Development of an Integrated Program of Water Reuse in a Pulp and Paper Mill

Zafar M. Chaudhri
Western Michigan University

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DEVELOPMENT OF AN INTEGRATED PROGRAM
OF WATER REUSE IN A PULP AND PAPER MILL

by

Zafar M. Chaudhri

A Thesis
Submitted to the
Faculty of The Graduate College
in partial fulfillment
of the
Degree of Master of Science

Western Michigan University
Kalamazoo, Michigan
December 1979
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WESTERN MICHIGAN UNIVERSITY, M.S., 1979
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INTRODUCTION

Water is a primary requisite to life, for plants, animals and industry alike. Man's dependence upon water for life as well as for agriculture, transport, power development and manufacturing has led him to live on water ways or near water sources. A tremendous increase in size of the kraft pulp and paper industry has taken place since the first kraft mill was operated in this country in 1910. The greatest increase has been from 1939 to present date. During that period many new kraft mills were built at new sites, but for the most part this increased production occurred at existing mills as a result of expanded production facilities. In many instances, what was once a more than adequate water supply by previous standards became an inadequate water supply as a result of increased production capacity.

A sufficient quantity of acceptable quality water is a necessity in kraft pulp and paper manufacturing operations. Water is one of the most important raw materials. Water has an important function in all the steps of pulp treatment from the moment that pulps are made until they are ready to be used in the finished products. It is used for power, steam, cooling, condensing and creating vacuums. Primarily water is used in preparation of cooking liquor and in cooking operation, washing, bleaching, sheet formation and as a carrier for the pulp throughout the manufacturing operations. With the realization that the use of superfluous water tends to increase fiber, chemical and dissolved wood substance losses, kraft manufacturers
are making continuous efforts to reduce water consumption per ton of paper.

The entire pulp and paper industry has always been conscious of resource conservation, with particular reference to timber, and this consciousness has carried over into water conservation. It is interesting to note that of the three renewable natural resources - soil, water and timber, the pulp and paper industry is a major user of all three. Perpetuation of the industry then is dependent on a wise and far sighted policy of resource conservation and replenishment.

Paper industry is water extensive. Water is not consumed but used in the paper making processes. Almost all of the water pumped to the mill is discharged from the mill carrying suspended solids and organic matter. These liquid discharges from the paper mill have the potential for polluting surface water ways on the basis of volume, amount of $BOD_5$ and suspended solids. The pollution of water becomes cumulative with water carrying increased burden as it moves downstream. While the adverse effects of water pollution may be seen along the water way, the most serious effects are seen in the estuarine zone where the pollutants which have been carried long distances down rivers flowing to the sea, end in estuary, and become trapped as the result of river deposition and washing from the sea.

Regulatory agencies have set limits on these items to prevent degradation of receiving streams. Suspended solids content may be reduced by primary treatment consisting of floatation, sedimentation or filtration devices. In addition it is frequently necessary to install secondary treatment. The secondary treatment processes are
expensive and difficult to operate and produce no by-products which can be used to decrease the cost. Legislation is forcing the industry to meet zero pollution goal, i.e. zero discharge of pollution by 1985. The paper industry finds itself in a bind facing a very serious problem, i.e. reducing losses. These stem directly from the size and competitiveness of the market. Quantities of fibrous substances, starches, pigments, etc are lost in effluent discharge from the plant. It also includes the large quantities of fresh water usage.

The corrective measure is evident, closing up the water system, i.e. recycling and reusing the process waters as much as possible. Throwing away fiber or fines is a waste of stock, preparation, horse power, as well as loss of chemicals and raw materials. The obvious solution is completely closing the water system and using the process water and white water over and over again like a conveyor belt.

The main objective in closing the Hudson Pulp & Paper water system is to increase the retention of paper making materials in the finished paper and to reduce the loss of these desirable materials to the sewer as well as to meet the N.D.E.S. permitted conditions in the years to come. This situation calls for the study of closing down the Hudson Pulp and Paper water system. Considering these factors, a study for recycling or closing the Hudson Pulp & Paper water system is made. Hudson is a manufacturer and convertor of kraft and tissue products. The specialty grades are kraft bag paper, multiwall, gum tape, market pulp, facial tissue, bathroom tissue, napkin and towel.
HISTORICAL BACKGROUND

The pulp and paper industry is the fifth largest in our economy and ranks third in its rate of extension (1). The per capita consumption of paper and its products is nearly 604 pounds (2). The pulp and paper industry has a long history of reducing process water consumption per unit of production. The water requirements without the use of process water for kraft pulping and bleaching operations were 175,000 gallons per ton of pulp in the 1920's (3). In 1936 the water requirements decreased to 110,000 gallons per ton of pulp in the mill utilizing the excellent techniques of water reuse (4). This water usage was reduced to approximately 40,000 gallons per ton of paper in 1956. The data compiled in 1954 indicated that kraft pulp and paper mills with highly developed water conservation measures were capable of operating successfully, utilizing 20,000 to 30,000 gallons of water per ton of pulp (6).

The passage in 1948 of Public Law 845, the first federal control act, introduced a new era in water management and water pollution control (7). Historically, water pollution control had been part of local, state and federal public health programs and was primarily oriented towards the control of waterborne communicable diseases. Until very recently, (1966), the federal program came under the supervision of U.S. Public Health Service. Since then this function has been transferred to a new agency, The Federal Water Pollution Control Administration, under the jurisdiction of the Department of Interior. Finally, the entire responsibility to restore the water ways to the natural state and save them from any
future degradation rests with The Environmental Protection Agency, (E.P.A.). Legislation has authorized the E.P.A. to force the industry to install the best available control technology to improve the environments.

Environmental problems caused by a paper mill mainly stem from the pollution caused by discharge of pulp mill, bleach plant and paper machine effluents. The release of these substances, i.e. suspended material and dissolved substances, can often be economically reduced by internal reuse of process water. A symposium in Ohio in 1953 (8) and Clouse (9) thoroughly discussed the advantages and disadvantages of closing the white water system. Equipment suppliers as well as paper companies are redesigning equipment and systems for increased water conservation (10).

In 1967, The Technical Association of Pulp & Paper Industries, (TAPPI), pulp bleaching committee authorized project CA6019 to study the requirements of water for pulp bleaching and practices of mills in economizing the use of water by reuse (11). TAPPI conducted a survey of industry in 1965 to determine water usage and disposal (12). Rapson proposed that pollution from kraft mill bleacheries can be eliminated by counter-current washing from bleached pulp right through the recovery furnace, (13, 14, 15 & 16). In 1969, Hisey (17) has reported economic advantages in reuse of filtrate from bleaching stages in counter-current fashion. Histed complied a survey in 1972 (18) showing the three main types of counter-current washing being practiced in the bleachers. Clark (19) reported that a partial "jump stage" counter-current washing system
at International Paper Company resulted in substantial savings in steam, water and caustic. Atkins (20) pointed out zero discharge status from the bleachery.

Yankowski (21) showed that the fresh water make up in the seal tanks could be reduced or eliminated. Tyler (22) described the several treatment methods such as lime treatment, coagulation and carbon absorption should benefit economically from smaller size of equipment possible if volume of bleachery effluents is reduced. Rapson (23) mentioned that a bleach plant with fewer stages had lower levels of effluents than those using more bleaching stages. Doughal (24) reported that mills have lightened their bleach plant systems from 6,000 to 14,000 gallons of effluents per ton of pulp bleached with minor problems.

Surveys of water usage on paper machines have been reported (25, 26, 27 & 28). A number of programs have considered water reuse on paper machines (29 & 30). Higher secondary treatment costs are forcing greater reuse (31). Aldrich and Janes (32) pointed out increased chemical retention and reduction in BOD loading with the increased water reuse on the paper machine, while negligible differences were found on the paper properties. Springer (33) mentioned some problems which can be caused by the extensive reuse of white water on paper machines. Alexander and Dobbins (34) reported the build-up of dissolved electrolytes in a closed paper mill system. Bansal (35) mentioned some of the techniques to purify the effluents for reuse purposes. A number of studies have been made to reuse the effluents in pulp and paper mills (36, 37, 38, 39 & 40). A new
effluent-free bleached kraft mill using corrosion resistant materials was built by Great Lake Paper using Rapson-Reeve (41) closed-cycle process.

Most of the authors who conducted studies to reduce the mill effluents have agreed upon the fact that excessive water recycling reduced BOD loading, chemical cost, fiber losses and final effluents.
PRESENTATION OF PROBLEM

The mill water treatment facilities were loaded to the maximum capacities. On frequent occasions the mill has suffered loss of production due to the lack of additional water. Aside from the high costs of expanding the water pumping and treatment facilities, it was extremely difficult to get increased water use permit from the local State Water Management Board. The intrusion of salt water in Jacksonville area has forced the industry to a strict conservation.

As a result of these circumstances, there was a strong need for an extensive Water Reuse Program to coincidentally make available enough water to eliminate water related process problems, while at the same time provide the additional water required to meet the expanding levels of production and decrease the final mill effluents.

The purpose of this study was to develop a Water Reuse Program for an integrated pulp and paper mill (i.e. Hudson Pulp and Paper Corporation) in order to reduce the final effluents, fiber losses, chemical losses and steam wastage.
SCOPE OF PROBLEM

The approach taken was to conduct the material balances and analytical analyses of various systems as following:

Water Balances

1. Overall water balance around the mill
2. Water balance around the evaporators
3. Water balance around kraft paper machines
4. Water balance around tissue paper machines
5. Water balance around bleach plant
6. Water balance around pulp mill
7. Water balance around power house

Analytical Analysis of Process Water

1. White water from tissue paper machine
2. White water from towel paper machine
3. White water from kraft paper machines
4. Bleach plant filtrates
5. Barometric condensers discharge

Process Water Analyzed for:

1. Total solids
2. Suspended solids
3. Dissolved solids
4. pH
5. Hardness
6. Chloride
7. Temperature
8. Alkalinity

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9. Acidity
10. Conductivity
11. Iron
12. Color
13. Samples were not tested for slime and foam as the biocide and defoamer control programs are always employed in the mill.

After establishing the quantity and quality of the process water, the water reuse at various locations was evaluated. Additional filtration, chemical treatment and/or equipment was employed to upgrade the quality of process water for reuse purposes.
APPROACH

Water distribution system in the mill was studied. Material balances were conducted to determine the quantities of water used at each process. The effluents from each major source were analyzed to determine their suitability for reuse in the same or other processes.

On the paper machines the moisture content of sheet leaving the wire and press section was determined by breaking the sheet. These samples were dried in the oven.

Various kinds of flowmeters were employed to determine the flows.

The reusable effluents were economically upgraded with chemical, mechanical and heat transfer means to the levels to be suitable for recycling in the process.

The water reuse program was developed. The approach used was to bring in the cleaner effluents from the tissue machines which run on bleached grades and reuse them with certain treatment when required in the bleach plant and pulp mill.

The usage of fresh water was reduced by cooling the turbine condenser's cooling water and recycling it. Barometric condensers were either replaced with surface condensers or equipped with cooling towers in order to reduce the overall effluents. By replacing the barometric condenser with the surface condenser the same quantity of water was supplied to the process, but just at a higher temperature.

The bleaching process was made to run hot through all of the
bleaching sequences. The cold fresh water was only supplied to the process where temperature is critical, like chilled water for ClO₂ absorption, chlorine injection, reactor cooling and cooling tower make-up.

From the material balance calculations the water requirements of the process were determined. The necessary quantities of water required by each process was first reduced by the reuse of process water and then through supplying the effluents from other processes. Finally the demand was satisfied with the fresh water.

A water reuse program was developed and the final fresh water requirements were determined.
PULP AND PAPER MILL PROCESSES

The pulp and paper mill processes consist of the following.

Pulp Mill

Batch Digesters  13 Total Digesters
5 Digesters 4900 Cu. Ft. Each
8 Digesters 4000 Cu. Ft. Each

Blow Tanks  3 Total at 50 Tons Capacity Each

Washers
No. 1 Line  4 Stage Impco
No. 2 Line  4 Stage Impco
No. 3 Line  4 Stage Impco
No. 4 Line  3 Stage Impco

Screens
5 Hot Stock Screens
4 Trimby Screens
2 Bird Screens

Reject System
Reject from all 4 Washer lines are refined and returned to blow tanks.

Deckers
No. 1 Impco
No. 2 Impco
No. 3 Dorr-Oliver

Bleach Plants
2 - CEHD Sequence

Bleach Chemical Plant
5 tons per day Solvay Process for Chlorine Dioxide.

High Density Storage
3 Tile Chests at 250 Tons Each
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<th>No. 1 Line with Barometric Condenser</th>
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<td>No. 2 Line with Barometric Condenser</td>
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<tr>
<td></td>
<td>No. 3 Line with Surface Condenser</td>
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<td>No. 4 Line with Surface Condenser</td>
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<tr>
<td>Recovery Boiler</td>
<td>1 - 1200 Tons per day C-E Odor-Free</td>
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<td></td>
<td>1350 psi Recovery Boiler</td>
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<tr>
<td>Causticizing</td>
<td>1 Green Liquor Clarifier</td>
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<tr>
<td></td>
<td>1 Dregs Washer</td>
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<td>1 Shaker</td>
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<tr>
<td></td>
<td>3 Causticizing Reaction Tanks</td>
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<td></td>
<td>2 White Liquor Clarifiers</td>
</tr>
<tr>
<td></td>
<td>2 Mud Washers</td>
</tr>
<tr>
<td>Lime Kiln</td>
<td>1 Allis Chalmers 320 Tons per day</td>
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<td>Kraft Paper Machines</td>
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<tr>
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<tr>
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<tr>
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<tr>
<td>Breast Roll</td>
<td>Fiberglass</td>
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<tr>
<td>Couch Roll</td>
<td>Bronze, Wire Drive</td>
</tr>
<tr>
<td></td>
<td>Rubber Cover</td>
</tr>
<tr>
<td>Control System</td>
<td>Accuray 1180</td>
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<td>Tissue Paper Machines</td>
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<td>Bronze</td>
</tr>
<tr>
<td>Pulp Drier</td>
<td>1 - Bleached Market Pulp</td>
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<tr>
<td>Fan Pump (GPM)</td>
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<tr>
<td>Capacity</td>
<td>250 A-D Tons/Day</td>
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### Water Treatment

#### No. 2 Water Treat Plant
- 3 Clarifiers: 5 Million Gallons Each per Day
- 1 Clarifier: 10 Million Gallons per Day
- 1 Reservoir: 3 Million Gallons per Day
- Capacity: 25 Million Gallons per Day

#### No. 1 Water Plant
- Capacity: 12 Million Gallons per Day
- 1 Reservoir: 1 Million Gallons per Day

### Waste Water Treatment
- 1 Clarifier: 10 Million Gallons
- Retention: 7 Hours
- 4 Oxidation Pond: 960 Acres
- Retention Time: 35-40 Days

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WATER DISTRIBUTION

A total of about 39 million gallons of water from the various sources after different treatments was pumped to the mill daily. All of the water used at the paper machines had been once used to cool the surface condensers in the power house. All of the water was ultimately discharged to the waste treatment system.

The water was supplied from the following sources.

1. No. 2 Water Treatment Plant
2. No. 1 Water Treatment Plant
3. Rice Creek Pump House

No. 2 Water Treatment Plant

The Entonia Creek fed by the mill artesian wells supplied the water to the No. 2 Water Treatment Plant. Here the water was treated with lime and alum and filtered through the sand filters. The filtered water was pumped to the 3 million gallon reservoir. A set level in the reservoir was maintained at all times. The water distribution of treated and filtered water from the No. 2 Water Treatment Plant is shown in Figure 1. About 22 million gallons of finished water was pumped to the mill daily through the reservoir. The blow down from the clarifier was discharged to the mill sewer. The water used for back washing the sand filters which amounted to about 1 million gallons per day was also discharged to the mill sewer.

From the reservoir the treated and filtered water was pumped by the transfer pumps to the mill. About 12 million gallons of the
Figure 1: No. 2 Water Treatment Plant
Water Distribution of Treated and Filtered Water

No. 2 Water Plant

Surface Condenser

Power House

Bleach Plant

No. 3 Tissue Machine

Pulp Mill

Pulp Dryer

No. 5 Towel Napkin Machine
Cold water was pumped through the power house turbine condensers for cooling purposes. About 2 million gallons per day was discharged to the mill sewer just after cooling various equipment like air compressors, pumps, I.D. fans and oil. The water after cooling the turbine condensers was discharged to the mill. All of this water was used at the bleach plant, No. 3 tissue machine, No. 5 towel napkin machine and pulp drier.

About 4 million gallons per day was pumped from the reservoir to cool the surface condenser on No. 3 set of evaporators. All of this water at about 110°F was used at the bleach plant for seal tank make-up.

The cold water supply to the mill was about 4 million gallons per day. This cold water was pumped from the reservoir through the same transfer pumps and it did not heat exchange any equipment. This cold water was used at the bleach plant, No. 3 tissue machine and No. 5 towel napkin machine.

Cold Water Usage

The cold water was used for chlorine injection, chemicals make-up, bleach caustic washer showers, chilled water production for the absorption of ClO₂, vacuum pumps and various pump seals cooling.

All of the water used for cooling the turbine condensers and the surface condenser at No. 3 set of evaporators was used only once to cool these condensers and then discharged to the mill for usage in various processes. This water after unloading the condensing loads was discharged ultimately to the mill sewer regardless of the production or processes requirement. For example bleach plant may have
been down for maintenance; even then the turbine condenser cooling water was continuously discharged to the sewer from the seal tanks. Same was the case for tissue, towel napkin and pulp drier machines. The condenser cooling water was independently discharged just after one pass. There were no provisions for cooling part of this cooling water and recycling.

Fresh cold water was supplied to the demineralizers for the removal of contamination by ion exchange. The deionized water was used for the high pressure boiler feed. About 1.2 million pounds of steam was generated per hour and 50% condensate was returned to the power house from the manufacturing areas. The water used for the regeneration of demineralizer resins was also discharged to the mill sewer.

No. 1 Water Treatment Plant

The water in this treatment plant was not filtered but the suspended solids were settled in the basin. The water from the top was decanted. All of the water processed in this plant was pumped through the condenser of No. 1 turbine for cooling (Figure 2). The water from the turbine condenser was discharged to the kraft paper machines and pulp mill. About 12 million gallons of water was pumped daily from this plant and was only used to cool the turbine condenser once and finally discharged to the mill sewer regardless of the production at the kraft paper machines. The primary purpose of this water was to unload the turbine condensing load and after that this water had to be discharged to the mill at a continuous rate in order to maintain the power generation at the power house.
Figure 2: No. 1 Water Treatment Plant
Unfiltered Fresh Water Distribution
Rice Creek Pump House

Water from Rice Creek was pumped directly without any treatment to the barometric condensers of No. 1 and No. 2 set of evaporators as shown in Figure 3. About 5.6 million gallons per day of this water was discharged to the mill sewer just after one pass. The water after cooling the barometric condensers was not used at all in the mill, but became a part of the final mill effluents.

Waste Water Treatment System

All of the effluents amounted to about 39 million gallons per day were pumped to the waste water clarifier. The suspended solids were allowed to settle down. Polymers were occasionally used to improve the flocculation. The sludge from the bottom of the clarifier was pumped to the sludge ponds. The waste water was pumped to the oxidation ponds.

The oxidation ponds covered an area of 960 acres where the waste water passed through the four ponds at the different levels. The total retention time in these ponds was about 35 to 40 days. Floating aerators were used for the aeration in these ponds. Finally these effluents were discharged to Rice Creek, which emptied in St. Johns River.
Figure 3: Rice Creek Pump House
Water for Barometric Condensers on Evaporators

Rice Creek Pump House

4000 GPM

1600 GPM
Barometric Condensers on No. 1 Set of Evaporators

To Sewer

2400 GPM
Barometric Condensers on No. 2 Set of Evaporators

To Sewer
MATERIAL BALANCE CALCULATIONS

Material Balance Around No. 3 Tissue Machine

Sheet leaving the wire after couch has 88% moisture. The sheet is dewatered in the press section from 88% moisture content to 70% moisture.

The yankee dryer lowers the sheet moisture content from 70% to 7%.

All of the water used in No. 3 TPM process is supplied from the fresh water header. Vacuum system is equipped with Nash pumps.

**Machine data**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine Production</td>
<td>79 A.D. ton/day</td>
</tr>
<tr>
<td>Fiber Losses</td>
<td>6 A.D. ton/day</td>
</tr>
<tr>
<td>Total Furnish</td>
<td>85 A.D. ton/day</td>
</tr>
</tbody>
</table>

Furnish consists of 80% hardwood and 20% pine.

In: Entering the machine system

85 A.D. tons/day at 4% consistency from high density storage chests = 318 GPM

<table>
<thead>
<tr>
<th>Description</th>
<th>GPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wire showers</td>
<td>350</td>
</tr>
<tr>
<td>Pick up felt showers</td>
<td>900</td>
</tr>
<tr>
<td>Bottom felt showers</td>
<td>650</td>
</tr>
<tr>
<td>Vacuum pumps seal water</td>
<td>500</td>
</tr>
<tr>
<td>Pump packing cooling and wash ups</td>
<td>182</td>
</tr>
<tr>
<td>Total In</td>
<td>2900</td>
</tr>
</tbody>
</table>

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Out: Leaving the machine system

7% moisture being carried with sheet at dry end = 13 GPM
Press section water removal = 59 GPM
Evaporation through the yankee hood = 27 GPM
White water discharged to the mill sewer = 2801 GPM
Total Out = 2900 GPM

Material Balance Around No. 5 Towel Napkin Machine

All of the water supplied to the machine was from the No. 2 water treatment plant, which was fresh treated and filtered.

Wet strength resins, softeners and various other additives were used during the towel manufacturing. Machine was equipped with Dorr-Oliver poly disc saveall.

Machine data

Production = 148 A.D. tons/day
Fiber Losses = 7 A.D. tons/day
Total Furnish = 155 A.D. tons/day
Stock Supplied from High Density Storage Chests at = 4%
Furnish = Bleached hardwood and softwood
Sheet moisture leaving the wire = 88%
Sheet moisture leaving the press section = 60.8%
Sheet moisture at dry end = 4.4%
In:

155 A.D. tons/day at 4% consistency = 581 GPM
Vacuum pump cooling = 250 GPM
Pick up felt showers = 900 GPM
Wet felt showers = 700 GPM
Breast roll, head box, needle and trim showers = 350 GPM
Stock preparation = 400 GPM
Saveall showers = 100 GPM
Wash ups = 150 GPM
Pump packing and equipment cooling = 250 GPM
Total In = 3681 GPM

Out:

Water carried with sheet at dry end = 24 GPM
Water evaporated in dryers = 35 GPM
Water removal in the press sections = 134 GPM
Excess of white water to sewer = 3488 GPM
Total Out = 3681 GPM

Material Balance Around Pulp Drier

Bleached hardwood pulp was pumped to the pulp drier at 4% consistency. Average 201 A.D. tons of bleached pulp was produced daily. The fiber losses were 4 tons per day. Fresh treated and filtered water was used at the pulp drier for dilution purposes.

The fresh water supplied to the Nash vacuum pump was discharged

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to the pulp drier seal pit. Pulp mat was compressed to 52% consistency in the press sections. Flakt dryers dried the sheet to 10% moisture.

The white water was discharged through the dropleg to the seal pit. White water for cleaner and head box dilution was pumped from the seal pit. Fresh water was added at the seal tank. Overflow from the pulp drier was pumped to the central white water chest and bleach plant chlorine dioxide showers. A generous quantity of white water from the seal pit was discharged to the sewer. The clean rejects were also sewered.

The seal pit was heated with live 50 PSIG steam. Temperature of stock at head box was maintained at 130°F.

**Machine data**

<table>
<thead>
<tr>
<th>Production</th>
<th>= 201 A.D. ton/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiber Losses</td>
<td>= 4 A.D. ton/day</td>
</tr>
<tr>
<td>Total Furnish to the Pulp Drier</td>
<td>= 204 A.D. tons/day</td>
</tr>
<tr>
<td>Sheet moisture leaving the press section</td>
<td>= 48%</td>
</tr>
<tr>
<td>Sheet moisture at dry end</td>
<td>= 10%</td>
</tr>
</tbody>
</table>

Bleached pulp is pumped to the pulp drier at 4% A.D. consistency.

In:

<table>
<thead>
<tr>
<th>205 ATD/D at 4% A.D. consistency</th>
<th>= 768 GPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylinder mold showers</td>
<td>= 200 GPM</td>
</tr>
<tr>
<td>Vacuum seal water</td>
<td>= 100 GPM</td>
</tr>
<tr>
<td>Make up water to the seal pit</td>
<td>= 400 GPM</td>
</tr>
<tr>
<td>Total In</td>
<td>= 1468 GPM</td>
</tr>
</tbody>
</table>
Out:

201 ADT/D at the dry end = 33 GPM
Evaporation = 25 GPM
To high density storage chest for stock dilution = 600 GPM
To bleach plant for ClO₂ washer shower = 400 GPM
Excess discharged to sewer = 380 GPM
Cleaner rejects to sewer = 30 GPM
Total Out =1468 GPM

Material Balance Around No. 1 Kraft Machine

All of the water used on the machine was supplied from No. 1 water treatment plant. The machine is provided with Nash vacuum system. Stock was supplied at 12% consistency to the machine system.

Machine data

Production = 398 A.D. tons/day
Fiber Losses = 16 A.D. tons/day
Total Furnish = 414 A.D. tons/day
Furnish = 100% softwood
Sheet moisture content leaving the wire = 83%
Sheet moisture content leaving the press section = 67%
Sheet moisture content at the dry end = 4.6%

In:

414 A.D. tons/day at 12% consistency entering the machine = 517 GPM
<table>
<thead>
<tr>
<th>Description</th>
<th>GPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wire showers</td>
<td>550</td>
</tr>
<tr>
<td>Breast roll showers</td>
<td>220</td>
</tr>
<tr>
<td>Felt showers</td>
<td>600</td>
</tr>
<tr>
<td>Deculator, surge tanks, head box showers</td>
<td>180</td>
</tr>
<tr>
<td>Nash vacuum pumps seal water</td>
<td>1300</td>
</tr>
<tr>
<td><strong>Total In</strong></td>
<td><strong>3367</strong></td>
</tr>
<tr>
<td><strong>Out:</strong> Water leaving the machine system</td>
<td></td>
</tr>
<tr>
<td>Water carried with sheet at dry end with 398 A.D. tons/day at 4.6 moisture content</td>
<td>70</td>
</tr>
<tr>
<td>Press section water removal</td>
<td>177</td>
</tr>
<tr>
<td>Evaporation</td>
<td>131</td>
</tr>
<tr>
<td>Excess white water to the mill sewer</td>
<td>2989</td>
</tr>
<tr>
<td><strong>Total Out</strong></td>
<td><strong>3367</strong></td>
</tr>
</tbody>
</table>

**Material Balance Around No. 2 Kraft Machine**

All of the fresh water supplied to the machine was from the No. 1 water treatment plant. Machine is equipped with Nash vacuum pumps system. Machine was supplied with 12% consistency stock from the pulp mill.

**Machine data**

- Production = 246 A.D. tons/day
- Fiber Losses = 12 A.D. tons/day
- Total Furnish = 258 A.D. tons/day
Sheet moisture content leaving the wire = 83%
Sheet moisture content leaving the press section = 71%
Sheet moisture content at dry end = 3.7%

In: Water entering the machine system

258 A.D. tons/day at 12% from the pulp mill = 322 GPM
Wire showers = 500 GPM
Breast roll showers = 220 GPM
Felt showers = 380 GPM
Fresh water added for the brown stock dilution at brown stock washer = 350 GPM
Nash vacuum pump seal water = 1200 GPM
Pumps and equipment cooling = 250 GPM
Wash up = 100 GPM
Total In = 3322 GPM

Out: Water leaving the machine system

246 A.D. tons/day with 3.7% moisture content = 43 GPM
Water evaporation by dryer = 93 GPM
Press section water removal = 94 GPM
Excess white water discharged to sewer = 3092 GPM
Total Out = 3322 GPM

Material Balance Around Bleach Plant

Two 4-stages bleach plant consisting of C-E-H-D sequence are supplied with treated and filtered fresh water. Hardwood brown stock washing line is included in the bleach plant system. The
chilled water used for the chlorine dioxide absorption was supplied by Croll-Reynolds Chill Victor. The water supplied to the barometric condenser was recycled by cooling it through the cooling tower.

The fresh water was used for stock dilution before the chlorine stage, seal tank make up, bleach washer showers, equipment cooling and making up of chemicals. Only the filtrate from the bleaching stages were sewered through the caustic and chlorination seal tanks. Other process water was discharged to the mill waste clarifier separately.

The washer shower water was either supplied from the fresh water header and/or from tissue machine effluents.

The bleach plant produced 479 A.D. tons of bleached pulp daily. Bleach plant operation is controlled by Nokia computer systems. Fiber losses amount to 10% of the total bleached production.

In:

Brown stock furnish 527 A.D. tons/day at 4% consistency = 1975 GPM
Make up water to seal tanks = 4000 GPM
Bleach washers shower flow rate = 2300 GPM
Chlorine injection = 450 GPM
Cold water to chill unit = 150 GPM
Reactors cooling, sodium chlorate storage cooling water = 200 GPM
Pumps gland, packing cooling, cooling tower make up, etc. = 300 GPM
Total In = 9375 GPM

Out:
479 A.D. tons bleached to high density storage chests at 10% consistency = 718 GPM

Effluents from seal tanks and U-drains = 8657 GPM

Total Out = 9375 GPM

Water usage per A.D. ton of pulp bleached = 28,184 Gallons

Water usage = 28,000 Gallons/A.D. ton bleached

Material Balance Around Pulp Mill

Pulp mill has 13 batch digesters. Hardwood and softwood was cooked separately by the kraft process and blown to the different blow tanks. Hardwood and softwood were kept segregated during cooking, washing, screening, bleaching and refining. Furnish was mixed in the machine chest.

Wood chips were cooked in the digesters with 165 PSIG steam directly. White liquor and black liquor were changed in the digester and cooked for the different time intervals depending on the production of finished grades. Pulp from the blow tanks was transported through the fibrillizers to the brown stock washers.

Hot stock screens were installed ahead of brown stock washers. About 30% of the total production was discharged to the reject tank by the hot stock screens. The rejects were refined and pumped to the kraft blow tank.
Blow tanks and brown stock washers

16.5 ADT in 4900 ft.³ volume digester is cooked with:

- White liquor = 12,560 Gallons
- Black liquor = 4,240 Gallons
- Steam 3,238 lbs./ADT = 6,406 Gallons
- Moisture in wood chips 65 tons at 47% moisture = 7,326 Gallons
- Total moisture contents = 30,532 Gallons
- Side relief = 360 Gallons
- Blow heat 2,381 lbs./ADT = 4,710 Gallons
- Flow from the blow tank pumped to the brown stock washers = 25,462 Gallons

25,462 Gallons of black liquor transport 16.5 ADT of pulp to the brown stock washer.

Total pulp production = 1,179 ADT/Day

\[
\frac{25,462 \text{ gallons}}{\text{cook}} \times \frac{\text{cook}}{16.5 \text{ ADT}} \times \frac{1,179 \text{ ADT}}{\text{day}} \times \frac{\text{day}}{1,440 \text{ min.}} = \frac{1,263 \text{ gallons}}{\text{min.}}
\]

\[
\frac{1,179 \text{ A.D. tons}}{\text{day}} \times \frac{1,800 \text{ lbs.}}{\text{A.D. ton}} \times \frac{\text{day}}{1,440 \text{ min.}} \times \frac{\text{gallon}}{8.34 \text{ lbs.}} \times \frac{100}{\text{x}} = \frac{1,263 \text{ gallon}}{\text{min.}}
\]

"x" consistency = 13.99% = 14%

Brown stock washers

On the steady state basis 1,179 air dry tons of daily production were discharged to the blow tanks at the rate of 1,263 gallons per minute. The pulp was diluted in the blow tank, fibrillizer and before the washer vat. The dilution was supplied from the first stage filtrate tank of brown stock washers. The vat consistency was maintained at 1%.
In:

1,179 A.D. tons/day at 1% consistency to brown stock washer vats  =  17,682 GPM

Counter current washing shower water for brown stock washing  =  2,100 GPM

Total In  =  19,782 GPM

Out:

Black liquor for pulp dilutions  =  16,419 GPM
Black liquor to evaporators  =  2,004 GPM
Pulp to the deckers 1,179 A.D. tons/day at 13% consistency  =  1,359 GPM

Total Out  =  19,782 GPM

Water Balance Around No. 1 Set of Evaporators

331 Gallons per minute of black liquor at 15.5% solids and 8.76 lbs/gallon density was pumped to the No. 1 set of evaporators. The concentrated black liquor at 47.5% solids at 210°F was pumped out of the first effect of evaporators. This set of evaporators is equipped with the barometric condenser.

In:

Black liquor feed  =  331 GPM
Steam flow  =  61 GPM
Barometric condenser flow  =  1,600 GPM
Pumps cooling and wash ups  =  100 GPM

Total In  =  2,092 GPM
Out:
To the recovery boiler = 91 GPM
Condensate to sewer = 240 GPM
Other effluents = 1,761 GPM
Total Out = 2,092 GPM

Water Balance Around No. 2 Set of Evaporators

Black liquor at the rate of 622 GPM at 7.3°Be, 195°F, 15.5% solid and 8.76 lbs./gallon density was pumped to the No. 2 set of evaporators from the storage tanks. The concentrated black liquor at 210°F, 29°Be, 48% solids and 10.42 lbs./gallon density was discharged to the recovery boiler. This set of evaporators was equipped with the barometric condenser.

In:
Black liquor feed rate = 622 GPM
Barometric condenser flow = 2,400 GPM
Pump cooling and wash up = 100 GPM
Steam flow = 86 GPM
Total In = 3,208 GPM

Out:
To recovery boiler = 169 GPM
Condensate to sewer = 453 GPM
Barometric condenser flow and other misc. to sewer = 2,586 GPM
Total Out = 3,208 GPM
Water Balance Around No. 3 Set of Evaporators

Black liquor at the feed rate of 615 GPM at 7.3°Be, 195°F, 15.5% solids and 8.76 lbs./gallon density was pumped to the No. 3 set of evaporators. Concentrated liquor at 48% solids, 28.7°Be, 218°F and 10.42 lbs./gallon was discharged to the recovery boiler at the rate of 167 GPM. This set of evaporators was equipped with a surface condenser.

In:
Black liquor feed rate = 615 GPM
Surface condenser flow = 2,800 GPM
Steam flow = 82 GPM
Pump cooling and wash up = 100 GPM
Total In = 3,597 GPM

Out:
Concentrated liquor to recovery boiler = 167 GPM
Condensate to the sewer = 448 GPM
Surface condenser water to the process = 2,800 GPM
Excess water to sewer = 182 GPM
Total Out = 3,597 GPM

Water Balance Around No. 4 Set of Evaporators

This set of evaporator was equipped with a surface condenser. The condenser cooling water was cooled by a cooling tower and recycled. There was no wastage of good quality from the surface condenser cooling water. Black liquor was fed at 174°F and 15.7% solids.
In:
Black liquor feed rate = 687 GPM
Steam = 47 GPM
Sweetener = 9 GPM
Cooling tower make up = 200 GPM
Total In = 943 GPM

Out:
Concentrated black liquor to recovery boiler = 165 GPM
Condensate to sewer = 778 GPM
Total Out = 943 GPM

Water Balance Around Power House

Cold fresh water from No. 1 water treatment plant was used to cool the No. 1 turbine condenser and then discharged to the kraft paper machines. Water at No. 1 treatment plant was not filtered.

Treated and filtered water from the No. 2 water treatment plant was pumped to cool the No. 4 and No. 2 turbine condensers and then discharged to the bleached grades manufacturing processes. Good quality water was supplied to the demineralizers for the boilers feed. Condensate return to the power house was 1,200 GPM from the mill.

In:
Black liquor fired to the furnace = 160 GPM
356 GPM, produced smelt
Week wash supplied for smelt dissolving = 640 GPM
Filtered fresh water supplied for cooling No. 4 and No. 3 turbine condensers = 8,000 GPM
Unfiltered water supplied for cooling No. 1 turbine condenser = 7,600 GPM
Condensate return from the mill to the power house = 1,200 GPM
Filtered water to the demineralizers for the boilers feed = 1,200 GPM
Total In = 18,800 GPM

Out:

Green liquor from smelt dissolving to green liquor clarifier = 800 GPM
Steam generation water requirement = 2,400 GPM
Filtered water to process after condensers cooling = 7,000 GPM
Unfiltered water to kraft process after cooling the turbine condenser = 6,800 GPM
Demineralizer regeneration, air compressors and equipment cooling, filter washing, boil outs, wash ups, etc. to sewer = 1,800 GPM
Total Out = 18,800 GPM

Overall Water Balance

No. 2 water treatment plant
To power house for turbine condenser cooling = 8,000 GPM
To tissue machines = 6,000 GPM
Blow down, back wash of sand filters = 1,400 GPM

No. 1 treatment plant
To turbine condenser cooling and kraft paper machines = 7,600 GPM
Rice Creek pump house

For barometric condensers on No. 1 and No. 2 set of evaporators and wash ups = 4,000 GPM

Total In = 27,000 GPM

Out:

Evaporation, loss of condensate, etc. = 1,200 GPM
Power house effluents = 1,500 GPM
KPMS effluents = 6,500 GPM
TPM effluents = 6,500 GPM
Bleach plant effluents = 9,375 GPM
Pulp mill effluents, causticizing, washer room, screen room = 1,925 GPM

Total Out = 27,000 GPM
= 38.9M^2GD
WATER USAGE PER TON OF PRODUCT

From the water and material balance calculations the following water usages were established.

<table>
<thead>
<tr>
<th>System</th>
<th>Water Usage</th>
<th>Basis</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 1 KPM</td>
<td>11,000</td>
<td>Gallons/ A.D. ton of paper</td>
<td>Unbleached kraft</td>
</tr>
<tr>
<td>No. 2 KPM</td>
<td>18,000</td>
<td>Gallons/ A.D. ton of paper</td>
<td>Unbleached kraft</td>
</tr>
<tr>
<td>No. 3 TPM</td>
<td>47,000</td>
<td>Gallons/ A.D. ton of paper</td>
<td>Facial and Bathroom bleached tissue</td>
</tr>
<tr>
<td>No. 5 TNM</td>
<td>30,000</td>
<td>Gallons/ A.D. ton of paper</td>
<td>Bleached napkin and towel</td>
</tr>
<tr>
<td>Pulp Drier</td>
<td>5,000</td>
<td>Gallons/ A.D. ton of pulp</td>
<td>Bleached market pulp</td>
</tr>
<tr>
<td>Brown Stock Washing</td>
<td>2,500</td>
<td>Gallons/ A.D. ton of pulp</td>
<td>Hardwood and softwood pulp</td>
</tr>
<tr>
<td>Bleaching</td>
<td>28,000</td>
<td>Gallons/ A.D. ton of pulp</td>
<td>Hardwood and softwood pulp bleached</td>
</tr>
<tr>
<td>Steam</td>
<td>2,950</td>
<td>Gallons/A.D. ton</td>
<td>Of total production</td>
</tr>
<tr>
<td>Barometric Condensers on Evaporators</td>
<td>12,000</td>
<td>Gallons/ A.D. ton of pulp</td>
<td>Hardwood and softwood liquor vapor condensa-</td>
</tr>
</tbody>
</table>
ANALYTICAL ANALYSES

TABLE I
Barometric Condensers

<table>
<thead>
<tr>
<th>Tests</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Solids ppm</td>
<td>261</td>
<td>901</td>
<td>489</td>
</tr>
<tr>
<td>Suspended Solids ppm</td>
<td>9</td>
<td>595</td>
<td>143</td>
</tr>
<tr>
<td>Dissolved Solids ppm</td>
<td>208</td>
<td>416</td>
<td>345</td>
</tr>
<tr>
<td>pH</td>
<td>7.16</td>
<td>10.03</td>
<td>8.74</td>
</tr>
<tr>
<td>Hardness ppm</td>
<td>6</td>
<td>44</td>
<td>31</td>
</tr>
<tr>
<td>Chlorides ppm</td>
<td>5</td>
<td>16</td>
<td>10</td>
</tr>
<tr>
<td>Acidity, ppm</td>
<td>0</td>
<td>102</td>
<td>22</td>
</tr>
<tr>
<td>Alkalinity ppm</td>
<td>88</td>
<td>130</td>
<td>103</td>
</tr>
<tr>
<td>Temperature °F</td>
<td>103</td>
<td>150</td>
<td>121</td>
</tr>
<tr>
<td>Conductivity μ-mhos</td>
<td>262</td>
<td>953</td>
<td>462</td>
</tr>
<tr>
<td>Iron ppm</td>
<td>0.1</td>
<td>2.3</td>
<td>0.91</td>
</tr>
<tr>
<td>Color ppm</td>
<td>300</td>
<td>1,000</td>
<td>500</td>
</tr>
</tbody>
</table>

Composited samples were taken from the barometric condenser hot well.
TABLE II  

KPM  

<table>
<thead>
<tr>
<th>Tests</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Solids ppm</td>
<td>380</td>
<td>1,525</td>
<td>803</td>
</tr>
<tr>
<td>Suspended Solids ppm</td>
<td>137</td>
<td>642</td>
<td>249</td>
</tr>
<tr>
<td>Dissolved Solids ppm</td>
<td>156</td>
<td>902</td>
<td>504</td>
</tr>
<tr>
<td>pH</td>
<td>6.05</td>
<td>10.39</td>
<td>7.78</td>
</tr>
<tr>
<td>Hardness ppm</td>
<td>34</td>
<td>92</td>
<td>54</td>
</tr>
<tr>
<td>Chlorides ppm</td>
<td>10</td>
<td>45</td>
<td>26</td>
</tr>
<tr>
<td>Acidity ppm</td>
<td>0</td>
<td>118</td>
<td>33</td>
</tr>
<tr>
<td>Alkalinity ppm</td>
<td>2</td>
<td>252</td>
<td>101</td>
</tr>
<tr>
<td>Temperature °F</td>
<td>103</td>
<td>111</td>
<td>108</td>
</tr>
<tr>
<td>Conductivity μ-mhos</td>
<td>211</td>
<td>1,563</td>
<td>648</td>
</tr>
<tr>
<td>Iron ppm</td>
<td>0.1</td>
<td>1.0</td>
<td>0.58</td>
</tr>
<tr>
<td>Color ppm</td>
<td>250</td>
<td>300</td>
<td>500</td>
</tr>
</tbody>
</table>

Composited samples were taken from the final effluents of kraft paper machines.
TABLE III

#3 TPM

<table>
<thead>
<tr>
<th>Tests</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Solids ppm</td>
<td>892</td>
<td>2,178</td>
<td>1,217</td>
</tr>
<tr>
<td>Suspended Solids ppm</td>
<td>600</td>
<td>1,886</td>
<td>989</td>
</tr>
<tr>
<td>Dissolved Solids ppm</td>
<td>99</td>
<td>381</td>
<td>227</td>
</tr>
<tr>
<td>pH</td>
<td>5.01</td>
<td>9.05</td>
<td>6.44</td>
</tr>
<tr>
<td>Hardness ppm</td>
<td>24</td>
<td>50</td>
<td>37</td>
</tr>
<tr>
<td>Chlorides ppm</td>
<td>31</td>
<td>81</td>
<td>47</td>
</tr>
<tr>
<td>Acidity ppm</td>
<td>8</td>
<td>80</td>
<td>36</td>
</tr>
<tr>
<td>Alkalinity ppm</td>
<td>8</td>
<td>44</td>
<td>19</td>
</tr>
<tr>
<td>Temperature °F</td>
<td>96</td>
<td>111</td>
<td>103</td>
</tr>
<tr>
<td>Conductivity μmhos</td>
<td>212</td>
<td>742</td>
<td>438</td>
</tr>
<tr>
<td>Iron ppm</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Color ppm</td>
<td>35</td>
<td>95</td>
<td>65</td>
</tr>
</tbody>
</table>

Composited samples were taken from the final effluents of No. 3 tissue paper machine.
### TABLE IV
**#5 TPM**

<table>
<thead>
<tr>
<th>Tests</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Solids ppm</td>
<td>137</td>
<td>630</td>
<td>444</td>
</tr>
<tr>
<td>Suspended Solids ppm</td>
<td>123</td>
<td>561</td>
<td>305</td>
</tr>
<tr>
<td>Dissolved Solids ppm</td>
<td>14</td>
<td>304</td>
<td>139</td>
</tr>
<tr>
<td>pH</td>
<td>5.42</td>
<td>7.54</td>
<td>6.59</td>
</tr>
<tr>
<td>Hardness ppm</td>
<td>26</td>
<td>48</td>
<td>39</td>
</tr>
<tr>
<td>Chlorides ppm</td>
<td>39</td>
<td>115</td>
<td>56</td>
</tr>
<tr>
<td>Acidity ppm</td>
<td>12</td>
<td>64</td>
<td>29</td>
</tr>
<tr>
<td>Alkalinity ppm</td>
<td>6</td>
<td>42</td>
<td>25</td>
</tr>
<tr>
<td>Temperature °F</td>
<td>101</td>
<td>119</td>
<td>113</td>
</tr>
<tr>
<td>Conductivity $\mu$-mhos</td>
<td>221</td>
<td>996</td>
<td>448</td>
</tr>
<tr>
<td>Iron ppm</td>
<td>NEG.</td>
<td>0.1</td>
<td>NEG.</td>
</tr>
<tr>
<td>Color ppm</td>
<td>35</td>
<td>100</td>
<td>65</td>
</tr>
</tbody>
</table>

Composited samples were taken from No. 5 towel napkin machine.
TABLE V

Bleach Plant

<table>
<thead>
<tr>
<th>Tests</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Solids ppm</td>
<td>668</td>
<td>1,665</td>
<td>1,120</td>
</tr>
<tr>
<td>Suspended Solids ppm</td>
<td>28</td>
<td>978</td>
<td>326</td>
</tr>
<tr>
<td>Dissolved Solids ppm</td>
<td>535</td>
<td>1,224</td>
<td>793</td>
</tr>
<tr>
<td>pH</td>
<td>2.31</td>
<td>7.01</td>
<td>3.87</td>
</tr>
<tr>
<td>Hardness ppm</td>
<td>118</td>
<td>232</td>
<td>153</td>
</tr>
<tr>
<td>Chlorides ppm</td>
<td>146</td>
<td>320</td>
<td>250</td>
</tr>
<tr>
<td>Acidity ppm</td>
<td>70</td>
<td>660</td>
<td>278</td>
</tr>
<tr>
<td>Alkalinity ppm</td>
<td>0</td>
<td>36</td>
<td>8</td>
</tr>
<tr>
<td>Temperature °F</td>
<td>106</td>
<td>110</td>
<td>108</td>
</tr>
<tr>
<td>Conductivity μ-mhos</td>
<td>996</td>
<td>1,755</td>
<td>1,239</td>
</tr>
<tr>
<td>Iron ppm</td>
<td>0.3</td>
<td>1.8</td>
<td>1.0</td>
</tr>
<tr>
<td>Color ppm</td>
<td>1,200</td>
<td>2,000</td>
<td>1,500</td>
</tr>
</tbody>
</table>

The composited samples were taken from the final bleach plant effluents.
DEVELOPMENT OF WATER REUSE PROGRAM

Bleach plant, No. 3 tissue paper machine and No. 5 towel napkin machine were the big users of water. These processes were furnished with the first quality treated and filtered water because of the critical brightness grades. This water has already been used to cool the No. 4 and No. 2 turbine condensers. The unfiltered water after cooling the No. 1 turbine condenser was supplied to the kraft paper machines and pulp mill. The suspended solids were allowed to settle by gravity in the water treatment plant. The water used at the barometric condensers of evaporators was pumped directly from Rice Creek.

A program was developed for water reuse and effluent reduction throughout the mill. The logical approach was to reuse the effluents in the same process from where originated with certain treatments. Good quality final remaining effluents from the tissue machines were used in the pulp mill as following:

Water Reuse at Paper Machines

Most of the fresh water quantities were used for wire showers, felt showers and vacuum pump seals. The white white system of the paper machines was segregated from the vacuum seal water. Water reuse at the paper machine was divided in the two categories: 1) Vacuum pump seal water for Nash pumps, and 2) Shower water for (wires and felts).
Recycling of the Nash Vacuum Pump Seal Water

The vacuum systems of both of the kraft machines and No. 3 tissue machine was equipped with Nash vacuum pumps. Previously 800 GPM of white water from the machine press sections and 3000 GPM of seal water were discharged to the mill sewer. In order to recycle these effluents on the vacuum seal the entire quantity of this water was segregated from the machine's white water system.

The water from all of vacuum pumps was collected in various sumps and pumped to the cooling tower. The recycling of vacuum seal water arrangement is shown in Figure 4. About 3650 GPM was cooled by the cooling tower from 100°-110°F to 80°-90°F, and 150 GPM of fresh water was added in the cooling tower sump. The cooled water was pumped to the vacuum pumps and bleach plant. Out of 3800 GPM, the 3000 GPM were recycled on the vacuum seals and remaining 800 GPM were supplied to the bleach plant caustic washer showers.

This water reuse system has not only eliminated the need of 3000 GPM of fresh water, but also have made 800 GPM of good process water available to the bleach plant. Also the effluent reduction by 3800 GPM was achieved.

No. 3 Tissue Paper Machine

All of the low pressure high volume showers previously using fresh water were changed to the clarified white water. The water reuse arrangement is shown in Figure 5. The saveall had the capacity to handle 2000 GPM of white water. The couch pit provided only
Figure 4: Recycling of Nash Vacuum Pump Seal Water

Strainer

Cooling Tower

150 GPM
F.W. Make up

1300 GPM
To No. 1 KPM

1200 GPM
To No. 2 KPM

500 GPM
To No. 3 TPM

800 GPM
To Bleach Plant

F.W.: Fresh Water

1500 GPM
From No. 1 KPM

1400 GPM
From No. 2 KPM

3,600 GPM

750 GPM
From No. 3 TPM
Figure 4: Water Reuse at No. 3 Tissue Paper Machine

To Bleach Plant

550 GPM

950 GPM

Felt Sump

900 GPM

Couch Pit

To Wire Showers

350 GPM

Filter

F.W. Make up

To Wet Felt Showers

650 GPM

To Pick Up Felt Showers

F.W. Make up

White Water Chest

300 GPM

Save-all
950 GPM. The felts shower water from the press section amounted to 1550 GPM, was collected in the sump. Out of 1550 GPM, 550 GPM was pumped to the bleach plant and remaining 1000 GPM were routed to the saveall along with the couch pit flocs. The clarified white water was filtered again before being supplied to the wire and felt showers. 300 GPM of fresh water was supplied to the system in order to maintain smooth operation.

The high pressure needle showers using about 50 GPM of fresh water was maintained on fresh water. The pump packing coding water and cleaner rejects were discharged to the mill sewer.

The following reduction in effluents or fresh water usage was accomplished from the reuse of white water.

<table>
<thead>
<tr>
<th>Description</th>
<th>Usage (GPM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wire showers</td>
<td>300</td>
</tr>
<tr>
<td>Felt showers</td>
<td>1,050</td>
</tr>
<tr>
<td>Total reduction in fresh water usage</td>
<td>1,350</td>
</tr>
<tr>
<td>Pump packing coding and cleaner rejects to sewer</td>
<td>212</td>
</tr>
<tr>
<td>Excess of white water pumped to the bleach plant</td>
<td>550</td>
</tr>
</tbody>
</table>

Water usage per A.D. ton of paper

\[
\frac{762 \text{ gallon min.}}{1440 \text{ min. day}} \times \frac{\text{day}}{7 \text{ a ton}} = 13,889 \text{ gallons/ton}
\]
No. 5 Towel Napkin Machine

All of the low pressure high volume showers on the felts which were on fresh water were changed to the clarified white water from the clear leg of the saveall. The white water after the saveall was filtered again to ensure low suspended solids concentration before being reused at the showers. High pressure needle showers were maintained on the fresh water.

A total flow rate of 700 GPM which included 510 GPM of fresh water (Figure 7) was supplied to the wet felt shower system. The water pressed out by the pressure roll from the wet felt was discharged to a gravity fed atmospheric filter. The filtered water was again pumped through the vent condenser on the condensate collection tank to pick up waste heat and discharged to the hot water felt shower tank. As shown in Figure 6, 240 GPM of fresh water was added to the felt shower tank and then pumped to the pick up felt showers at the rate of 900 GPM.

The continuous cleaning showers on low pressure and high volume were changed to high pressure and low volume. The excess of the white water from the machine was pumped either to the central white water chest or to the bleach plant as dictated by the process demands. The effluents were only the equipment cooling water and the tertiary cleaner rejects.

The fresh water usage was significantly reduced by slightly modifying a part of showering system. All of the felts were 100% synthetic which made the application of high pressure showers very attractive.
Figure 6: White Water Reuse on Pick up Felt Showers No. 5 TNM

- Press roll pan
- Filter
- Vent Condenser
- F.W. Make Up
- Hot Water Shower Tank
- To Pick Up Felt Showers
- To Sewer

240 GPM
900 GPM

F.W. = Fresh Water
TNM = Towel Napkin Machine
Figure 7: Clarified White Water Reuse on the Wet Felt Showers No. 5 TNM

- 100 GPM to Showers
- 1730 GPM from Couch Pit
- 1360 GPM to Wet Felt
- 470 GPM to Consistency Regulation
- 400 GPM to central white water chest
- 300 GPM to Wire Showers
- 450 GPM to Bleach Plant
- 40 GPM to Sewer
- 510 GPM to Fresh Water Make up

F.W. = Fresh Water
The fresh water usage was restricted to the following applications.

- Fresh water usage on high pressure showers = 200 GPM
- Fresh water make up for wet felt showers = 510 GPM
- Head box, couch roll, press roll showers, edge squirt
- Wash ups, additives, misc. = 100 GPM
- Equipment cooling water = 150 GPM
- Total In = 1,150 GPM
- Reduction in fresh water usage = 3,100 - 1,150 = 1,950 GPM

The following water reuse arrangements are made.

- Excess white water to the bleach plant = 400 GPM
- Excess white water to central white water chest
- Cleaner rejects, equipment cooling, wash up to sewer = 350 GPM
- Effluents discharged to the mill sewer = 504,000 Gallons/Day
- Water usage per ton of paper produced = 11,189 Gallons/A.D. Ton

Kraft Paper Machines

The unfiltered fresh water was supplied to the kraft paper machines after cooling the No. 1 turbine condenser in the power house. All of the water once passed through the turbine condenser was used at kraft machines and finally sewered at a continuous rate in order to ensure the smooth generation of electricity. Prior to the water reuse the majority of fresh water was sewered without any significant recycling.
These machines were installed in 1947. At that time it was considered economical to build an unbleached softwood paper machine without the saveall at the expense of fiber losses. Accordingly, the kraft machines were built without savealls. The felts were 25% woolen.

It was found economically prohibitive to reuse the clarified white water on the felt showers, because major machine design changes like new saveall, press section, synthetic felts and different showering system were required. Majority of wire showers on fresh water with the exception of high pressure needle showers were replaced with the clarified white water.

Pulp Dryer White Water Reuse

There were not any changes in flow made at the pulp drier. The fresh water usage has been maintained at the same levels, but the seal pit overflow to the sewer was picked up and pumped either to the bleach plant and/or to the central white water chest.

The white water pumped to the central white water chest was used for the dilution of bleached stock at the high density storage chests. This diluted stock was pumped to tissue, towel napkin and pulp dryer machines.

The white water pumped to the bleach plant was used on the ClO₂ washer showers and became the part of filtrate which was reused for the counter current washing on the last three stages of bleach plant.
Excess of white water available for reuse = 1,400 GPM
White water pumped to ClO₂ washer showers = 1,000 GPM
White water pumped to central white water = 400 GPM

Kraft Paper Machines

Water Reuse at No. 1 Kraft Machine

The wire cleaning, wire knock off and wire return showers amounting to 700 GPM were replaced with the white water. The white water excess from the fan pump dilution requirement was filtered through a strainer and reused on these showers.

Fresh water usage reduction = 700 GPM = 1 Million Gallons per Day

Total effluents from the machine = 2,466 GPM
system discharge to the waste treatment system

Water usage for A.D. ton of paper = \( \frac{2,466 \text{ Gallons} \times 1,440 \text{ min}}{\text{min.}} \times \frac{\text{day}}{298 \text{ tons}} \)

= 8,922 Gallons/A.D. ton of paper

Out of 2,466 GPM of water, about 1,500 GPM were pumped to the cooling tower and recycled back to the vacuum pumps for sealing.

The remainder effluents with the exception of cleaner rejects and pump packing cooling water were pumped to the pulp mill for the reuse on the brown stock washers and deckers.

Effluents reused:

At brown stock washers and deckers = 416 GPM
At the caustic washer in bleach plant = 200 GPM
At the Nash vacuum pumps seal = 1,300 GPM
Effluents discharged to the waste clarifier = 350 GPM

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Through the reuse of white water on the wire showers 700 GPM reduction in fresh water usage was achieved. The white water excess from the machine system being discharged to the mill sewer was reduced by 616 GPM due to the reuse at the washers or deckers.

Effluents reduced through water reuse = 1,316 GPM on the machine system and pulp mill

= 1.9 Million Gallons/Day

Water Reuse at No. 2 Kraft Machine

As in the case of No. 1 GPM the wire knock off, wire return and wire cleaning showers were changed from fresh water with the clarified white water. The wire showers using 600 GPM of fresh water were charged with the filtered white water.

Reduction in the fresh water usage and effluents = 600 GPM

=840,000 Gallons/Day

Total water usage = 2,586 GPM

Water usage per ton of paper = \( \frac{2,586 \text{ Gallons}}{\text{min.}} \times \frac{1,440 \text{ min.}}{\text{day}} \times \frac{\text{day}}{246 \text{ tons}} 

= 15,138 Gallons/Ton

Out of 2,586 GPM of effluents about 1,400 GPM were pumped to the vacuum seal cooling tower. After cooling the hot water by 20°-25°F, 1,200 GPM of this water were pumped back to the vacuum seals of Nash vacuum pumps on No. 2 KPM.

Excess of process water = 1,186 GPM
From the 1,186 GPM the cleaner rejects and the pumps packing cooking water amounting to about 350 GPM was discharged to the waste clarifier and remaining 836 GPM were pumped to the pulp mill for reuse on the brown stock washers and deckers.

Effluents reused:

At brown stock washers and deckers = 836 GPM
At the Nash vacuum pumps seal = 1,200 GPM
At the caustic washer in the bleach = 200 GPM

Effluents discharged to the waste clarifier = 350 GPM

Through the water reuse a reduction in fresh water usage by 600 GPM was achieved. Also by reusing the white water on the brown stock washer the effluents from No. 2 KPM were reduced by 836 GPM.

Total effluent reduction = 1,536 GPM

Water Reuse at Bleach Plant

Both of the bleach plants consist of CEHD sequence. The water usage was about 28,000 gallons per ton of bleached pulp. The cause for such a high water usage was the generous fresh water make up for chlorine dioxide and sodium hypochlorite seal tanks, brown stock dilution with fresh water and minimum water recycling, as shown in Figure 8. The seal tanks were supplied with 2000 GPM of fresh make up water. The overflow from chlorine dioxide and sodium hypochlorite seal tanks was supplied to chlorine and caustic seal tanks respectively for make up purposes.
Figure 8: Bleach Plant Jump Stage Arrangement of Seal Tanks

Fresh and White Water

C

350 GPM

E

KAD 00

H

1,358 GPM

Fresh Water

D

To Sewer 1,358 GPM

To Sewer 350 GPM

25,996 GPM

1,773 GPM

700 GPM

1,300 GPM
Significant modifications were made in the water system of the bleach plant in order to reuse water. Jump stage seal tank arrangement was replaced with the series connected seal tank for the counter current washing at the last three stages (Figure 9). The flow rate through the bleach washer showers have been increased to 500 GPM in order to maintain a good displacement ratio at all of the washers. Only the chlorine dioxide seal tank was supplied with the fresh water make up.

All of the water used in the bleach plant did not discharge through the seal tanks. The water used for cooling the pump seals, \( \text{ClO}_2 \) reactors, sodium chlorate storage and various equipment along with the spills, wash ups, dumps, blow down from barometric condenser cooling tower at chill unit, and screen room effluents was discharged through the U-drains to the mill sewer.

The most reduction in fresh water usage was accomplished by lowering the make up flow to \( \text{ClO}_2 \) and hypo seal tanks. The other big reduction in fresh water usage was obtained by diluting the screened stock for chlorination with the white water supplied from the tissue effluents. The dilution water pumped to the high density storage chests was recycled in the process.

In the counter current washing arrangement the only make up water supplied to the seal tanks was at \( \text{ClO}_2 \) stage, which was further reduced to 300 GPM.
Figure 9: Water Reuse at Bleach Plant

Fresh and White Water

C

500 GPM

C

1,181 GPM

To Sewer

E

1,934 GPM

1,354 GPM

H

708 GPM

To Sewer

D

300 GPM

F.W. Make Up

F.W. = Fresh Water
Reduction in fresh water usage at the seal tanks due to counter current washing at each bleach plant = 1,700 GPM

Fresh water usage reduction at both of the bleach plant seal tanks = 3,400 GPM

Total water supplied to bleach plant = 4,900 GPM

Water usage at bleach plant

For brown stock dilution prior to chlorination stage from 10% to 4% consistency = 1,185 GPM

The white water for bleach washer showers from the tissue towel machines effluents = 2,365 GPM

Fresh cold water for ClO₂ absorption and equipment cooling = 350 GPM

Fresh water supplied from surface condenser cooling header = 1,000 GPM

Total water usage = 4,900 GPM

In the reuse program the bleach washer showers were provided with 4,000 GPM of total shower flow. Out of 4,000 GPM, 2,365 GPM of shower flow was supplied from the white water discharged from the tissue and towel machines. Remaining 1,635 GPM were furnished from the seal tanks. The filtrate from the last stage was used on the previous stage washers as shown in Figure 10.

Total water usage for bleaching = 14,730 Gallons/A.D. ton of bleached pulp

Fresh water usage = 4,058 Gallons/A.D. ton of bleached pulp
Figure 10: Bleach Plant Filtrate Reuse at Washer Showers
Water Reuse at Pulp Mill

The pulp mill production, 1,179 A.D. tons per day, was washed on the 4 lines on brown stock washers. Fresh and/or white water from the kraft paper machines was used for the counter current washing.

The brown stock washers discharged the pulp at 12% consistency from the last stage to the washed stock chest. It has been determined that a dilution factor equivalent to 3.5 was adequate for economical washing considering the soda losses and evaporation costs.

Water carried with 1,179 A.D. tons of pulp at 12% consistency from the washers last stage = 1,296 GPM

Dilution water added to the black liquor for maintaining 3.5 dilution factor for 1,179 A.D. tons = 618 GPM

Counter current washing water requirement = 1,914 GPM

Reduction in water usage = 2,100 - 1,914 = 186 GPM

= .27 Million Gallons per Day

The water usage reduction has the good potential for steam savings in the evaporators.

The water for the brown stock counter current washing was supplied from the following sources.

Excess of white water from the kraft paper machines = 1,000 GPM

Cooling water from the power house after running it through the oil separator = 500 GPM

Fresh water header = 500 GPM

Total supply of water for washing the pulp = 2,000 GPM
All of the water used for the counter current washing was heated through the blow heat recovery system to about 160°F prior to use on the washer. This will also save the live steam being used to heat the wash water. An improved washing efficiency with considerably less pitch deposits in the system will result by using the higher temperature water for washing.

Water Recycling at Barometric Condenser on No. 1 Set of Evaporators

No. 1 set of evaporators has a barometric condenser at the last effect. About 1,600 GPM was discharged to the mill sewer from this barometric condenser just after one pass. A cooling tower as shown in Figure 11 was installed to cool this water and recycle it over and over again. The cooling tower cooled the condenser water by about 25°F.

The losses from cooling tower due to evaporation and dissolved solids can amount to 4% of the flow rate. About 64 GPM of fresh water make up was supplied to compensate the tower losses.

\[
\text{Blow down from cooling tower to sewer} = 32 \text{ GPM} \\
\text{Effluent reduction} = 1,600 - 32 = 1,568 \text{ GPM} \\
= 2,258,000 \text{ Gallons/Day}
\]

The analytical tests of the barometric condenser effluents are shown in Table I. Due to high level of contamination this was not reused in any other process.
Figure 11: Water Recycling at Barometric Condenser on No. 1 Set of Evaporators
Replacement of Barometric Condenser with Surface Condenser on No. 2 Set of Evaporators

No. 2 set of evaporators was previously equipped with a barometric condenser and 2400 GPM of creek water was discharged to the sewer just after once condensing the vapor produced by concentrating 622 GPM of black liquor from 15.5% solids to 48% solids. The condensate amounted to 453 GPM and was discharged to the mill sewer along with the condenser cooling water.

The effluents generated by the condenser cooling water were eliminated when the barometric condenser was replaced with the surface condenser as shown in Figure 12. About 3000 GPM of fresh cold water already being supplied to the bleach plant and tissue machines was used to cool the surface condenser.

Effluent reduction = 2,400 GPM

= 3.36 M^2GD

Reuse of Demineralizer Regenerants

All of the high pressure boilers use demineralized water with a minimum level of contamination. The boiler feed water was deionized by ion exchange through the cation and anion exchangers (demineralizers). The resins used in the cation and anion exchangers were regenerated with H_2SO_4 and NaOH. The regenerants were discharged to the mill sewer.

During the resin regeneration the pH of total mill effluents jumped from the one extremity to the other. The sudden change in
Figure 12: Replacement of Barometric Condenser with Surface Condenser at No. 2 Set of Evaporators

From No. 2 Water Plant 3,000 GPM at 50°-70°F

To Bleached Grades Production Processes
pH caused the problems at the waste water clarifier, plugged the sludge pumps and dissolved the concrete sewer lines. Black liquor was mixed with the regenerants to keep the pH from shifting towards acidic values and then these effluents were discharged to the mill sewer.

A reuse program was developed which involved the collection of the regenerants and control of pH with caustic addition to the alakine side. After the pH adjustment the regenerants were pumped to the smelt dissolving tanks at the average flow rate of 165 GPM as shown in Figure 13.

The cation resin was generated with 6 lbs. 66°Be H₂SO₄ per ft.³ of resin. The anion resin was generated with 5 lbs. NaOH per ft.³ of resin.

**Data**

No. of regenerations = 2

Volume of cation resin = 600 ft.³

H₂SO₄ used for cation regeneration = 600 ft.³ \times \frac{6 \text{ lbs.}}{\text{ft.}^3} = 3,600 \text{ lbs. of } 66°\text{Be}

Total H₂SO₄ usage = 3,600 \times 2 = 7,200 \text{ lbs.}

Volume of anion resin = 430 ft.³

NaOH required for anion regeneration = 430 ft.³ \times \frac{5 \text{ lbs.}}{\text{ft.}^3} = 2,150 \text{ lbs. NaOH}

Total NaOH usage = 2,150 \times 2 = 4,300 \text{ lbs.}
Figure 13: Reuse of Demineralizers Regenerants
Neutralization

\[
\begin{align*}
H_2SO_4 + 2NaOH & \rightarrow Na_2SO_4 + 2H_2O \\
7,200 & + \left( \frac{7,200}{98} \right) \\
73.47 + 2(73.47) & \rightarrow 73.47 + 146.94
\end{align*}
\]

Lbs. of NaOH required for neutralization = \(2(73.47) \times 40 = 5,877.6\) lbs.

Available NaOH in the regenerants = 4,300 lbs.

Addition of NaOH required for neutralization = \(5,877.6 - 4,300 = 1,577.6\) lbs.

Water used for regeneration of demineralizers = 237,600 Gallons per Day

Reduction in effluent = 237,600 Gallons per Day

Integrated Program of Water Reuse

After the water reuse has been established at each operating system, the effluents from the mill were studied. Most of the effluents were generated from the paper machines, pulp mill and bleach plant. The effluents from the pulp mill and bleach plant were highly colored and loaded with contamination (Table V) and were eliminated from reuse considerations.

The effluents from the paper machines were quite (Tables III and IV) significantly better than bleach plant and pulp mill. The effluents from the paper machines were reused in the bleach plant and the pulp mill. The paper machine effluents were categorized in two classes and were reused separately.

1. Effluents from the machines manufacturing the bleached grades.
2. Effluents from the machines manufacturing the un-bleached grades.

The analytical analyses (Tables II, III & IV) have shown that the water discharged from the machines producing te bleached grades was quite different and better in quality than the machines producing the unbleached grades. Based on the analytical analyses these white water systems were segregated from each other.

**Effluents from the machines manufacturing the bleached grades**

The excess of white water from the pulp drier, tissue and towel napkin machines was found quite suitable for reuse purposes in the bleach plant at the bleach washer showers, brown stock dilution for chlorination stage and dilution of bleached stock at the high density storage chests. The white water tests are shown in Tables III and IV. The entire effluents from these machines with the exception of cleaner rejects and pump packing cooling water were reused in the bleach plant. The effluents from the machines even on colored grades can do excellent jobs of washing the chlorinated and caustic extracted pulp. An effort was made to discharge these effluents through the bleach plant.

**White water available for reuse from machines:**

- Effluents from No. 3 tissue machine = 550 GPM
- Effluents from No. 5 towel napkin machine = 800 GPM
- Effluents from the pulp drier = 1,400 GPM
- From vacuum seal cooling tower = 800 GPM
Total white water available for reuse in the bleach plant = 3,550 GPM

In addition to the above supply of white water, the fresh water was supplied as following:

- Fresh water from the surface condenser cooling water header = 100 GPM
- Cold water for producing chilled water at Croll Reynolds unit and chlorine injection = 350 GPM
- Total fresh water supplied to bleach plant = 1,350 GPM
- Total water supplied to bleach plant = 4,900 GPM
- Water usage in bleach plant = 14,730 Gallons/A.D. ton of bleached pulp

Effluents from the machines manufacturing the unbleached grades

The excess of white water from these machines was reused for the counter current washing at the brown stock washers, dilution of brown stock to deckers and brown stock dilutions from the deckers. After using all of the white water being discharged from these machines the fresh water was used to satisfy the pulp mill water requirements.

White Water Available from Kraft Paper Machines for Reuse in Pulp Mill

- Effluents from No. 1 kraft paper machine = 900 GPM
- Effluents from No. 2 kraft paper machine = 500 GPM
- Turpentine condenser cooling water = 500 GPM
- Power house cooling water = 600 GPM
- Total effluents available = 2,500 GPM
The cleaner rejects and pump packing cooling water was discharged to the mill sewer.

Additional pulp mill water requirements were satisfied from the fresh water header.

Fresh water supplied to pulp mill = 500 GPM
Total water supplied to the pulp mill = 3,000 GPM

The water requirement for counter current washing showers at the brown stock washers with 3.5 dilution factor was about 2,000 GPM. About 300 GPM of fresh water were used for equipment cooling and remaining 700 GPM were used for decker dilutions.

Fresh Water Requirements of Water Reuse Program

While developing the reuse program the fresh water requirements of treated and filtered water from No. 2 water treatment plant were determined. Following quantities were required at the described locations for the implementation of integrated water reuse program as shown in Figure 14.

Power house = 1,800 GPM
Pulp mill = 500 GPM
Bleach plant = 1,000 GPM
No. 3 tissue machine = 800 GPM
No. 5 towel napkin machine = 1,150 GPM
Pulp dryer = 500 GPM
Cooling towers make up water = 800 GPM
Cold water for ClO₂ absorption = 350 GPM
Figure 14: Water Recycling of Turbine Condenser Cooling Water From No. 2 Water Treatment Plant

Bleach Plant

800 GPM

6,500 GPM

1,000 GPM

800 GPM

6,200 GPM

2,800 GPM

2,800 GPM

800 GPM

1,150 GPM

500 GPM

800 GPM

1,000 GPM

500 GPM

To Pulp Mill

Start ups and Boil Outs

No. 5 TNM

Pulp Dryer

Cooling Tower Make Up

To Pulp Mill

350 GPM

Bleach Plant

2,800 GPM

No. 3 Surface Condenser

8,000 GPM

1,950 GPM

2,800 GPM

8,000 GPM

Cooling Tower
For start up, shut down, wash ups, = 1,000 GPM
upsets, boil outs, etc.

Total treated filtered fresh water = 7,900 GPM
requirements

The turbine condensers required huge quantities of cooling water, which were not needed in the mill. In order to unload the turbine condensing load the condenser cooling water was recycled.

Water Recycling of Turbine Condenser Cooling Water

The treated and filtered water requirements were 7,900 GPM from the No. 2 water treatment plant. The cooling water requirements for No. 4 and No. 2 turbines were 8,000 GPM alone. The other surface condensers on No. 2 and No. 3 set of evaporators required 5,600 GPM for cooling. More water was needed for the condensers cooling than required at the manufacturing processes. The condensers cooling water recycling arrangement is shown in Figure 14.

The water excess from the mill demand after cooling the turbine condensers was discharged to the cooling tower, where it was cooled and pumped back to the turbine condensers. Power house fresh water make up requirement was reduced to 1,950 GPM. From the cooling tower 150 GPM were discharged as blow down to the main mill water header and 6,050 GPM were recycled at the power house turbine condensers.

Unfiltered Fresh Water Requirements of Water Reuse Program

Fresh water from No. 1 water plant without any filtration was used for cooling the No. 1 turbine condenser. After cooling the following quantities of this water were required at the following locations.
Power house = 600 GPM
No. 1 kraft paper machine = 1,050 GPM
No. 2 kraft paper machine = 700 GPM
Pulp mill = 750 GPM
Turpentine condenser = 500 GPM
Total unfiltered fresh water required = 3,600 GPM

The manufacturing processes required 3,600 GPM of this water. The No. 1 turbine condenser required 7,600 GPM of cooling water as shown in Figure 15. Out of 7,600 GPM, the 4,000 GPM after cooling were recycled at the turbine condenser, and 600 GPM were used for equipment cooling. The remaining 3,000 GPM were discharged to the kraft paper machines and pulp mill. The 500 GPM used for the turpentine condenser cooling were pumped to the main header and were reused at the kraft paper machines and/or the pulp mill. The fresh water usage was reduced to 3,600 GPM, which was supplied from the No. 1 water treatment plant.

Total Water Requirements

Filtered and treated water required from No. 2 water treatment plant = 7,900 GPM
Unfiltered fresh water required from No. 1 water treatment plant = 3,600 GPM
Total water required = 11,500 GPM
= 16.7 Million Gallons per Day
Figure 15: Water Recycling of Turbine Condenser Cooling Water From No. 1 Water Treatment Plant

No. 1 Water Plant

3,600 GPM → 7,600 GPM

F.W. Make Up

Power House No. 1

Turbine Condenser

Cooling Tower

2,900 GPM

4,000 GPM

600 GPM

Turpentine Condenser

Pulp Mill

Pulp Mill Equipment Cooling

500 GPM → 850 GPM → No. 1 KPM

500 GPM

No. 2 KPM

500 GPM

250 GPM → 400 GPM → KPMS Equipment Cooling
Due to installation of cooling tower on the barometric condenser of No. 1 set of evaporators and replacement of barometric condenser with the surface condenser on No. 2 set of evaporators the need of the Rice Creek pump house water was eliminated. Filtered treated water from No. 2 water treatment plan already being supplied to bleach plant, tissue and towel napkin machine was used as cooling medium for the surface condenser on No. 2 set of evaporators and then fully used in the process.

Implementation of integrated water reuse program is shown in Figure 16. All of the water required by the mill was supplied by the No. 2 water treatment plant. Out of the total 11,500 GPM of water only 350 GPM were pumped separately to the bleach plant. Remaining 11,500 GPM after cooling the condensers were discharged to the mill. Two cooling towers were installed to cool and recycle 10,050 GPM of water at the condensers. Finally, 11,500 GPM of water used and reused in the process were discharged to the mill waste water treatment plant.

Effluent Reduction from Water Reuse Program

Water usage from No. 1 water treatment plant, No. 2 water treatment plant and the Rice Creek pump house was 27,000 GPM prior to reuse program.

After the development of integrated program of water reuse the water usage was reduced to 11,500 GPM. The need of No. 1 water treatment plant and the Rice Creek pump house was eliminated.

\[
\text{Effluent reduction} = \left( \frac{27,000 - 11,500}{27,000} \right) \times 100 = 57.4
\]

Final effluents were reduced by 57%.

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Figure 16: Final Fresh Water Distribution Only From No. 2 Water Treatment After the Implementation of Integrated Water Reuse Program

1. Cooling Tower
2. No. 4 and No. 2 Turbine Condensers
3. Cooling Tower
4. No. 1 Turbine Condenser
5. Surface Condenser on No. 2 and No. 3 set of Evaporators
DISCUSSION

In an integrated process the dependence on a continuous constant supply of cold fresh water is considerably increased. In excess of 96% of the total power used for pulp and paper manufacturing is generated at the mill. All of the steam generated by recovery boiler, power boiler and bark boiler is at high pressure, which is extracted by the turbine to generate the electricity. The steam generated at 1,250 PSIG is extracted at 160 PSIG. The condensing loads of the turbines are unloaded by the surface condensers which are cooled with the fresh water. Generous quantities of fresh water are used to cool these turbine condensers and ensure a continuous steady state generation of steam and electricity.

The mills built ten or more years age were designed for higher production and minimum emphasis was placed on water and energy conservation. The water once used to cool the turbine condensers was discharged to the manufacturing areas and finally to the mill sewer without any significant reuse and recycling. Barometric condensers were frequently preferred over the surface condensers for being low maintenance equipment. All of the water used at the barometric condenser was sewered just after one pass.

The extracted steam with a significant degree of superheat is used for digester cooking, pulp and paper drying, liquor evaporation, making chilled water and heating the process water. About 50% of total steam generated is returned to the power house as condensate.
The water reuse program has the potential to reduce the fresh water usage by 57%. The effluent reduction by water reuse and recycling is discussed at the following.

1. Power House
2. Evaporators with Barometric Condensers
3. Paper Machines
   a. Kraft Paper Machines
   b. Tissue Paper Machines
   c. Pulp Drier
4. Pulp Mill
5. Bleach Plant

Power House

Turbine condenser cooling water

The first main big usage of the fresh water being pumped to the mill is to cool the turbine condensers in order to maintain a steady state generation of steam and electricity. All of the manufacturing and allied processes are entirely dependent upon the power house for steam and electricity. Any upset in the power house can disturb the manufacturing operation which can result in the loss of production.

Previously the water once used to cool the turbine condensers was discharged to the mill and finally to the sewer. There was a tremendous potential to reuse this water after cooling it through the cooling tower.
The flow of water through the turbine condensers was maintained at the same levels, but the flow from the condensers to the mill was reduced. The demand of fresh water in the process was satisfied with the process water. The excess of cooling water from the turbine condensers was cooled by the cooling tower and pumped back to the condensers.

Demineralizer Regenerants

The demineralizer regenerants were neutralized with the black liquor and discharged to the mill sewer. These regenerants were upgraded with chemical treatment and reused as weak wash in the smelt dissolving tanks. The weak wash was supplied with fresh water.

The cation and anion regenerants were collected in a tank and pumped at a constant rate to the smelt dissolving tanks. An automatic pH control loop was installed on the discharge site of the pump. The pH was maintained at about 8 with 10% caustic.

Although the reuse of regenerants reduced the fresh water usage by about 150 GPM, but the main reduction was in the BOD loading to the mill sewer. Also the sulphuric acid and caustic used for the regeneration of resins were a gain in the form of salt cake.

Evaporators with Barometric Condensers

No. 1 and No. 2 set of evaporators were equipped with the barometric condensers. The water used once at these barometric condensers was discharged to the mill sewer along with the condensate
removed from the black liquor. This water was one of the major contributors of BOD. About 6 million gallons of water was discharged to the sewer daily from these barometric condensers.

The high color, high temperature and bad odor made this water unsuitable for reuse purposes in the other process without any significant improvements. These effluents were eliminated by the following techniques.

**Barometric condenser on No. 1 set of evaporators**

The water from the barometric condenser was discharged to a cooling tower and cooled by $20^\circ\text{F} - 25^\circ\text{F}$. The cold water from the cooling tower was recycled again at the barometric condenser. This reduced the BOD loading to the mill sewer. The dissolved solids level was maintained by the addition of cold fresh water as make up and a certain blow down.

**Barometric condenser on No. 2 set of evaporators**

About 4 million gallons of effluents and significant quantity of BOD was discharged to the waste treatment system daily from this barometric condenser. These entire effluents with the exception of condensate were eliminated by the following process modifications.

The barometric condenser was replaced with a surface condenser. There was a fresh filtered and treated water header carrying in excess of 3,000 GPM to the process located very close to this condenser. This cold water was used to cool the surface condenser. The warm water from the condenser was supplied to the pulp mill.
bleach plant and tissue machines. An additional pipe line was installed to transfer about 350 GPM of cold water to the bleach plant.

Paper Machines

Majority of the fresh water being used at the paper machines has been used to cool the various condensers in the power and recovery area. The biggest fresh water usage was on the wire and felt showers.

Kraft paper machines used more water on the wire than the felt showers. The felts were 25% woolen and 75% synthetic. These felts under the current operating conditions could not use white water showers. The machines run on heavy basis weight grades and are vacuum limited. These felts must be kept cleaned and unplugged at all times in order to maintain a smooth operation.

White water from the simple mechanical filtration at the atmospheric pressure could not be upgraded to suitable levels for reuse purposes on the felts, and the felt showers were maintained at fresh water.

Since the felts on these kraft paper machines used less water than the wire, so the wire showers on fresh water were charged with the filtered white water. The excess of white water was pumped to the pulp mill for brown stock washing at the washers and dilution for the deckers.

Kraft paper machines run on the unbleached softwood grades. The softwood due to its natural structure has long fiber and high freeness and good retention on the wire. These machines have
synthetic wires. Excellent filtration was achieved from the soft-
wood furnish white water through simple atmospheric filtration.
In addition the synthetic wires were quite suitable for white water
applications.

Since all of the white water was reused from these paper machines,
it was realized that fresh water used on felts would be healthy for
the process. Otherwise the reduction in white water supply to the
pulp mill would have to be compensated with the fresh water addition.
Only the cleaner rejects and pump seals cooling water was discharged
to the mill sewer.

Tissue machine, towel napkin machine and pulp dryer produced
bleached grades. The water used at the pulp drier was for dilution
purposes and all of the white water and the vacuum seal water was
returned to the pulp dryer seal tank. From the seal tank the white
water excess from pulp dryer dilution needs was pumped either to
the central white water chest or to the bleach plant for ClO₂
showers. The only effluents discharged to the waste water clarifier
were the cleaner rejects.

Only the required quantities of fresh treated and filtered
water after cooling the turbine were supplied to the tissue machines.
All of the wire showers with the exception of needle showers were
charged with the clarified white water.

In order to reclaim fiber and reuse white water on the machines
all of the excess white water from the press section was filtered.
The higher usage of the fines due to the reuse of white water has
increased the sheet handfeed and reduced the pin holes in the low basis weight sheets. The filtered white water from the press section was recycled back on the pick up felt showers with some make up of fresh water.

The clarified water from the saveall was filtered again through a strainer with automatic back wash system and with some fresh make up water pumped to the wet felt showers. This water after being used was filtered and reused on the pick up felts and accordingly this water was finally returned to the bleach plant. The tissue and towel machine felts were 100% synthetic and non-compressible, which made them highly suitable for reuse of white water. Machine runnability due to the reuse of filtered white water on the felt showers was not affected because the machine produces low basis grades which do not require high vacuum and the machines are not vacuum limited.

From these machines only the cleaner rejects and equipment cooling water were discharged to the mill sewer. The excess of white water from these machines if on white grades were pumped to the central white water chest for the dilution of bleached stock from the high density storage chests. The excess of white water while machines producing white or colored grades was pumped to the bleach plant and the pulp mill without any treatment. White water supplied to the bleach plant was used for the screened stock dilution prior to chlorination stage and on the chlorine and hypo washer showers.

The synthetic clothing could accomodate the high pressure low volume showers and the final effluents from the paper machine would
by further drastically reduced. But in an integrated operation it may not be a good approach. All of the effluents from the tissue paper machines with the exception of cleaner rejects and pump seal cooling water were brought back in the mill to be reused in the process to replace the fresh water. The tissue machine white water was of better quality and contributed to the improved process efficiencies as the white water contains fiber, chemicals and heat.

The water reuse program has the potential to reduce the water usage from 47,000 gallons per ton of paper to 14,000 gallons per ton of paper produced at No. 3 TPM. On No. 5 towel napkin machine the water usage has been reduced from 30,000 gallons per ton of paper to 12,000 gallons per ton of paper produced. Though a significant reduction in the fresh water usage was obtained, the water system was open enough to keep the system from plugging, and gave no slime and dissolved solids built up problems.

Energy Conservation at the Paper Machines

The fresh water formerly supplied to the pick up felts shower was heated with live steam from 70°-95°F to about 140°-160°F. The fresh water was replaced with the white water and due to recycling the temperature of white water increased to about 110°-120°F and the consumption for heating this water was decreased. Also this white water was used to condense the flashed steam from the condensate collection tank, which resulted in additional gain of heat.
Thermal build up in the white water system due to the increased recycling improved the drainage specially in winter months, as live steam was used to aid the drainage.

Potential Problems

Extensive water reuse on the paper machine causes the potential problems of higher build up of dissolved solids, suspended solids and thermal energy. If the water system of the machine is closed any tighter than 6,000 gallons per air dry of paper produced, build up of components in the white water may create a wide spectrum of operational problems as listed below.

1. Plugging of felts, wires and shower nozzles
2. Corrosion
3. Scaling
4. Foaming
5. Slime deposits
6. Problems with sizing on kraft paper machines
7. Brightness reversion on the bleached grades

It was recommended that a preventive maintenance program for corrosion and scale control be initiated in each paper mill. Foam and slime are always controlled by treating the machine system with defoamers, biocides and slimicides.

The developed water reuse program did not require a tighter closure of water system as the excess of white water was reused in the process. Accordingly none of the above-mentioned problems were anticipated.
Clarified white water was used only on the 100% synthetic felts on tissue and towel napkin machines. The potential of felt hair problems was eliminated. Even if there was felt hairs in the white water system, they would be cut many times in the refiners. There were no felt hairs found in the press section water samples worthy of mentioning.

**Vacuum Seal Water for Nash Vacuum Pumps**

The vacuum system of No. 1 kraft machine, No. 2 kraft machine and No. 3 tissue machine is equipped with the Nash vacuum pumps. About 3,000 GPM of fresh water was used for the vacuum pump seals and discharged to the mill sewer. About 800 GPM of white water was also drawn off the wires and felts and became a part of the effluents from the vacuum pumps.

A cooling tower was installed to cool these effluents by about 20°F or lower depending upon the weather conditions. The cooling tower was capable of handling 3,800 GPM of water at 105°F and cooling it down to 85°F during the summer months. A part of the cooled water excess from the vacuum pump needed about 800 GPM pumped to the bleach plant for reuse on the caustic washer showers and the remaining water was recycled on the vacuum pump seals. This water was not abrasive and was cool enough to allow the vacuum pumps to maintain good efficiency levels.

A strainer was used ahead of tower to filter out as much fiber as possible.
Pulp Dryer

The fresh water usage at the pulp dryer was not changed. The excess of white water at 120°F previously discharged to the mill sewer was picked up and pumped to the bleach plant and the central white water chest.

The excess of white water supplied to the bleach plant was used on ClO\textsubscript{2} washer. Showers were again reused for counter current washing on the last three stages. The white water supplied to the central white water chest was used for bleached stock dilution, which was pumped to the paper machines and the pulp dryer.

A vent condenser was installed at the separator of the flakt dryer condenser then flashed clean. The fresh water used as the cooling medium was reused on the cylinder mold showers. Significant improvements in drying were achieved by making the use of wasted steam.

Pulp Mill

The water usage in the pulp mill was for counter current washing at brown stock washers, knock down at the last stage of washers, decker dilution and decker knock down purposes.

About 2,000 GPM comprised of fresh and white water was previously used on the brown stock washers for the counter current washing. The fresh water was replaced with the excess of white water supplied from the kraft paper machines. This white water was heated to about 160°F by reclaiming the blow heat from the
blow tanks. Although the cooling water used in the power house for cooling the air compressors and turbine oil had little chance of contamination due to the positive pressure, even then it was logical to run these effluents through an oil separating unit.

The water used for knock down at the last stage of washers was supplied from the paper machines white water system. In general all of the white water excess from the machines system was routed to the brown stock washers for knock down and for decker dilutions before it was discharged to the mill sewer. The only effluents from the paper machines discharged to the sewer were the equipment cooling water and the cleaner rejects.

Evaporators

Two out of four sets of evaporators had barometric condensers on the last effect. No. 1 set of evaporators was furnished with a cooling tower and the condenser cooling water was recycled. The barometric condenser effluents to the mill sewer were reduced by 1,600 GPM.

The No. 2 set of evaporators had a barometric condenser and that was replaced with a surface condenser. The cold water being already supplied to the bleach plant, tissue and towel machines was used to cool this surface condenser. This technique not only eliminated the effluents about 2,400 GPM to the mill sewer but also provided the heat from unloading the condensing load to the process for improved performance.
Three surface condensers on three sets of evaporators discharged the condensate from the black liquor vapor condensation. This condensate was used for the mud washing on the mud washer showers.

Evaporator boil out

Clean evaporator tubes provide a good heat transfer to the liquor and improved steam economy. With time the organic and inorganic substances start to plate at the tubes. The coating is developed into scale build up. As the scale build up on the evaporator tubes is increased, accordingly the heat transfer and steam economy is reduced.

The pulp mill is run at the maximum capacity. Every effort is made to process as much cooking liquor as possible. Good cleaned tubes in the evaporators play a positive role in the recovery process. Evaporators are boiled out twice per week with fresh water from 4 to 6 hours in order to dissolve the scale formation in the tubes. These boil outs required about 600 GPM of fresh water for at least 4 hours.

At one time one set of evaporators was boiled out. In this case the condensate from the other evaporators on line was used for boil out. The effluents from the boil out were used normally for mud washing on mud washers, and the mud washers filtrates in the smelt dissolving tanks. In this arrangement the fresh water was only required for the first 15 minutes and after that the process was stabilized and significant reduction in fresh water usage and effluents were realized.
Mud Washing

The mud washers were supplied with fresh water which has been heated by the blow heat. The mud washer used between 800-1,000 GPM of fresh water, which has been replaced by the evaporator condensate.

The mud washer filtrate was used in the smelt dissolving tank. The smelt dissolving tanks requirements were 800 GPM at the optimum operation.

Bleach Plant

The bleach plant maintained the status of biggest user of water in the entire pulp and paper manufacturing processes. The major application of fresh water was make up for hypo and ClO₂ seal tanks, brown stock dilution for chlorination and bleach washer showers. A relatively small volume of water was used for equipment cooling, chlorine injection chemical make up and chlorine dioxide absorption. Unattended wash up hoses were left open and resulted in a significant volume of water wastage. The majority of the fresh water was fully or partially replaced with the bleaching process water, excess of white water from the tissue machines and pulp dryer as discussed in the following.

Dilution of washed and screened brown stock for chlorination

The washed and screened brown stock was diluted with the fresh water from about 10% consistency to 4% consistency for the chlorination stage. This fresh water was replaced with the excess of white...
water from the tissue paper machines. This water substitution has saved about 1,000 GPM of fresh water and equivalent effluent reduction was achieved.

The temperature of the chlorination stage increased due to the hot white water usage for the stock dilution. The rate of chlorination reaction increased with temperature. Optical sensor with temperature compensation was used to control the chlorination at optimum level.

The higher stock temperature also saved the stear in the caustic extraction stage because the pulp was heated in the caustic mixer with live steam to 170°F. The chlorine injection was continued with the fresh water.

Bleach washer showers

The material balance conducted around the bleach plant showed that the volume of water supplied to the bleach washer showers was quite inadequate. On certain washers the displacement ratio was quite less than 1:1, which represented a poor displacement of dissolved solids from the mat to the seal tank. This poor washing was compensated for by the addition of large quantities of fresh water at the seal tanks. The washer shower water was either supplied from the effluents of tissue machine and/or from the fresh water header.

The fresh water on the first three bleach washers was replaced with the effluents of the tissue machine.
Wire cleaning showers

All of the wire cleaning showers utilized high volume and low pressure showers. These high volume low pressure showers were changed with the low volume high pressure showers. This reduced the fresh water usage by about 300 GPM.

Counter current washing

The filtrate seal tanks were equipped with the jump stage arrangement. The acidic chlorine dioxide seal tank overflowed to the acidic chlorination seal tank and the alkaline sodium hypochlorite seal tank to the alkaline caustic seal tank. Fresh water was used for make up of the chlorine dioxide and sodium hypochlorite seal tanks.

The counter current washing is a method of recycling filtrate effluents from each stage to the preceding stage for washing, diluting the stock, and aiding in pH adjustments necessary between stages, thereby providing substantial fresh water savings. The seal tank filtrate was used at the washer showers at a stage preceding the seal tank from which it was drawn.

In order to have counter current washing, the chlorine dioxide and sodium hypochlorite seal tanks were connected. A small amount of fresh water (about 300 GPM) was supplied to the chlorine dioxide seal tank. The overflow from the chlorine dioxide seal tank was supplied to the sodium hypochlorite and then to the caustic seal tank. This eliminated any fresh water make up to the sodium
hypochlorite seal tank and overflow from the chlorine dioxide seal tank to the chlorination seal tank. A generous volume of shower water was used to maintain the desire levels in the seal tanks. The amount of fresh water needed to reduce the foaming problems was minimized by modifying the design of seal tank to increase the retention time in seal tank and tangential entry of filtrate in it.

SO$_2$ s an antichlor was used on chlorine dioxide filtrate to protect the sodium hypochlorite washer from corrosion. This corrosion is caused by chlorine dioxide being generated inside the washer when alkaline chlorine dioxide or sodium chlorite in chlorine dioxide filtrate comes in contact with the acid and residual chlorine.

**Caustic filtrate**

Filtrates from the caustic washer were used as shower water on the chlorination washer's third and fourth showers. These filtrates were used at this point of application since they would cause foaming and increased chemical consumption if they were allowed to pass through the pulp mat on the chlorine washer. The excess of caustic filtrates not used for stock dilution and shower water was discharged to the waste water clarifier.

**Sodium hypochlorite filtrate**

The filtrate from sodium hypochlorite seal tank was used on the caustic washer. The increased temperature of this bleaching stage required advanced control for the residual chlorine control.
as the rate of reaction increases considerably with the increased temperature. The sodium hypochlorite filtrate was used on the last two showers of the chlorination washer and the excess filtrate was discharged to the caustic seal tank.

**Chlorine dioxide filtrate**

Chlorine dioxide filtrate was used as shower water on the first and second chlorination washer showers and the third and fourth sodium hypochlorite washer showers. The excess of chlorine dioxide washer filtrate overflowed from the chlorine dioxide seal tank to the sodium hypochlorite seal tank.

**Seal tanks and drop leg vacuum**

Foaming problems in the seal tanks were eliminated by providing increased retention time, tangential entry of filtrate into the seal tanks and maintaining a displacement ratio at the washer drums. The supply of filtrates for washer showers will provide a stand by arrangement in case the supply of white water for these showers is discontinued from the tissue machines effluents due to a certain break down.

**Operation After Closure**

After the implementation of water reuse program the following protective measure were taken to ensure the dependability of the program.

1. The cooling towers were chemically treated.
2. Preventive maintenance program to control the corrosion and sealing was initiated.
3. Instrumentation was routinely checked and the faulty instruments were recalibrated.
4. The slime control program was revised for the increased use of white water on the paper machines.
5. The sand filter back washings, demineralizer regenerations, and evaporation boil out were coordinated in order to minimize the surges in the mill water system.
CONCLUSION

The final mill effluents were reduced by 57% through the implementation of the integrated program of water reuse. A water reuse program was developed which reduced the fresh water usage from the past levels of 39 million gallons per day to the present levels of 17 million gallons per day.

All of the fresh water requirements amounting to 17 million gallons per day was supplied from the No. 2 water treatment plant. The need for water from No. 1 water treatment plant and the Rice Creek pump house was eliminated and accordingly both of the facilities were shut down.
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