for color removal.

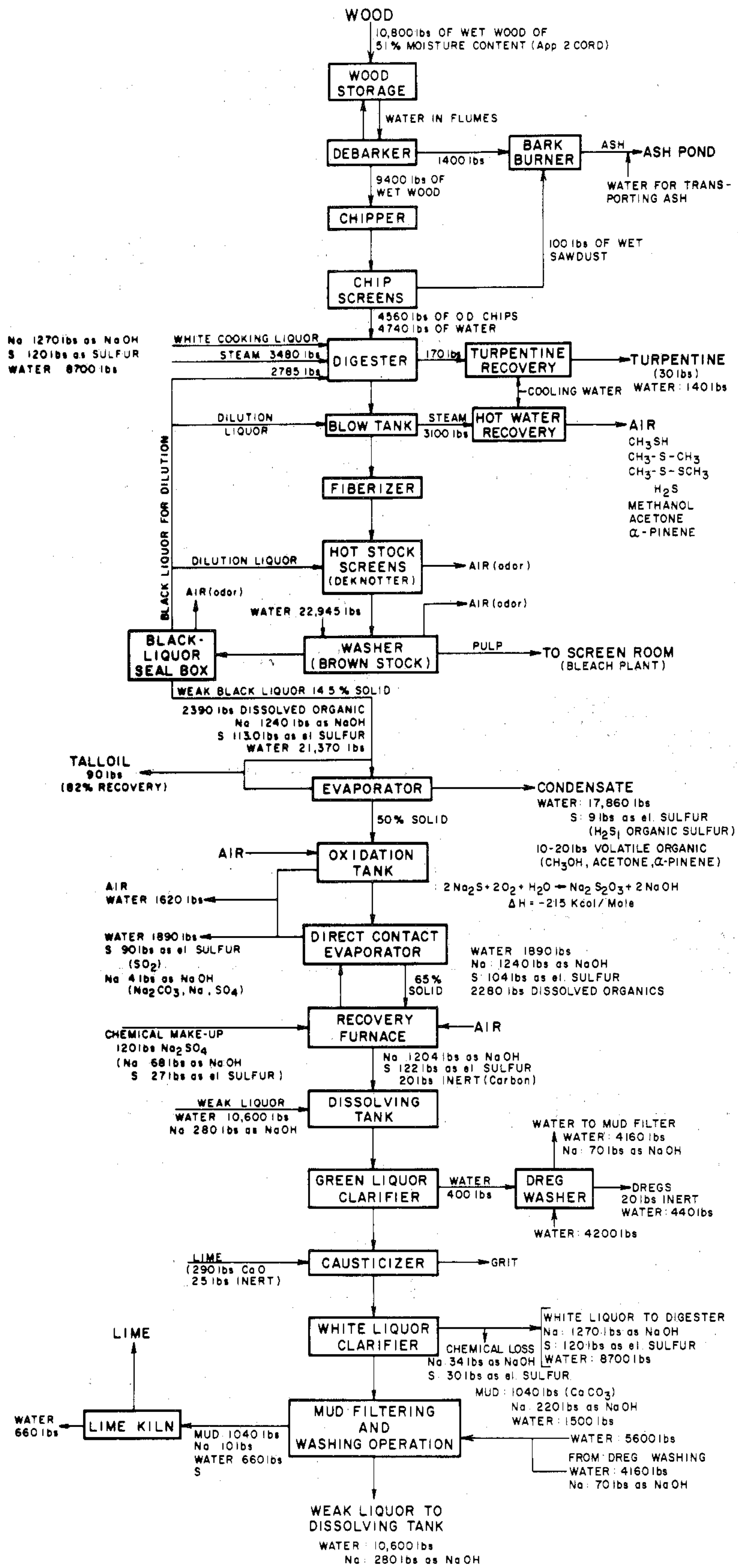

Figure 1. Pulping and chemical recovery operations in a Kraft mill (approximate materials balance for production of 2,070 lbs of bleachable pulp from Southern pine wood)

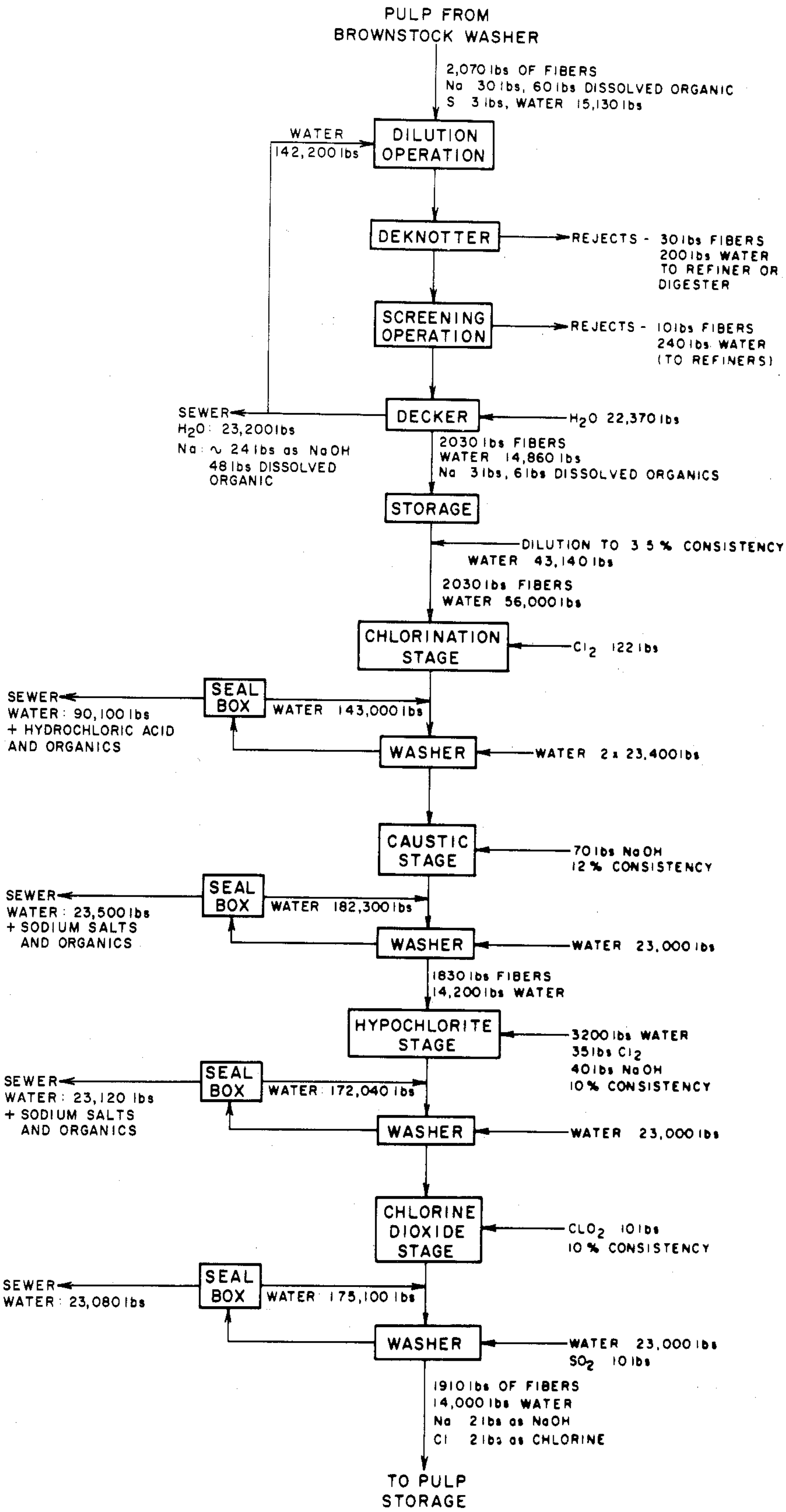

Figure 2. Pulp screening and pulp bleaching operations in a Kraft mill (approximate materials balance for production of 1,910 lbs of bleached pine pulp)

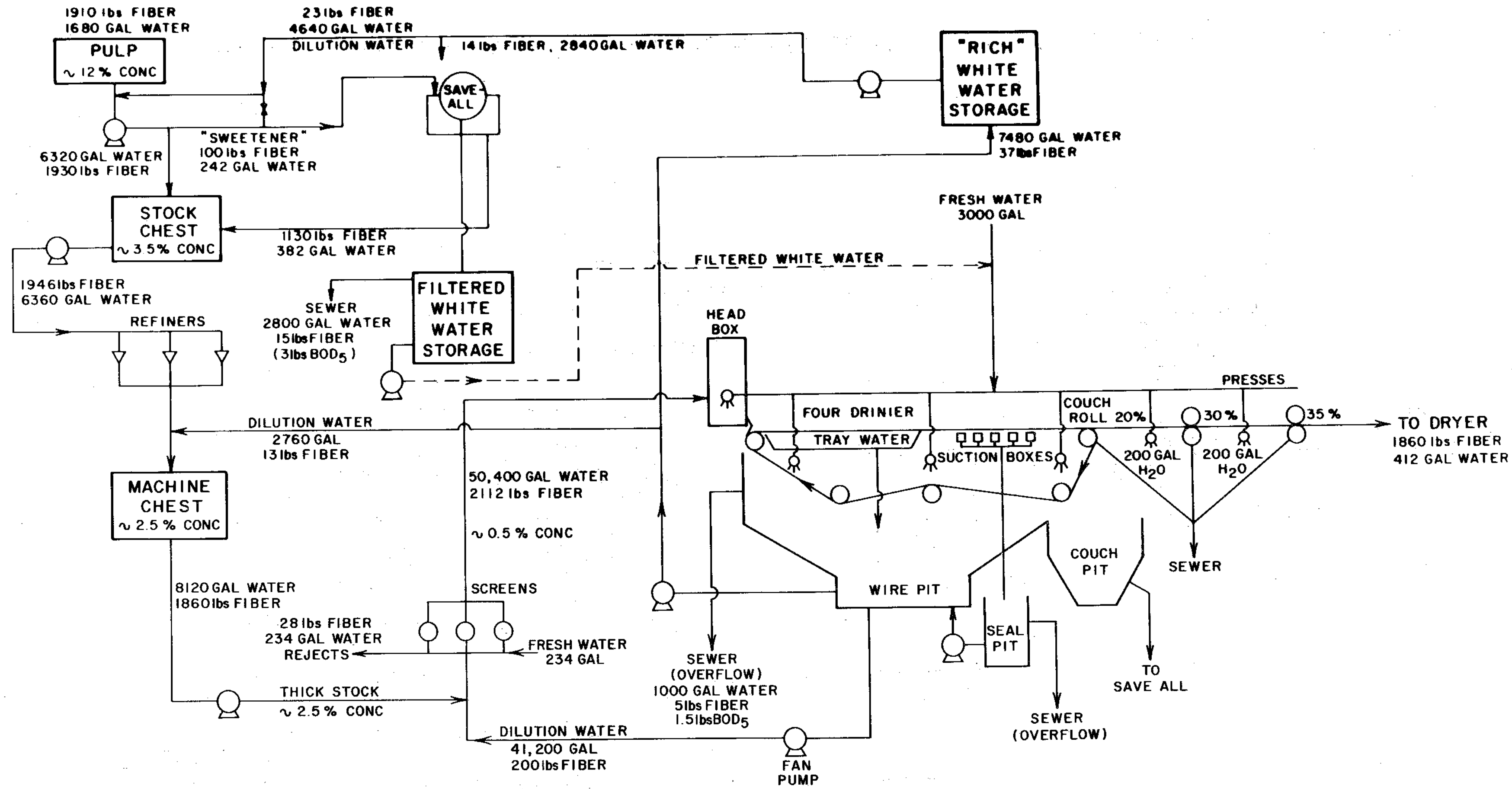

Figure 3. Papermaking on a Fourdrinier paper machine (approximate materials balance for production of 1 ton of high brightness paper board)

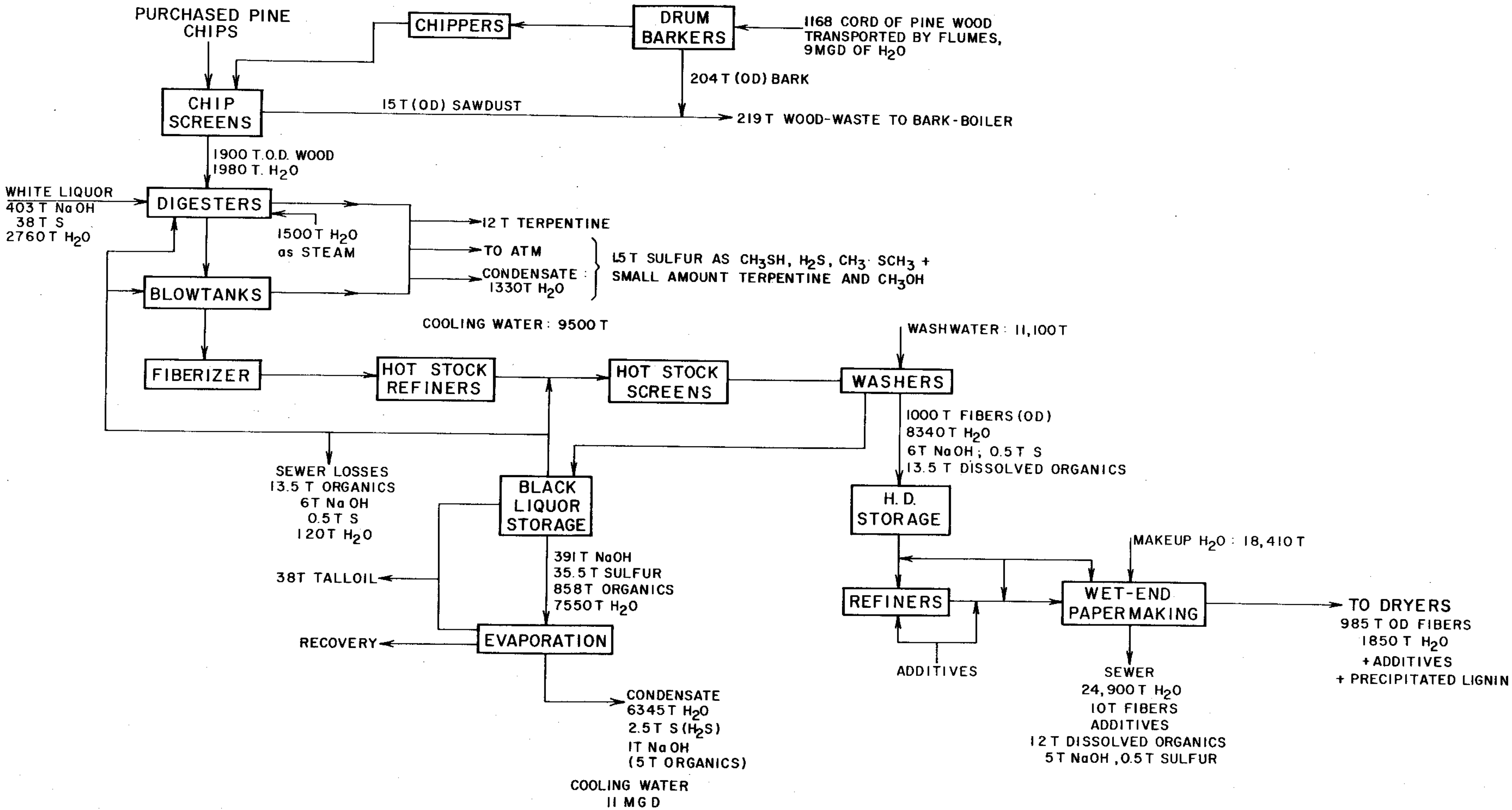

Figure 4. Approximate materials balance for production of 1,100 tons per day of Kraft linerboard

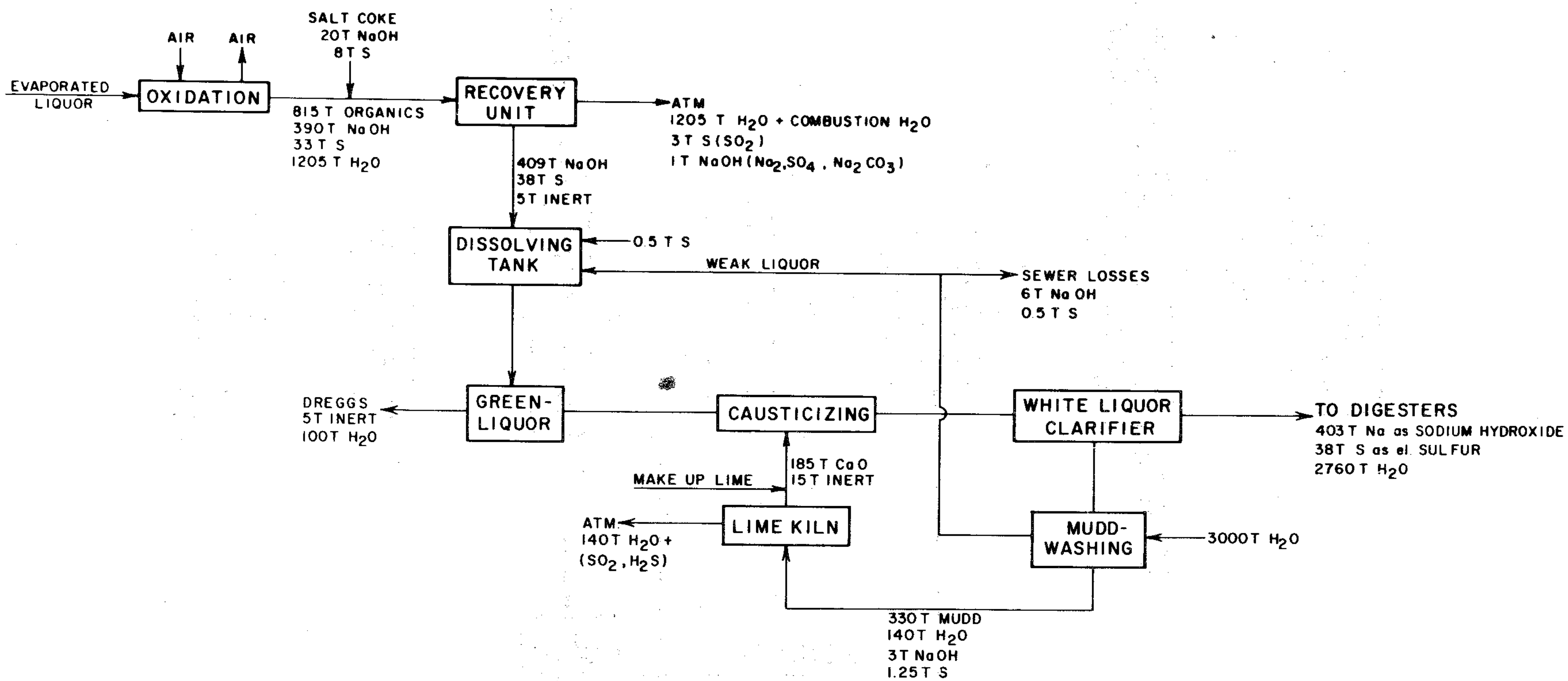

Figure 4. (Continued) Approximate materials balance for production of 1100 tons per day of Kraft mill

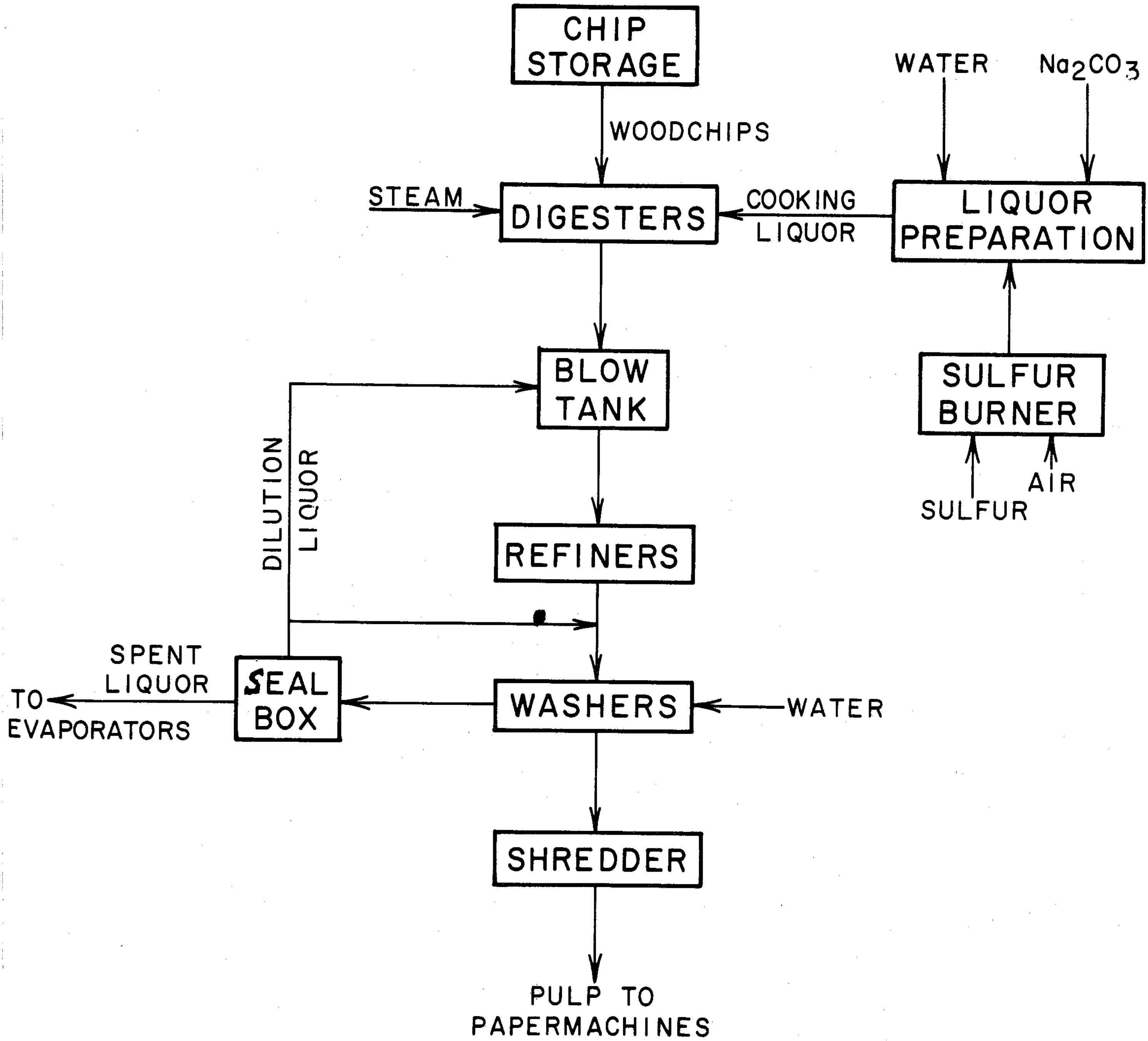

Figure 5. Unit operations in neutral sulfite semi-chemical pulping

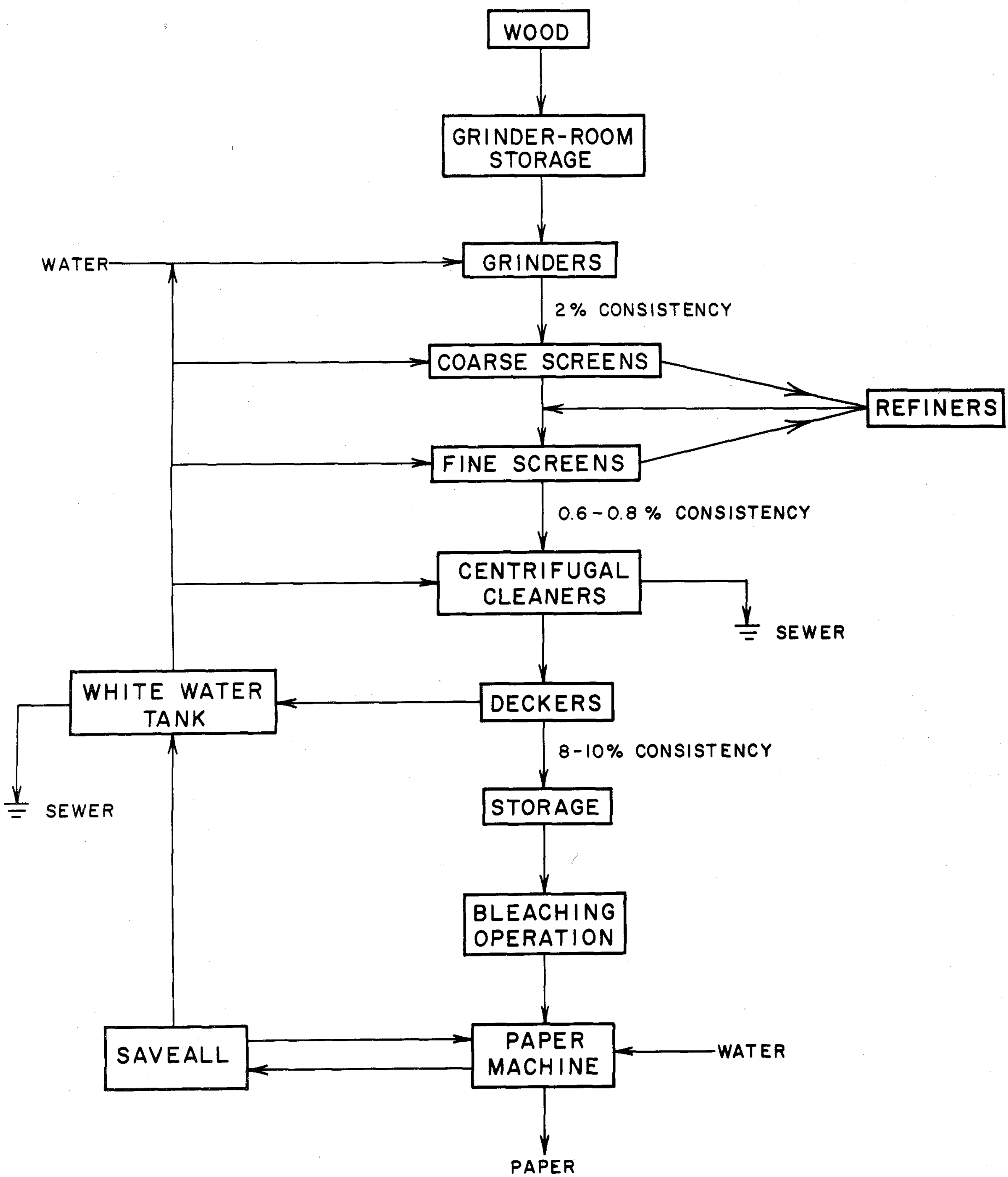

Figure 6. Unit operations in production of groundwood pulp and newsprint paper

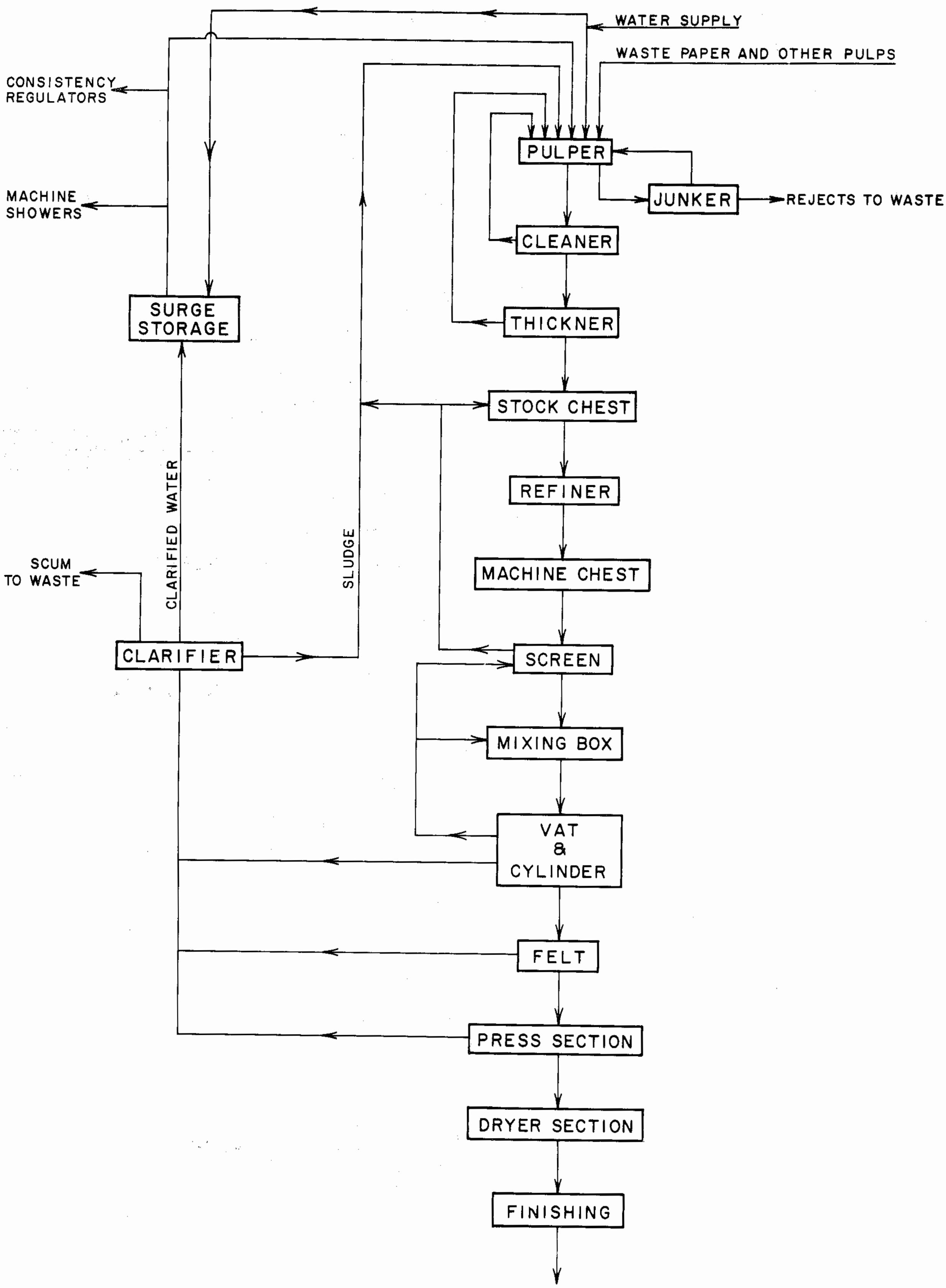

Figure 7. Unit operations in production of paper board from waste paper

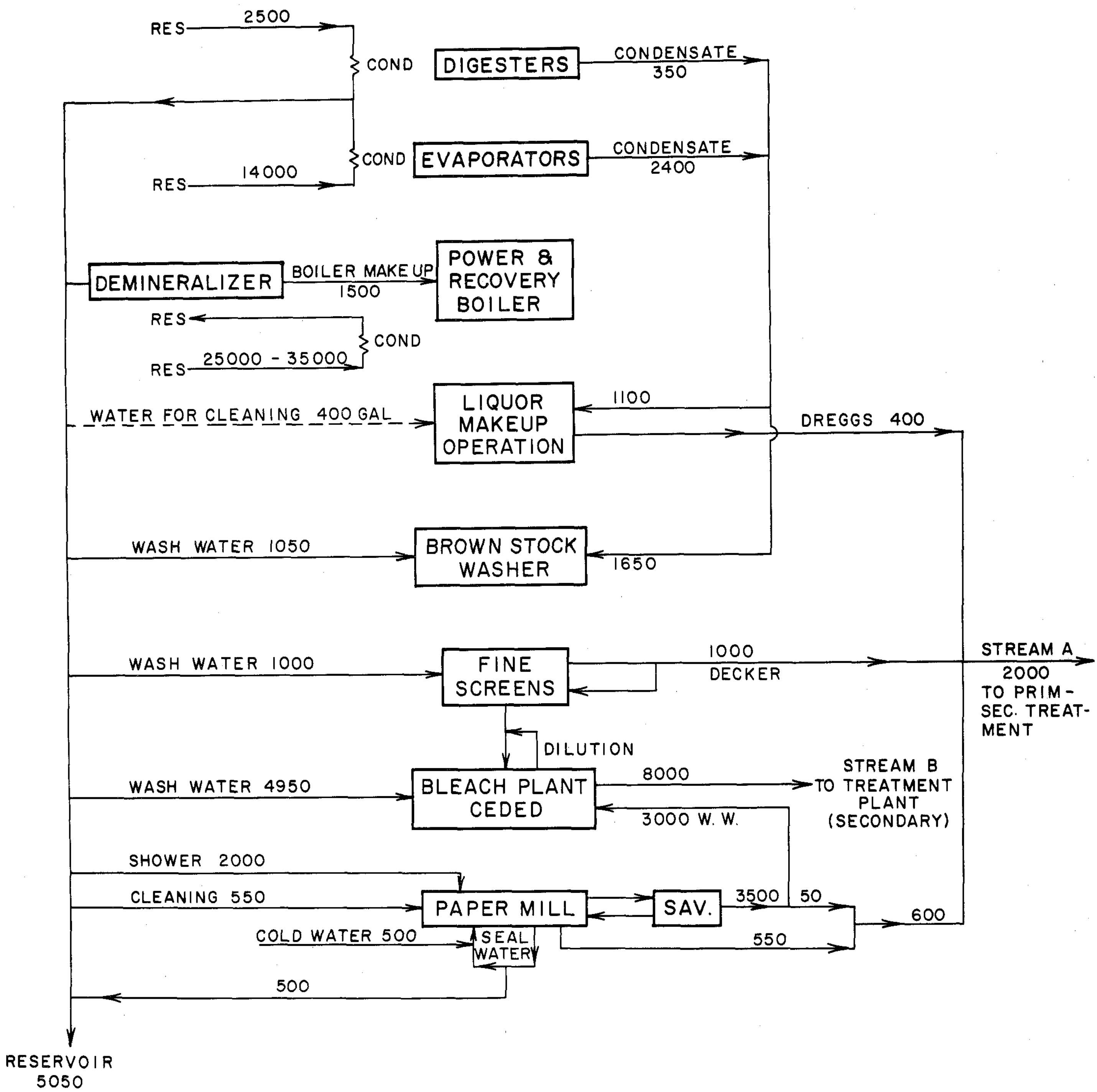

Figure 8. A suggestion for extensive reuse of water in an integrated Kraft pulp and paper mill.
(The numbers represent gallons of water per ton of final product)