The Closed-Cycle Bleached Kraft Plup Mill

Presented by

ERCO Envirotech Ltd. and AHL Engineers

Introduction

One of the more demanding concerns confronting pulp mills today is the problem of handling their wastes. At the present time, polluted liquid discharges from bleached kraft pulp mills vary from 100 to 350 m^3 per ton of pulp; the BOD content is 40 to 60 kg/ton of pulp; the suspended solids are 25 to 60 kg/ton of pulp; and the color is 150 to 240 (Pt.) kg/ton (1,2). As shown in Figure 1, these wastes are from five primary sources: Wood preparation, washing and screening in the unbleached sections of the pulp mill, contaminated condensates, the bleachery, and spills, leakage, etc., from all departments. Of these, the major contributor is the bleachery. Waste from this area averages 60 to 120 m^3/ton and has a BOD of 12 to 20 kg/ton, most of the color, much of the fish toxicity and is contaminated with chlorids. To date most of the effort to minimize the impact of the discharge of such wastes into receiving waters has been in the direction of external treatment. Such action usually involves primary treatment or gravity sedimentation of these voluminous pollutants to remove the majority of the suspended solids, and a minor fraction of the BOD. As diagramed in Figure 2, this has been followed in many instances by secondary treatment, where the BOD laoding has been satisfied by the introduction of some form of oxygenation. This is accomplished through the use of relatively large aerated lagoons of 8 to 10 days residence time, or activated sludge systems having aerated tanks of 6 to 8 hours detention time. These systems can reduce BOD by 80 to 90 percent and eliminate much of the fish toxicity. However, the outfall from these systems still contains 10 to 20 percent of the BOD, some of the fish toxicity, some suspended solids, all the chlorides and the majority of the color. As a consequnce, supplementary efforts to further decrease the pollution load would dictate the use of tertiary systems such as activated carbon absorption, or chemical coagulant systems, employing lime or alum treatment or combinations of the same.

Total costs for such external waste treatment, including operating expense and capital write-off, have been reported in the literature to be approximately \$7/ton of pulp for primary and secondary treatment (3,4,5,). Much of this data is based on 1971 cost figures. Recently, this has been updated using current costs and the revised estimate shows that this figure has doubled to \$14/ton of pulp (6). With additional treatment being required to attain 98 percent removal of BOD, projections were made in the same studies that indicate that external treatment total costs would increase to \$24 to \$30/ton of pulp.

As capital and operational costs for external treatment are quite expensive, alternate 'within plant' methods of handling the wastes from a kraft pulp mill have been investigated by numerous groups. One of the most promising approaches is the total recycle of 'waste' streams within the pulp mill itself, conceived and introduced by Professor W.H. Rapson of the University of Toronto (7). This concept suggests that through internal recycling, all, organics producing a BOD level would be combusted in the recovery furnace, thereby increasing steam production with simultaneous elimination of these wastes. To make provisions for this possibilitity, the volume of process water consumed must be drastically curtailed through the use of countercurrent washing procedures. This would also diminish steam consumption, as this technique would re-use waters for washing that were already in the proper temperature range. In this concept, sodium chloride derived from bleaching chemicals would be introduced into the recovery system. Then, this salt would have to be removed at the same rate that it's injected to avoid buildup. Therefore, this would involve special salt recovery technology. Many of the concepts envisioned by Dr. Rapson in 1965 have already been implemented and are presently being utilized by the pulp and paper industry. A considerable num-

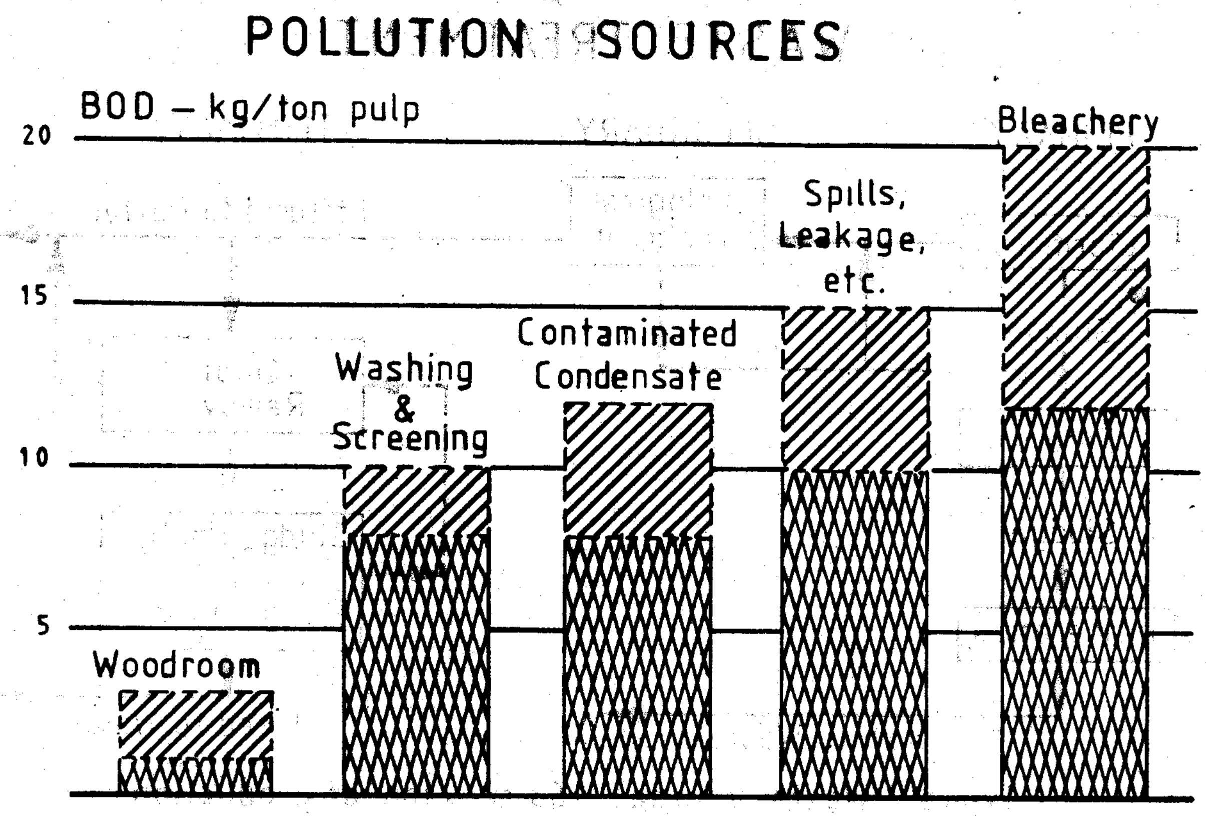

Fig. 1 – POLLUTION SOURCES IN A BLEACHED KRAFT PULP MILL SHOWING MINIMUM AND MAXIMUM AVERAGE WORLD VALUES

ber of mills use countercurrent washing techniques in the bleachery to reduce water consumption and fiber losses and save on energy requirements. Additionally, many mills have substituted chlorine dioxide for the major part of the chlorine in the chlorination stage as recommended by Dr. Rapson.

To further implement the closure of the mill, or what is now termed a closed-cycle mill, the following practices must be employed. First, dry debarking must be used in the woodroom to eliminate aqueous pollution in that area. Secondly, accidental discharges must be contained through the use of spill tanks with subsequent reclamation of the segregated spills to proper locations in the mill. Thirdly, contaminated condensates must be steam stripped to remove methanol and malodorous gases for burning and for re-use of the stripped condensates for washing or dilution purposes. Finally, bleach plant effluent must be totally recycled and a salt removal system must be employed to recover the sodium chloride introduced with this bleach cycle. In modern pulp practice, most of the techniques described for completely closing up a pulp mill have already been adopted. The only aspect of the closed-cycle system that has not been proven in pulp mill operation is the total reclamation of all bleachery effluent within the liquor recovery cycles and the coincident removal of sodium chloride. The latter feature is being proven at the new 700 TPD mill of Great Lakes Paper Company at Thunder Bay, Ontario (8,9). This mill has the ERCO Envirotech closed-cycle system and the SRP* salt control process. The mill started production of unbleached pulp mid November 1976 and started the SRP system and recycle of bleach plant filtrate in April 1977.

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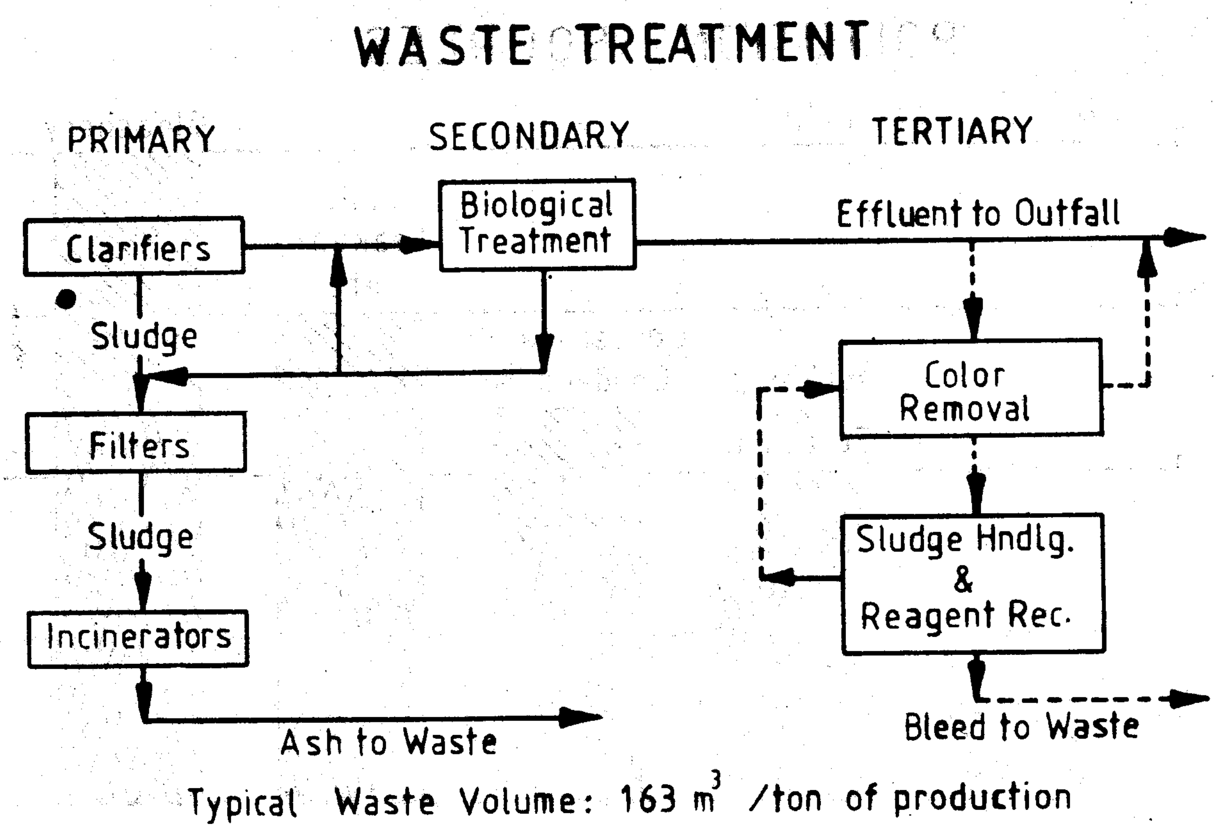

Fig. 2 - EXTERNAL WASTE TREATMENT METHODS USED IN PULP MILLS CURRENTLY

The mill production is at capacity and high quality pulp is being produced. The SRP system is keeping up with production and the salt recovered is being used to generate chlorine dioxide in an ERCO R3 generator.

Details of the Close-Cycle System

The closed-cycle mill eliminates aqueous pollution through internal recycling techniques, and only clean cooling waters will be discharged. Such cooling waters may be reused if disrable through application of evaporative type cooling. These techniques are now applicable to any bleached kraft pulp mill, existing or new, or whether producing pulps from deciduous or coniferous wood, or to any bleaching sequence now in commercial operation.

For the closed-cycle mill to be realized, the following important facets must be included:

1. Dry debarking.

2. Collection tributaries and adequately sized spill tanks (3 or 4), separated as to character of liquid streams, which will contain these inadvertent discharges until properly reclaimed.

3. A drastic decrease in process water consumption so that there is no increase in the conventional dilution factor or displacement ratio used for unbleached pulp washing. Note that all waters entering the system must be handled in the recovery cycle, whether it be wash medium, solutions, condensed steam, wire cleaning showers, leaks, gland waters, etc.

4. Implementation of countercurrent displacement washing in the bleachery.

5. Utilization of substantial substitution of dioxide for equivalent chlorine in the first bleaching stage. The

numerous benefits of high ClO_2 substitution have been detailled by Dr. Rapson (10).

6. Balance of the chloride and sodium ions so that sodium chloride is the product in the recycled bleachery effluent.

7. Use of the SRP system for control of the salt load, whether the sodium chloride originates as a contaminant from the raw materials, wood, water chemicals, tall oil processing, heater descalings, or from any of the commercially known bleachery treatments and the many sequences containing Hypochlorite (Na), ClO_2 or Cl_2.

8. Reclamation of all of the bleachery filtrates into the recovery cycle.

9. Closed screen room with sealed or pressurized types of knotters and screens.

10. Incorporation of high volume steam stripping and selective use of the contaminated condensates so as to remove the menthanol by-product.

11. Control techniques to satisfy other levels of contaminants introduced such as Ca, K, Si, S, Fe, Mn, etc., which are encountered due to their varying concentrations in the materials.

12. Use of only indirect condensers for the black liquor and white liquor evaporating systems.

13. Finally, yet one of the most important considerations is to have a proper attitude of implementation of the closed-cycle system throughout top management, supervision, operators and helpers, engineering and technical personnel, tradesmen, etc., in short everyone in the mill.

Mill design

The majority of the mill requires no change in adapting to the closed-cycle system. Cooking may be by batch or continuous digesters. Washing may be by diffusers or drum-type units; however, sufficient washing must be available to minimize black liquor solids carryover to the bleach plant. The screen room should be closed and pressure type screens will probably be preferred. The bleach plant will employ countercurrent type washing, and the bleach plant filtrate will be recycled as shown in Figure 3, which presents a typical water balance in normal operating conditions. Weak black liquor will be concentrated in conventional black liquor evaporators. However, contaminated condensate steam stripping equipment may be incorporated with the evaporators to economize on steam usage. The concentrated black liquor is fired in a standard recovery furnace. Particular matter is removed from the furnace gases by high efficiency electrostatic precipitators, and recovered salt cake is recycled to the strong black liquor. The inorganic smelt from the furnace is causticized in a conventional recausticizing plant to produce cooking liquor.

The closed-cycle mill concept is relatively new; however, most of the steps required to achieve this design are well known in the pulp and paper industry and have been commercially proven. In the bleachery, countercurrent washing of pulp is being practiced with both softwood and hardwood furnishes. First stage bleachery is being recycled to the high density storage. High temperature chlorination and dioxide substitution are also commercially proven. Steam stripping of condensates and selective use of contaminated condensates are known dictates to control the level of methanol by-product and effluent BOD. Although some have expressed concern with the recycle of NaCl to the recovery, in excess of 25 mills in the world (Canada, U.S.A., Japan, Sweden) have substantial salt contaminations with well demonstrated histories for at least 30 years. Many have concentrations in excess of the levels recommended in the closed-cycle mill. Therefore, the only new procedural item in the closed-cycle mill is the recycle and total reuse of bleachery filtrate so that it becomes part of the recovery cycle liquor.

Within the bleachery, to be sure, considerable modification as to process water routing is necessary to achieve the design volume decrease (11). Countercurrent washing increases temperature, particularly in the first stage, and requires special consideration with respect to the recycle of various streams due to the solubilized solids, contaminants, and chemicals in these streams. For example, unless proper displacement ratios

THE CLOSED-CYCLE MILL WATER BALANCE
U. S. GAL/AD. TON.

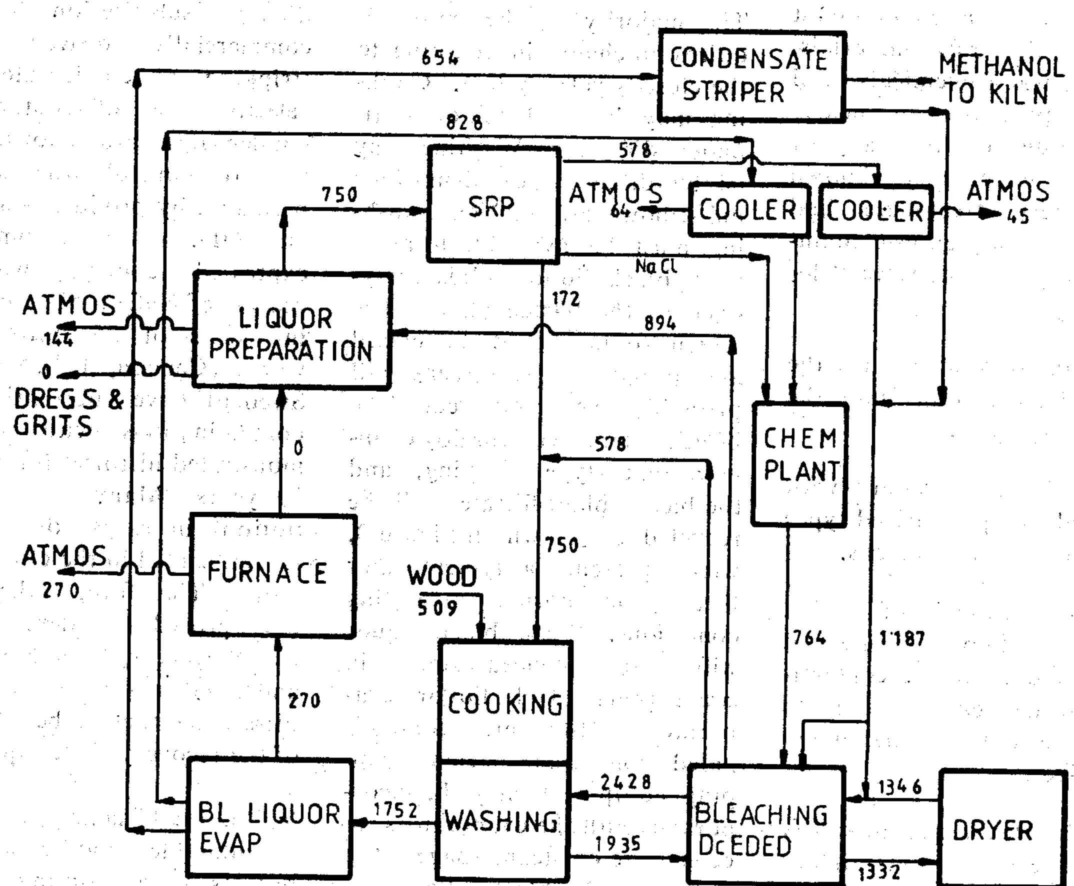

Fig-3 CLOSED-CYCLE MILL SCHEMATIC WITH WATER BALANCE INDICATED IN U. S. GAL/AD. TON.

are employed, chemical consumption will undoubtedly increase (12). Moreover, careful consideration must be given to proper materials of construction, particularly in the first stage (no rubber may be employed in the first stage with chlorine dioxide inclusion).

Many mills (commencing at least 15 years ago) have resorted to the use of spill tanks. Temporary and accidental discharges, as they are termed, may be classified into three (3) major groups according to their cause: Defective equipment, human element, and incorrect control strategy. Such accidental discharges comprise 20 to 50 percent of the total chemical losses and 30 to 50 percent of the total fiber losses from a mill.

Auxiliary collection systems such as 'U' drains acting as tributaries are equipped with sumps, pumps, weirs and cylinder-operated closure gates actuated by conductivity probes for diversion of the contaminated streams to said holding tanks for subsequent reclamation. In the closed-cycle mill four spill tanks are recommended. One tank will serve to hold all black liquor and E_1 filtrate spills. The third will contain all acidic bleachery filtrate and brown decker spills. The third will collect all fibre spills and the fourth will collect recausticizing spills.

For the balance of the mill equipment, the specifications, sizing, materials of construction design characteristics, etc., are unchanged from those normally set by industry standards. The equipment and systems used for the SRP white liquor evaporation, salt filtration and purification steps and related processing are similar to those used for years in the electrolytic caustic soda industry except for materials of fabrication For the latter, nickel tubes are used in the heat exchangers, but for this application, due to the sulfide content, the material must be Inconel 600 or Monel 400 where conditions of elevated temperature and high caustic concentrations are encountered.

Countercurrent washing in bleachery

Figure 4 illustrates the countercurrent washing flow sheet as employed in a closed-cycle mill. For the sequence $D_cE_1D_1E_2D_2$ shown, the following basic procedure for recycles would be recommended. The first stage treatment, consisting of high dioxide substitution amounting to 70 percent of its chlorine demand, may be either a mixture of chlorine dioxide and chlorine or sequential (ClO_2 always first). Either of these producers will provide the least pulp brightness reversion, the same pulp — final brightness viscosity and strength preservation with identical overall salt loadings. Reclaimed hot white water from the pulp machine wet end with some clean condensate is employed as the sole displacement wash on the final drum using a displacement ratio of at least 1.4 (depending on local conditions). The entire D_2 filtrate volume, (wash showers augmented by the dioxide solution, steam condensate and wire cleaning shower) is transferred to the E_2 drum showers as the sole displacement source. This mode of operation is adhered to for the D_1 washer utilizing all of the E_2 filtrate. Basically speaking, the sequence for this portion of the bleachery has been a straight backward flow of the displacement wash medium.

There is a different approach, however, to handling the D_1 filtrate due to the ever increasing volume of filtrate as practiced in this countercurrent manner and the strict requirement of selective re-use to ensure substantantially normal bleach chemical consumption. Therefore, the majority of the D_1 filtrate is used as the entire E_1 wash fluid with the minor balance being diverted to the initial showers on the D_c washer.

The E_1 filtrate (most highly contaminated of all the bleachery filtrates) is split into several streams for its re-use and recycle as follows:

(i) Recycle within stage.

(ii) Controlled volume, not to exceed 0.75 displacement ratio, is transferred to the balance of the D_c washer showers.

(iii) Considerable volume is consumed as diluent of the concentrated white liquor from the SRP system.

(iv) The balance serves as a partial wash for the unbleached pulp.

The D_c filtrate, although not as highly colored or polluted as E_1 filtrate, must also be prorated for several end uses as follows:

(i) Recycle within stage.

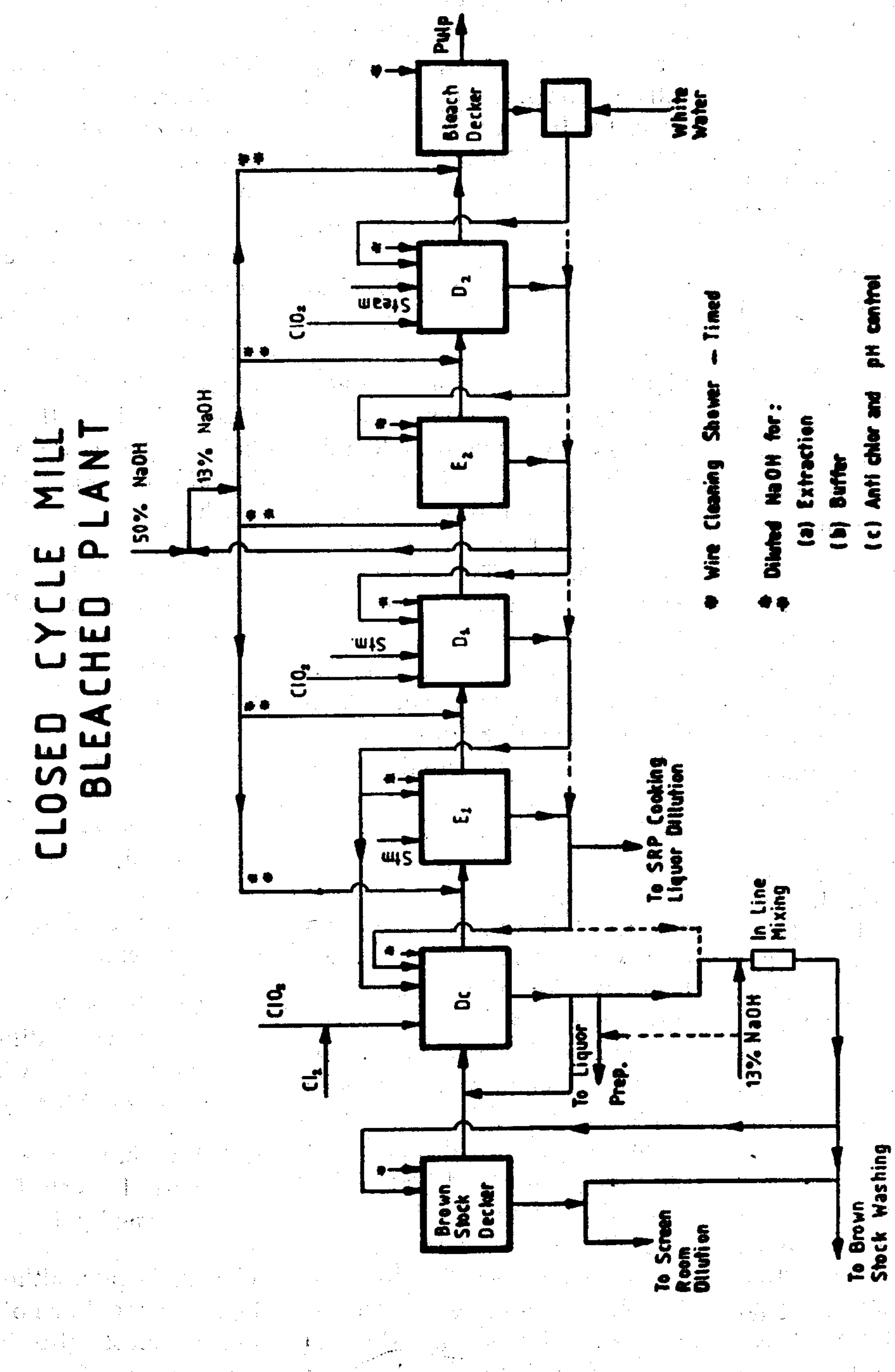

Fig. 4—CLOSED CYCLE MILL BLEACH PLANT FLOW SHEET

(ii) Diluent for the high-density storage and feed consistency control.

(iii) Mixed with dilute caustic for pH adjustment and then used for unbleached pulp washing.

(iv) Controlled diversion to the lime recovery cycle as the kiln scrubber wash fluid, serving thus as a calcium ion 'bleed'.

To further reduce water consumption in the ERCO Envirotech bleach plant design, hydraulic doctors should be replaced with air doctors, each having its own blower and control. Additionally, conventional wire cleaning showers of the high pressure, low volume type are regulated on each washer with a field adjustable time control valve which employs cleaned condensate (as indicated in Figure 3). Alternately, filtrate may be recycled within its own stage and used as wire cleaning showers with open type fishtail nozzles. Purchased caustic soda is diluted to the desired concentration level with the use of E_2 filtrate. This eliminates the need for fresh water dilution and at the same time eliminates the need for steam addition at that point as the diluted caustic is already at the proper temperature.

Overall, the dilution factor achieved for the unbleached washing amounts to 3.0 kg H_2O/kg a.d. pulp (usual design for washers and black liquor evaporating systems). The total volume of process water recycled from the bleachery will amount to approximately 15 m^3/ton of pulp. The actual volumes today in conventional mills range from 60 m^3/ton to 120 m^3/ton from the bleachery alone, with averages of 83 m^3 per ton for North America and 212 m^3/ton for the world for the total effluent discharged from the mill. Cooling waters vary considerably according to local conditions.

Research and field investigations in North America conducted over the last four years have confirmed that countercurrent washing techniques resulting in a final 'effluent' of 15 m^3/ton are possible (13). Howrver, if such volumes are lowered substantially from this level such that the displacement level is less than 1.2, there is a decided tendency to increase the chemical consumption (12).

The initial stage (D_c) will operate at an elevated temperature in the range of 52°C up to 60°C depending upon the degree of substitution and the temperature of the chilled solutions. The other four stages may be operated in the 66 to 75°C range with minor differences as selected by the mill.

If a hypochlorite stage exists or is desired by the customer, this will fit into the closed-cycle mill, providing it is soda base. In order to decrease the usual water and steam consumptions, this stage may be operated in a 'modified' hot manner as is practiced in several North American mills without pulp strength impairment. Conditions are adjusted dependent on the type of pulp being processed and bleaching targets. Temperatures have been employed up to 63°C by commensurate decrease in retention time. It is important to maintain adequate pH (9.5 minimum) and control of residual. For mills without hypochlorite needs, ERCO Industries Ltd. has a method of chlorine dioxide manufacturing which permits the production, storage and consumption as desired to two 10 g/l Clo_2 solutions—one for the D_c stage with up to 6 g/l Cl_2 and the other for both the D_1 and D_2 stages at approximately 2 g/l Cl_2. This later system thereby handles the ratio of chlorine dioxide and chlorine as generated without "extra" or by-product chlorine water or hypochlorite.

Another alternative is to produce chlorine water at 3 to 5 g/l (depending on degree of chilling of absorption water) and use as such for the first chlorination stage. This approach is not as desirable as the former due to the increased water load.

Corrosion has been a problem that pulp mill personnel have had to contend with since the beginning. However, attitude have changed on production down-time, replacement costs, and origional expenditures since this undesirable facet is ever present. Mill management teams now consider cost, strength and corrosive resistance in the selection of fabrication and construction materials.

Corrosion is a major expense item constituting up to 8 percent of the capital costs and also represents some 20 percent of the annual maintenance charges. Nearly every known type of corrosion is encountered in the kraft mill — general corrosive wear, srtess corrsion cracking, pitting and crevice corrosion. Most everyone is also aware that the bleachery has contributed a major portion of the overall problem; hence, several recommendations are put forth on the choice of materials as well as operational targets. Several foctors may be isolated due to their predominance:

(i) Improper fabrication of FRP pipes and tanks.

(ii) Use of alloys not considered optimum, e.g., 317 Stainless Steel (even 316 Stainless Steel) for the first stage washer due to water volume decreases and increased chloride concentration, temperatures and acidity with recycle. Corrosion is aggravated in these cases by operating with residuals (which are not necessary) due to inadequacy of control techniques.

(iii) Re-use of D_1 filtrate on the first stage washer when the D_1 filtrate has a residual. Resultant contact with the acidic conditions in the first washer will generate gaseous ClO_2 within the washer proper, thereby leading to severe corrosion.

The first washer in the bleachery, whether closed-cycle or not, should be either Titanium, or a Titanium-FRP combination, or one of the special high percent average molybdenum alloys. The balance of the washers should be 317L Stainless Steel with the special alloy units as an alternative for the D_1 and D_2 stages.

Both the first stage and the D_1 stage should be operated with zero residual.

SRP System

In a closed-cycle pulp mill, all impurities, no matter how small their input rate, will accumulate unless a purge for each of them is built into the system. Heavy metal cations are purged in the same manner as in an open mill, mainly in the dregs from settling the green liquor. Fewer heavy metal ions per ton of pulp are introduced in the closed-cycle mill, because the quantity of wood used will be less due to the higher yield, and the make-up chemicals and make-up water requirements are decreased. Silica and phosphorus are removed with the grits from the lime kiln in the same manner as in an open mill. Both grits and dregs are removed as dewatered solids for burial. The largest impurity quantity, sodium chloride, will accumulate when the bleach plant effluent is introduced into the chemical recovery system. All chlorine in the bleaching chemical ends up as sodium chloride when it is recycled into the chemical recovery system, and it must be removed at the rate at which it is introduced. Since there is no purge for salt in the normal chemical recovery system, it was necessary to develop the SRP process for salt recovery and control. The process chosen was the invention of D.W. Reeve and W.H. Rapson and consisted of evaporation of white liquor to crystallize sodium chloride (14).

The ERCO Envirotech SRP system, diagramed in Figure 5, consists of a two-stage evaporation process, wherein mill produced white liquor is concentrated from an approximate 11 percent weight concentration ($NaOH+Na_2S$) to 36 weight percent concentration. During the evaporation process, sodium carbonate, sodium sulfate and sodium chloride are crystallized from the solution. The unregenerated pulping chemicals, sodium carbonate and sodium sulfate are removed from Stage 1 of the system and recycled to chemical recovery. Sodium chloride is crystallized in Stage 2 of the system and purified such that it may be used for the manufacture of bleaching chemicals. The concentrated white liquor, clarified of the crystallized solids, is rediluted with recycled streams such as E_1 filtrate from the bleachery to the desired concentration prior to being stored and charged to the digesters. In Stage 1 of the SRP system, white liquor with a salt content of 25 to 35 g/l is evaporated in multiple effect, forced-circulation type evaporators from 11 percent weight concentration ($NaOH+Na_2S$) to 27 percent weight concentration. Up to this concentration, most of the sodium carbonate and sodium sulfate (which is in a double salt form called burkeite) crystallizes out without the crystallization of any sodium chloride. The crystalline burkeite and sodium carbonate are separated from the liquid portion through decantation and filtration techniques, and the discharged filter cake containing the crystalline material is recycled to the recovery area. Most of these solids are sent directly to the green liquor part of the recausticizing system with the remaining portion being diverted

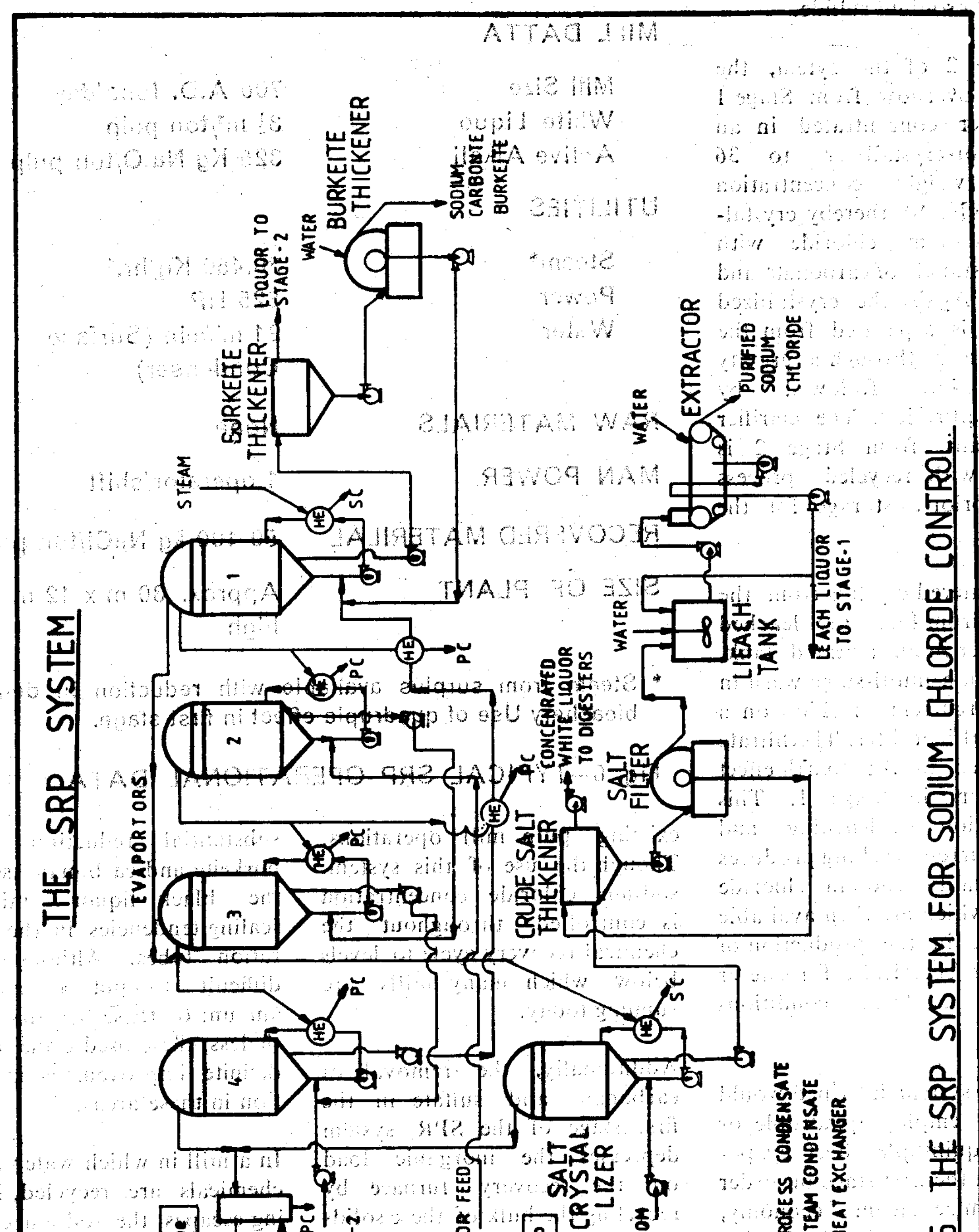

FIG-5 THE SRP SYSTEM FOR SODIUM CHLORIDE CONTROL.

indirectly to the recovery furnace for reduction of the sulfate content to sodium sulfide.

In Stage 2 of the sytem, the clarifier overflow from Stage 1 is further concentrated in an evaporator-crystallizer to 36 percent weight concentration ($NaOH + Na_2S$), thereby crystallizing sodium chloride with minor residuals of carbonate and sulfate. Again, the crystallized material is separated from the liquid stream through a gravity sedimentation followed by vacuum filtration. The clarifier supernatant from Stage 2 is diluted with recycled process streams prior to storage for the digester.

The dewatered crystals from the vacuum drum filter are leached with water in an agitated tank, then given a multi-stage wash in a countercurrent fashion on a horizontal belt filter. The filtrate is recycled to the fourth effect evaporator in Stage 1. This combination of leaching and countercurrent washing produces high quality sodium chloride crystals which are then available for re-use in the production of bleaching chemicals, for sale or disposal as local conditions dictate.

The SRP system described would normally employ quadruple or possibly quintuple effect evaporators in the first stage in order to maximize steam economy, dependent on local cooling water temperature. The details of the operating parameters are listed in Figure 6. The system is flexible enough to meet the demands of a wide range of pulping and bleaching conditions without the need to change the

SRP OPERATION

MILL DATTA	
Mill Size	700 A.D. tons/day
White Liquo	3½ m^3/ton pulp
Active Alkali	325 Kg Na_2O/ton pulp
UTILITIES	
Steam*	30,450 Kg/hr.*
Power	825 HP
Water	21 m^3/min (Surface Condenser)
RAW MATERIALS	None
MAN POWER	1 operator/shift
RECOVFRED MATERILAL	50-100 kg NaCl/ton pulp
SIZE OF PLANT	Approx. 30 m x 12 m x 18 m high

* Steam from surplus available with reduction in demand in bleachery Use of quadruple effect in first stage.

Fig. 6—TYPICAL SRP OPERATIONAL DATA

existing pulp mill operations. Though the use of this system, sodium chloride concentration is controlled throughout the chemical recovery cycle to levels below which many mills are running today.

Additionally, the removal of carbonate and sulfate in the first stage of the SPR system depresses the inorganic load on the recovery furnace by recycling the bulk of these solids directly to recausticizing (14). As a consequence, even with the sodium chloride load added to the recovery area by bleachery filtrate recycle, the net load of inorganics on the furnace is lower with the closed-cycle mill. Moreover, the elimination or substantial reduction of the burkeite and carbonate solids in the black liquor minimizes scaling tendencies in the evaporation tubes. Although it is difficult to put a monetary amount on these benefits, nevertheless, the closed-cycle offers a definite improvement in operation in these areas.

In a mill in which water and all chemicals are recycled, if nothing escapes, the sodium chloride removed must balance stoichiometrically with the sodium hydroxide, chlorine and chlorine dioxide used in the process. If it does not, the chemical inventory will increase or decrease. It also follows that the amount of sodium chloride removed is exactly that required to produce the bleaching chemicals. The sodium chloride may be electrolyzed to produce sodium chlorate and also sodium hydroxide and chlorine. The sodium hydroxide would be used directly in the bleach plant. The chlorine would be burned with hydrogen and resulting hydrochloric acid combined with the sodium chlorate to make chlorine dioxide. Theoretically, in an entirely closed mill the chemical inventory should be constant, only electricity being consumed. In practice, there will be some sodium, potassium, chloride and sulfur introduced with the wood and some loss of solid particles to the atmoshpere, although this must be minimized. The chemical plant is an optional consideration.

Boiler information

Salt contaminations caused by seawater log transport have been recorded as far back as 1947 in North American coastal mills. To alleviate this influx and increasing concentration, the mills have been practicing several partial control measures. However, the sodium chloride levels in the white liquor are in the 35 to 65 g/l range—somewhat higher than the proposed 25 g/l avg. values in the closed-cycle mill.

Moreover, this salt load and its water content are supplemented by other heat absorbing inorganic materials—the ever present carbonate and burkeite. On the other hand, in the closed-cycle mill, the inorganic salt load on the boiler is just about balanced, while the organic solids load is somewhat increased.

Visits have been made to mills with salt contamination of 4 weight percent up to 14.5 weight percent in their black liquor to observe firsthand operations and data. There has been no substantiation of increasing corrosion, tube fouling, smelt-water explosions or need for cleaning (15). Moreover, the associated depression of the smelt melting point may prove beneficial in diminishing the smelt spout plugging occurrences.

Economics of System

In reviewing the economics of the close-cycle system, capital and operating costs will be detailed in comparison with those from external waste treatment. For the external waste treatment costs, primary and secondary treatment together with sludge handling and disposal will only be considered. Actually, the closed-cycle mill eliminates the discharge of polluted effluents and discharges of only clean cooling waters. Consequently, a more factual comparison should be made between an external treatment system employing tertiary treatment as well, however, the only external waste treatment sytems reported to remove 100 percent of the BOD are in the Soviet Union and there has been no published cost information on such operation to date.

Great Lakes Paper Company has reported that the differential capital costs between a conventional bleached kraft mill without external waste treatment and the closed-cycle mill is $8 million for their new 250,000 short ton/year mill (16). This differential includes the capital costs for the SRP system, the spill tanks and associated piping, the contaminate condensate steam strippings sytem, the additional, more noble, metallurgy required when closing up a mill, and items pertinent to the closed-cycle system as itemized in Figure 7.

The capital cost for primary and secondary waste treatment, together with sludge handling ann disposal for an equivalent size mill, was estimated at $8 million. However, this is based on 1974 cost figures while recent information on capital expenditures information indicates that this is closer to $12 million Therefore, it is concluded that the capital outlay for the closed cycle mill is slightly lower or, conservatively, at least equivalent to the capital cost for primary and secondary external waste treatment.

With respect to operating costs, the closed-cycle mill actually shows a net savings when compared to external waste treatment. As will be detailed, subsequently, there is a considerable steam saving with the use of countercurrent washing in the bleachery and the consumption of available warm process water with this concept. Then, there is actually a net steam increase with the recycle of all organics in the bleachery effluent to the recovery furnace. The steam required for the evaporation of white liquor in the SRP system is subtracted from the savings and there is still a net savings of steam which will be credited in the cost savings for the closed-cycle mill. The cost for the power, water and operators associated with the SRP

CAPITAL COST COMPARISON CONVENTIONAL vs CLOSED-CYCLE MILL

700 AD STPD Mill		
	M$	
Operation	C-CM	Conv. Mill
Dry barking or closed wet system Closed screen room CC washing in bleachery Condensate steam stripping Re-use of bleach plant filtrate Spill tanks	$3,800	
Salt Control Process – SRP	$4,200	
Primary & Secondary Waste Treatment	—	$8,000
Total	$8,000	$8,000

Fig. 7 — CAPITAL COST COMPARISON BETWEEN CLOSED-CYCLE MILL DIFFERENTIAL COST AND COST FOR PRIMARY AND SECONDARY WASTE TREATMENT

system as detailed previously in Figures 6, is estimated at $0.60 per short ton of pulp. The cost associated with condensate stripping when such stripping is incorporated in the black liquor evaporator train, is approximately at $ 1.30/short ton pulp. Therefore, the additional operating costs for the closed-cycle mill are $1.90/short ton. As opposed to this, external waste treatment operating costs, as detailed in the recent OECD report, show a total operating cost of $6.34/short ton (6). The majority of this cost occurs in the secondary treatment due to the horsepower required to achieve an 87.5 percent reduction on BOD. The remaining major item in these costs is for maintenance and repairs (4 percent of capital cost). Therefore, if a closed-cycle system were used instead of primary and secondary waste treatment, there would be a net operating cost savings of $6.37-$1.90, or $4.47/short ton pulp.

C-CM annual cost savings

As stated previously, counter-current re-use of filtrates in the bleachery, coupled with a modification in the concentration of the bleach solutions and improvements in wire cleaning constitute a considerable saving in steam usage in the bleachery. It is estimated that a 700 short ton/day mill operating with conventional fresh water usage in the bleachery would require approximately 53,000 kg per hour of steam. The steam requirements for the SRP system in this size mill would be approximately 28,000 kg. per hour, and subtracting this from the steam savings and using a cost for steam of $4.86 per metric ton, the steam savings amounts to $1,006,000 per year, using 345 operating days per year.

Similarly, assuming a 6 percent overall bleachery shrinkage and a recovery boiler efficiency of 65 percent, the recycle of the organics to the recovery furnace will provide an additional steam production worth $212,000/year. In the total recycle of all filtrates back within the system in counter-current washing procedures, coupled with a completely closed unbleached side of the pulp mill, fiber losses are eliminated from normal filtrate discharges in 'waste' streams. Moreover accidental spills are recovered through the use of a specific spill tank for fibre discharges. All of this material is reclaimed and, after proper cleaning, sent back to the system. As a consequence, the normal losses encountered in a mill, which range from 1/2 to 3 percent of production, are recovered. It is assumed that, conservatively, one percent increase in production is realized with the closed-cycle mill in this fiber recovery. Based on a price of $250/short ton for in-plant pulp, the savings amount to $604,000 per year.

With the high substitution (70 percent) of chlorine dioxide for equivalent chlorine in the first stage, controlled tests have shown that a one percentage point yield increase will be achieved, when compared to a hot chlorination stage (10). This enhancement is due primarily to the protection of the hemi-cellulose. Taking the in-plant value for the pulp at the beginning of the bleaching stage, the one percent yield increase is conservatively believed to be valued at $604,000 per year.

In the closed-cycle mill, there must be a stoichiometric balance between chloride and sodium ions. The use of a high substitution of 70 percent chlorine dioxide for chlorin lessens the input of chloride ions and therefore substantially decreases the amount of balancing sodium ions required. Thus, the sequence D_cEDED saves substantially in chemical costs when compared with the conventional bleaching sequence CEDED. This is calculated at $413,000/year.

Note that this last savings relates to specific chemical type usage in closed mill operations. In comparison with an open mill practicing external waste treatment, the balancing sodium hydroxide in closed-cycle operations would constitute an added cost instead of a savings. This would be slightly offset by the cost of lime or limestone used for pH control preceeding secondary treatment; however the closed-cycle mill would still show a chemical cost of $3.4/ ton.

As stated previously, the water conservation techniques employed in the bleachery have substantially abated the water requirements of the mill. Now the recycled discharge from the bleachery has been reduced to approximately 15m³/ton. This volume is made up of some minor fresh water, but primarily with the white water from the pulp machine wet end. It is estimated that a conservative saving, even with the best North American mill practice, would at least be 17,000 U.S. gallons/ton. At 3 cent per thousand U.S. gallons, the savings would amount to $123,000 per year.

Taking the operating cost of external effluent treatment minus the cost of operating the SRP system and condensate steam stripping, the net savings on a yearly basis is $1,063,000 for a 700 short ton per day capacity pulp mill. No credit has been been taken for the approximate 120 lb/t sodium chloride removed and purified in the SRP system. Nor has any credit been taken for the fuel replacement value of the methanol, etc., removed in steam stripping and burned at the kiln. These credits plus the slightly lower pumping power requirements of the closed-cycle mill should partially offset any chemical costs as nated previously.

Therefore, as itemized in Figure 8, the total annual operating costs savings for a 700 STPD closed-cycle mill is estimated at $4,025,000. Obviously, costs very from location to location and these figures are offered only as guidelines for what are probable areas of savings. The definite costs may be computed by taking the figures from a specific operation and applying them in a similar fashion.

As a consequence of the savings, it is seen that the capital cost for a closed-cycle mill may be written off in slightly over two years' time. Moreover, even if the savings are reduced from those itemized in Figure 8, based on lower savings in a different location, there is a substantial return on investment with the closed-cycle mill as opposed to external waste treatment where there is no return on investment The use of the closed-cycle mill features will eliminate aqueous pollution and solve the problem of handling such wastes, once and for all.

ESTIMATED ANNUAL OPERATING COST SAVINGS CLOSED-CYCLE MILL

1. HEAT SAVINGS	
A. Decreased Steam Consumption	$1,006,000
B. Additional Steam Production from Reclaimed Organics	$212,000
2. FIBER SAVINGS	$604,000
3. YIELD INCREASE	$604,000
4. CHEMICAL SAVINGS	$413,000
5. WATER SAVINGS	$123,000
6. SAVINGS IN EFFLUENT TREATMENT COST	$1,063,000
	$4,025,000

BASIS : 700 TPD Coniferous Pulp — KAPPA No. 32
Bleached Pulp Brightness — 90 (G.E.)

Fig. 8 — ESTIMATED ANNUAL OPERATING COST SAVINGS FOR A 700 STPD CLOSED-CYCLE MILL

SUMMARY

The closed-cycle bleached kraft pulp mill eliminates aqueous pollution through internal recycling techniques. In this recycling process, the system also reclaims heat, fibre, chemicals and organics previously lost in effluent from the mill. The values associated with this recovery produce cost savings that insure a return on the capital cost investment and allow pay-back in just over two year's time.

In the closed-cycle mill, all bleachery filtrates with their associated combination product sodium chloride will be reclaimed through preselected channels so that the salt containment is introduced into the pulping recovery cycles.

Use of the ERCO Envirotech (SRP) salt control process, accomplished by evaporation of white liquor and various phase separations, ensure removal of said salt as well as that derived from any other source and precise control of its residual concentration.

With implementation of the closed-cycle concept and utilization of this prescribed salt control technique, there are no major alterations to either the systems, processes, or equipment specifications in the pulp mill.

Re-use and ultimate consumption of these filtrates does mean, however, that there are some modifications in rerouting of bleachery filtrates piping, as compared to those in a conventional mill, to permit selective countercurrent displacement wash — with minimum consumption of fresh process water and steam as well as no significant changes in cooking or bleaching chemicals. Insofar as can be determined with control of salt concentrations, as proposed, providing the sulfidity levels are less than 50 percent, there are no discernible adverse effects in digestion, washing, screening evaporation or liquor preparation phases. There are minor changes in characteristics of back liquor, smelt, and fume, but all of little consequence.

The adoption of the technology previously outlined may be fitted into any bleached kraft mill, existing or new, or whether producing pulps from deciduous or coniferous wood. The amount of capital expenditure will, of course, be higher for the existing and older mills.

Economic advantages will very what depending upon local conditions, however, the practicing of inplant measures to the fullest extent should prove much more beneficial than those afforded through use of external treatment.

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