Status Report on XL-2 Projects at IP Androscoggin Mill
(Fourth Progress Report)

By

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April 25, 2001

MANAGEMENT SUMMARY

This report summarizes the status of the XL-2 project being conducted at the International Paper (IP) mill in Jay, Maine -- a coated fine paper mill with accompanying kraft mill and groundwood facilities. Under the terms of the XL agreement, the IP mill is exempt from Best Management Practice (BMP) in the water pollution portion of the Cluster rules. In exchange for this exemption, IP has agreed to improve the quality of the mill effluent for COD and color beyond the levels likely to be attained through implementation of the BMP requirements. The present report focuses on the quantification of the impact of implemented, approved, and potential new projects to reduce the discharge of COD and color associated with the black liquor cycle. International Paper Company has also agreed to spend $780,000 in capital and engineering costs to implement process modification projects to meet the effluent reduction goals of the project.

The COD effluent discharge goal following the three-year XL project is 26 kg COD per unbleached ADMT (air-dried) metric ton based upon a monthly average. COD discharge in the current effluent averages about 42 kg COD per ADMT and has been gradually trending upwards. The color goal is 50 pounds per U.S. ton (air-dried) of kraft pulp produced as a quarterly average. The color discharge from the mill is approximately 109 pounds per U.S. ton, and has been relatively the same since the 1st quarter of 1998. No toxicity standards are contained in the performance goals.

Four projects associated with closing the screen rooms in the two kraft pulp mills have been implemented to reduce black liquor discharge to the sewer. It is estimated that these projects have reduced the COD discharge to the waste treatment system by approximately 7 kg COD per metric ton. These projects represent approximately 10% of the total discharge from the black liquor cycle, and represent a reduction of about 1.3 Kg COD per ADMT going to the Androscoggin River after passing through the wastewater treatment system which removes COD at an efficiency of 81%. The total cost for these projects is estimated to be about $127,000. Two new projects, also associated with pulp screening, are about to be implemented during the spring of 2001 and will reduce the COD discharge to the waste treatment system by approximately 4.0 kg COD per metric ton, and to the river by approximately 0.8 Kg/ADMT. These additional projects represent approximately 5.7% of the total COD discharge emanating from the black liquor cycle, and will cost approximately $80,000. Thus, the total of the six projects implemented and approved will reduce the effluent going to the river by approximately 2.1 Kg/ADMT at a cost of approximately $207,000.

Ten (10) new projects have been identified for further study. The combined COD reduction going to the Androscoggin River of these projects represents approximately 6 Kg/ADMT. The project with the greatest potential for COD reduction is the recovery of turpentine. However, implementation of the turpentine recovery exceeds the budget of the XL-2 project several fold. Two other relatively large projects deal with the discharged evaporator condensate streams. Presently, these are not considered as potential XL projects because they will be handled in the so-called "Hardpipe" project, whereby the condensate will be transported in a separate pipe (rather than in the regular sewers) to the waste water treatment system. The remaining seven smaller projects represent 15% of the total discharge of black liquor cycle, or a reduction in COD discharge to the river of about 2 Kg COD/MT pulp. Despite their relatively small contribution in percentage reduction of pulp mill COD discharge, some of these other projects appear to be quite cost efficient, and might be accommodated within the available limited budget of the XL-2 Program. Preliminary data indicate that preventing the carryover of black liquor solids with the flash steam from the softwood digester, and optimization of the oxygen delignification system on the softwood side have considerable potential.

The COD data of the final effluent for the entire mill have continued to increase even though the XL-2 Team has implemented several COD reduction projects associated with the black liquor cycle. Most of this increased COD is thought to result from discharges from the paper machines. This illustrates the fact that the effluent of each mill is uniquely related to the production facilities at the entire site, and that without a reduction in COD from the paper machines, the COD effluent release goals of the present XL-project will not be met. Finally, the relationship between COD, color, and toxicity is quite different for the pulp production and paper manufacturing facilities. Therefore, basing future standards on final effluent COD emissions to control black liquor releases may not be correct, in general. At the Androscoggin mill site, reducing the discharge of black liquor should reduce toxicity in the mill final effluent as suggested by recent toxicity results, while the COD in the mill final effluent will increase, or decrease, depending on the operation and technology used at the paper machines.

INTRODUCTION

An XL-Project is being conducted at the IP paper mill in Jay, Maine[1]. Under the terms of the XL agreement, the IP mill is exempt from Best Management Practice (BMP) in the water pollution portion of the Cluster rules. In exchange for this exemption, IP has agreed to take a number of steps designed to improve the quality of the mill effluent for COD and color beyond the levels likely to be attained through implementation of the BMP requirements.

There are two groups that are actively participating in this project. These are the Technical Assessment Subgroup and the Collaborative Process Team. The Technical Assessment Subgroup is comprised of personnel from the EPA, the Maine DEP, the University of Maine, and the Androscoggin mill technical and operating staff. The Technical Assessment Subgroup is charged with identifying a list of potential effluent improvement projects at the IP facility primarily associated with the pulping and bleaching operation. These projects, when implemented, will reduce color and COD discharges to the Androscoggin River, which hopefully will achieve the goals of the XL project. The Collaborative Process Team is composed of the same constituent groups present on the Technical Subgroup plus stakeholders from the Town of Jay, Maine and environmental groups in the state of Maine. The function of the Collaborative Process Team is to evaluate and recommend effluent improvement projects from the list generated by the Technical Assessment Subgroup. Projects recommend by the Collaborative Team are thought to be most suitable for meeting the performance goals established in the XL agreement. The Jay mill is currently implementing projects recommended by the Collaborative Process Team and hopes to implement additional projects as the Collaborative Team approves them.

[1] International Paper XL Project: Effluent Improvements", Final Project Agreement, Androscoggin Mill, Jay, Maine (June 29,2000).

Project Goals and Fiscal Constraints

The goal following the three-year XL project is 26 kg COD per unbleached ADMT (air-dried) metric ton based upon a monthly average. COD discharge in the current effluent averages about 42 kg COD per ADMT and has been gradually trending upward since March 1999 (Figure 1). The long-term color goal is 50 pounds per U.S. ton (air-dried) of kraft pulp produced as a quarterly average limitation. Current color discharge from the mill is approximately 109 pounds per U.S. ton and has been relatively the same since the 1st quarter 1998 (see Figure 2). No toxicity standards are contained in the performance goals. Additionally, International Paper Company has agreed to spend $780,000 in capital and engineering costs to implement process modification projects to meet the effluent reduction goals of the project. This amount is the equivalent financial obligation that would have been spent to comply with the Best Management Practice provisions of the Cluster rules.

Objective of This Report

The objective of this report is to summarize the status of the IP XL-2 project as of the Spring 2001. The present report focuses on the quantification of the impact of implemented, approved, and potential new projects to reduce the discharge of COD from the black liquor cycle.

Project Approach

The Collaborative and Technical Teams are using a two-pronged approach to achieve the goals and intent of the XL-2 project.

1. **Identify and Implement COD Reduction Projects.** The first stratagem recommended to the Collaborative Team was to continue to identify and implement projects which lead to reduced black liquor discharges from the pulp mill, bleach plant, and recovery area.

2. Reduce COD and Color Discharge in the Effluent from Paper Machines. The second stratagem was to stimulate actions that lead to reduction in COD and color originating from the five (5) paper machines at the Androscoggin mill. Without a reduction in COD from the paper machines the COD effluent release goals of the XL-project will not be met.

This two-pronged approach was necessitated because the results of the mill-wide BOD/COD balance showed that most of the organic material in the mill effluent originates from the paper machines and associated coating operations (see Table 1). Based upon COD measurements of the mill effluent, it was estimated that the COD discharge in the mill effluent was approximately 34 kg COD per metric ton of pulp during August 2000. Using a mill-wide COD/BOD balance, it has been identified that the discharge associated with the black liquor cycle represents about 151,000 lbs COD/ day, compared to about 495,000 lbs COD/day for the entire mill based on the summative analysis results. Of this later total, the discharge from the paper mill represents about 324,000 lbs COD/day. Thus, the COD discharge to the Androscoggin river originating from the black liquor cycle constitutes approximately 11 kg COD per metric ton of the 34 kg COD per metric ton for the mill, while the contribution from the paper machine contributes approximately 23 kg COD per metric ton.

Organic material originating from the paper mill was shown to be relatively resistant to removal in the wastewater treatment plant, but is relatively low in toxicity. By contrast, considerably smaller amounts of organic material are released from the black liquor cycle, which moreover is more efficiently removed in the waste water system. However, organic compounds in the effluent released from the black liquor cycle, predominately lignin degradation and bleached lignin products, are known to have a much higher toxicity than material from the paper mill.

Thus, reduced discharge from the paper mill would help achieve the COD emission goal of the XL project, while increased system closure of the black liquor cycle will address the intent of the project, which is to reduce the toxic effects of the mill discharge. The two-stratagem approach adopted by the Collaborative Team is also thought to be effective for achieving the effluent color goal of the XL Project. Color in the final mill effluent going to the Androscoggin River would be expected to correlate both with release of organic compounds in the black liquor, measured as COD, and that the effluent originating from the paper mill if TiO_2 is used in the coating operation. This latter conclusion is inferred from information contained in NCASI Technical Bulletin 803, May 2000. It was understood by the stakeholders that the effluent from a kraft pulping operation with integrated coated paper mill, as present at the IP-Jay, Maine facility, represents a unique situation that requires a flexible approach in agreement with the mission of the XL program of Excellence, Leadership, and Transferability.

Table 1

COD From Mill Production Units

Process Stream	Process Discharge (lbs COD/Day)	Normalized Discharge (kg COD/MT pulp)	Treated Effluent Kg COD/MT pulp)
Entire Mill	495,000	225	34
Black Liquor Cycle	151,000	69	11[a]
Bleach Plant		25	5
Paper Mill	324,000	147	22
IP-XL-2 Goal			26

Footnote [a]. The COD load on the Androscoggin river was estimated for the black liquor cycle as (1-.81) x (69/225)x181= 11 kg COD/MT

IMPLEMENTED AND APPROVED XL-2 PROJECTS

The COD reduction projects approved and implemented so far have dealt with the minimization of the release of black liquor from the screen room of the pulp mill. Although the Technical Team and the Collaborative Team will continue to focus on the black liquor cycle, it will also stimulate actions to reduce discharges from the paper mill. It will do this by measuring and documenting the discharges from the paper mill and by inviting the management and technical staff of the paper mill to become involved in achieving the environmental goals of the XL-2 program.

Table 2 lists implemented and approved projects. Four screen room projects have been implemented, the “A” and “B” side sluice filtrates, the “B” screenings sluice filtrates, and the “B” cleaner rejects. It is estimated that these projects have reduced the COD discharge to the waste treatment system by approximately 7 kg COD per metric ton, representing approximately 10% of the discharges from the black liquor cycle. The total cost for these projects is estimated to be equal to about $127,000. Two new projects are about to be implemented during the spring of 2001. These are the "A" screenings sluice filtrate and the "B" cleaner rejects. The addition of these two new projects will reduce the COD discharge to the waste treatment system by approximately 4.0 kg COD per metric ton, or approximately 5.7% of the total COD discharge emanating from the black

liquor cycle. This will add approximately another $80,000 to the funds expended. Table 3 summarizes the impact of these projects in terms of the COD discharge to the waste treatment plant and to the Androscoggin River. Prior to the implementation of the XL-2 project, it was estimated that the COD discharge from streams containing black liquor was 76 Kg/MT pulp, which decreased to about 14.4 Kg/MT pulp after treatment in the waste water treatment system. With the implemented and approved XL-2 projects the COD load on the effluent treatment system will be reduced by approximately 11 Kg/MT pulp. Assuming 81% of the COD going to the treatment plant is broken down, this leads

Table 2

Implemented and Approved Projects

Source	**Project**	**Pulp Mill COD Reduction**		**Cost**
		(kg COD/MT)	**(%)**	**($1000)**
		Implemented Projects		
"A" Knot sluice filtrate	Use cyclone water	0.9	1.2	4
"B" Knot sluice filtrate	Pipe to process; improve "B" screen efficiency	1.4	2.0	0
"B" Screenings sluice filtrate	Use cyclone water	0.6	0.9	3
"B" Cleaner rejects	"B" screen upgrade	4.1	5.9	120
Total Projects Implemented		**7.0**	**10**	**127**
		Approved Projects		
"A" Screenings sluice filtrate	Replace with PM white water	2.6	3.7	45
"B" Cleaner rejects	Installation of timed dump of cleaner	1.4	2.0	35
Total Approved Projects		**4.0**	**5.7**	**80**

to a reduction of the COD discharge to the Androscoggin River from about 14.4 Kg COD per MT pulp to approximately 12.4 kg COD per MT pulp. This may be compared to a total discharge of approximately 42 Kg COD per MT pulp presently going to the river, and to the goal of 26 Kg COD per MT.

Table 3

Impact of Implemented and Approved Project

Process Situation	Normalized Discharge To Waste Treatment (kg COD/MT pulp)[a]	Treated Effluent From Waste Treatment (kg COD/MT pulp)[a]
Before implementation	76	14.4
After implementation	69	13.1
With approved projects	65	12.4
Entire Mill	181	34
IP-XL-2 Goal		26

[a] Estimates for summer 2000.

STATUS OF POTENTIAL NEW PROJECTS

Several potential new XL projects have been identified with black liquor under the XL-2 project. These are listed in Table 4 together with a potential contributor.

Projects to Reduce Bleach Plant Discharge

Effluent from the bleach plant is thought to contribute approximately 52% of the black liquor-related COD discharges to the waste treatment plant. Four potential projects have been identified; (1) optimize the mini-O2 delignification system in the softwood ("A") mill, (2) improve the post oxygen washing system, (3) the installation of kappa number analyzers prior to the bleach plant, and change the counter current cooking zone in the A digester to co-current (or down flow) cooking. The Technical Team is investigating all these potential projects.

Table 4

Potential New Pulp Mill Projects

Process Source	COD Contribution (kg COD/MT)	(%)	Potential Projects
Bleach Plant	36	52	**1.** Optimize O_2 Delignification **2.** Improve Post O_2 Washing **3.** Kappa number analyzers **4.** Down flow cooking
Evaporator Condensates	12	18	**5.** Condensate Stripping **6.** Reverse Osmosis on Stripped Condensate
Black Liquor from SW and Turpentine	9	13	**7.** Minimize Black Liquor Carry-over **8.** Turpentine Recovery
Screen Room + Miscellaneous	12	17	**9.** Knots and Screenings Processing **10.** Sewer Conductivity and Flow Monitoring
Black liquor Cycle	**69**	**100**	

Optimize Mini-Oxygen System in the Softwood "A" Mill

Improving the existing oxygen delignification system is attractive because the dissolved solids from the system are recycled to the recovery boiler. Thus, these solids, although very dilute, are used as a heat source rather than going to the bleach plant where they are discharged as COD. Figure 3 illustrates the softwood "mini" O_2 delignification system at the Androscoggin mill. Process conditions are summarized in Table 5. In this system, caustic is added to brownstock kraft pulp having an approximate Kappa number of 28.5. From a standpipe, the pulp is pumped with a medium consistency pump through a high shear mixer and through a pressurized reactor with a residence time of about 15 minutes. The pulp then is brought to atmospheric pressure in a blow tube and pumped through an atmospheric tower and then washed in post-oxygen washers.

Table 5

Conditions in Oxygen Delignification System

Item	**Condition**
Production Rate	490 Metric. Tons/Day (Design) 600 Metric Tons/Day (Current)
Kappa number	28
Residence time	20 minutes (Design) 15 minute (Current)
NaOH Addition Rate	1.3 to 1.5% on Pulp
Oxygen Addition Rate	1.3% on Pulp
Pressure	100 Psig (60 to 70% valve position)
Temperature	180 to 185 F
Kappa No. Reduction	28 to 30%

The system was designed for 490 Metric tons per day (about 540 U.S. tons per day) but because of increases in pulp production, the residence time in the pressurized reactor is only 15 minutes. Also, there is no second stage reactor so that the slow second phase of the oxygen delignification reaction is not achieved. Currently the reduction in kappa number is about 30 to 32%.

Mr. William Miller of GL&V[2], the original designer of Androscoggin's O_2 delignification system, inspected the system in January 2001 and prepared a list of recommendations. Mr. Miller made two suggestions to improve the degree of oxygen delignification:

1. **Raise Temperature. The first suggestion was to increase the temperature in the reactor from the present condition of 182 °F (range 180 to 184 °F) to 190 to 195 °F.**

2. **Increase Gas Mixing. The second suggestion was to add a second mixer before the reactor to increase the contact between the oxygen and the pulp.**

[2] Miller, W., personal communication, April 10, 2001.

Anticipated benefits to be derived from these changes would be a decrease in the permanganate (K) number by about 1 to 1.5 units, which is equivalent to a decrease in kappa number of approximately 1.5 to 2.25 units. This would increase the kappa number reduction to approximately 38% from the current 30 to 32%. The installed cost of adding a second O_2 mixer was estimated by Mr. Miller to be approximately $70,000[2]. In his estimate, the cost of the mixer constructed of 316 SS was $35,000. The project multiplier including a 50-75 hp motor, foundation and piping work, engineering hours, etc. was estimated at two (2), which puts the mixer at an installed cost of $70,000. A possible negative effect of increasing the temperature in the oxygen reactor could be a lower vacuum in the drop leg of the post oxygen washers. Thus, pulp washing may not be as efficient, and the carry over of black liquor solids going to the bleach plant could increase.

The present authors estimated the amount of COD generated per unit kappa number drop based upon data presented by Dence and Reeve[3]. Dence and Reeve[3] published data on COD, BOD, and Color for ECF bleaching of softwood (see Table 6), which may be interpreted to represent a normalized COD discharge of approximately 1.4 Kg COD per ADMT per unit Kappa number, that is:

$$\text{Normalized Discharge} = \frac{(34+60)/2}{[(30+37)/2]} = 1.4\, Kg\ \ COD/ADMT\ \ per\ kappa\ no\ drop$$

McCubbin[4], using the published data of Vice, Sieber and Bicknell[4] for softwood, suggested that the normalized COD discharge associated with lowering the kappa number going to the bleach plant to be about 2.40 Kg COD per ADMT per unit Kappa number.

In making the estimate for the potential of optimizing the oxygen delignification system the following assumptions were made.

3. **Kappa No. Drop.** The decrease in kappa number expected from optimization of the oxygen system is 1.5 to 2.25 units.

4. **COD to Recovery System.** The normalized COD discharge per unit kappa number drop is an average considering the data of Dence and Reeve[3] and that suggested by McCubbin[4], i. e. 1.9 Kg COD/ADMT per day.

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[3] Dence, C. W., and Reeve, D. W., "Pulp Bleaching- Principles and Practice, pages 752-753 (1996).

5. **Washing Efficiency**. Washing in the post oxygen washer and in the two deckers before the bleach plant removes 90% of the COD dissolved in the oxygen delignification reactor. This material is then recycled back to the evaporators and recovery boiler where it is eventually burned.

6. **Efficiency in Waste Treatment System.** The efficiency in the waste treatment plant for removal of COD 81%.

Table 6

ECF Softwood Kraft Bleach Plant Effluent[3]

Effluent Parameter	Kappa No. Range	Normalized Discharge Kg/ADMT Pulp
COD	30-37	34-60
BOD	30-35	8-16
Color	25-45	26-150

$$COD\ \mathrm{Re}\,duction\,to\,effluent\,treatment = (1.5\,to\,2.25\,kappaUnits)\ x1.9)(x\,0.6\,SW)\,x0.9$$
$$= 1.54\ to\,2.31\,Kg\ COD\,/\,ADMT$$
$$COD\,\mathrm{Re}\,dcution\ to\,Andoscoggins\,River = 1.54\ to\ 2.31\,Kg\ COD\,/\,ADMTx(1-0.81)$$
$$= 0.30\ to\,0.44\,Kg\,COD\,/\,ADMT$$

By optimizing the oxygen delignification system, it is estimated that the bleach plant effluent going to the waste treatment plant can be reduced by approximately 1.5 to 2.3 Kg COD per ADMT. After reduction in the waste treatment plant this would amount to approximately 0.3 to 0.44 Kg COD per ADMT going to the river. If the McCubbin number of 2.4 Kg COD per ADMT is correct, that would improve the COD reduction going to the river to 0.4 to 0.6 Kg COD per ADMT.

Thus, it was concluded that the Technical and Collaborative Teams may wish to consider further the Oxygen Delignification Optimization project. In addition, the present authors recommend that oxygen delignification experiments be performed to delineate the kappa number and COD discharge improvements that can be expected.

[4] Vice, K. M., Sieber, R. E., and Bicknell, B., "Cost of Upgrading Bleach Plants to Minimize COD Discharges, International Non-Chlorine Bleaching Conference, Amelia Island, FL (March 1995).

McCubbin[4] also notes that oxygen delignification is a good avenue to pursue at the Androscoggin mill if energy costs stay high because oxygen delignification should lower the cost associated with the energy intensive bleaching chemicals ClO_2 and NaOH.

Improve Washing

Another possible project would be the improvement of washing of the brownstock pulp prior to going to the bleach plant. Carry-over of black liquor solids consumes chemicals in the bleach plant, specifically ClO_2 and caustic, and leads to black liquor solids being discharged as COD to the sewer. This material is then treated in the waste treatment system and a portion will eventually be discharged to the river.

Pulp washing is being done on the softwood side in two (2) brown stock washers operated in series, followed by one post oxygen washer and then finally in two softwood deckers operated in parallel. On the hardwood side, washing is being done in a two-stage Kamyr diffusion washer prior to the screen room and then in two drum brownstock deckers. Samples of COD were taken off the deckers on both the softwood "A" and hardwood "B" sides during December of 1998. These data were repeated recently during January 2001. The values for the COD in the pulp going to the bleach plants are summarized in Table 7. These data were used to make an estimate of the COD in the effluent to the Androscoggin River originating from the carryover going to the bleach plant. Several assumptions were made to facilitate this calculation. These are:

1. **Production Rate.** The production rate on the softwood "A" side is 600 ADMT/D and on the hardwood side is 400 ADMT/D.

2. **Softwood Deckers.** The production on the softwood side is split equally between the No. 1 and 2 deckers, each handling 300 MT/Day.

3. **Hardwood Deckers.** On the hardwood "B" side, there are two deckers, but only one decker handles the entire production.

4. **COD Destruction in the Bleach Plant**. 80% of the organic matter measured as COD in the carryover is destroyed in the bleach plant by reaction with ClO_2. This material leaves the system as CO_2 and water.

5. **COD Washout.** Of the remaining 20% COD in the carryover not reacted by ClO_2, 90% is removed by the bleach plant washers.

6. **Efficiency in the Waste Treatment Plant.** The efficiency for breakdown of COD originating from the bleach plant is 81% in the waste treatment plant.

This analysis is summarized in Table 7 and showed that currently approximately 0.24 Kg COD per ADMT in the effluent going to the Androscoggin River originates from carryover going to the bleach plant. Using the COD numbers in the carryover measured in December 1999, this same analysis showed that the effluent leaving the treatment plant contained approximately 1.15 Kg COD per ADMT at that time. The current lower COD numbers result from several major improvements in the process that have taken place over the years. Several operational issues were discovered and fixed on the hardwood side shortly after the December 9th data were taken. Another improvement was made in February 2001 related to a mechanical problem at the base of the Diffuser. When compared to the estimate of 13 Kg COD per ADMT in the effluent currently originating from all black liquor sources, the results of this analysis lead to the conclusion that washing most likely is not an area where major improvements can be made.

Table 7
COD Discharge to Androscoggin River
From Carryover to Bleach Plant

Location	Consistency (%)	Production Rate (ADMT/D)	Dec. 9, 1998		Jan. 2001	
			COD (Mg/Liter	Discharge to River (Kg/ADMT)	COD (Mg/Liter	Discharge to River (Kg/ADMT)
A Decker 1	10	300	2741	0.84	461	0.142
A Decker 2	10	300	3890	1.20	537	0.165
HW "B" Decker	12	400	5315	1.33	1431	0.359
Weighted Average		1000		1.15		0.24

Installation of Kappa Number Analyzers

A desirable strategy to pursue is to lower the kappa number of the pulp going to the bleach plant. This can be done in a number of ways, one of which involves the installation of kappa number analyzers leaving the digester. Alternatively, the kappa analyzer can be installed ahead of the bleach plant provided the signal is used to control the degree of cooking. One advantage of Kappa number analyzers is that they reduce the variation in the kappa number of the pulp leaving the digester and that going to the bleach plant. Kappa number analyzers thus afford the opportunity of reducing the kappa number leaving the digester and thereby increasing the solids going to the evaporators and to the recovery boiler. This strategy will work only if there is sufficient capacity available for brown stock washing and recovery of black liquor solids.

An estimate was then made of the reduction in COD in the process effluent from the bleach plant going to the waste treatment system and then eventually going to the Androscoggin River. For our analysis, several assumptions were necessary:

Kappa Number Reductions. By using the kappa analyzers it would be possible to reduce the kappa number going to the bleach plant by approximately two (2) units on the softwood side and one (1) unit on the hardwood side.

COD to Recovery System. The usual assumptions were made for this calculation, similar to those used in the reduction in COD arising from the optimization of the oxygen delignification system. The most important parameter is the COD loss coefficient. A value of 1.9 Kg COD per ADMT per unit Kappa number drop was assumed for both hardwood and softwood. This value is the average of the values given by Dence and Reeve[3] and McCubbin[4] for softwood, and was also used for hardwood because of lack of data.

Washing Efficiency. 90% of the COD dissolved by lowering the kappa number would be removed in the washers. This material is then recycled back to the evaporators and recovery boiler where it is eventually burned.

Efficiency in Waste Treatment System. The efficiency in the waste treatment plant for destruction of COD was assumed to be 81%.

$$COD\ \mathrm{Re}duction\ to\ effluent\ treatment = [\left(2\ kappa\ x\ 1.9 \frac{Kg\ COD/ADMT}{Kappa\ No.\ Drop}\right) x\ 0.6$$

$$+\left(1\ kappa\ x\ 1.9 \frac{Kg\ COD/ADMT}{Kappa\ No.\ Drop}\right) x\ 0.4]\ x\ 0.9 = 2.74\ Kg\ COD/ADMT$$

$$COD\ \mathrm{Re}duction\ to\ Andoscoggins\ River = 2.74\ Kg\ COD/ADMT\ x\ (1-0.81)$$
$$= 0.52\ Kg\ COD/ADMT$$

Thus, the addition of kappa number analyzers would reduce the COD in the effluent from the waste treatment system by approximately 0.52 Kg COD per ADMT. Similar to optimization of the oxygen delignification system on the softwood "A" mill, the Technical and Collaborative Teams may wish to consider further the installation of kappa number analyzers. Here it is recommended that cost estimates be obtained for the kappa number analyzers.

Replacement of Digester Extraction Screens

This project will be pursued outside the XL-2 project. However, it is being strongly encouraged by the XL collaborative and Technical teams. Adding new profile type extraction screens in the Kamyr digesters significantly reduces screen plugging by fines, and thus digester upsets, and will significantly improve counter-current chip washing. Also, a higher amount of wash liquor could be added to the digester. The result of this change will be less carry-over of black liquor with the pulp, and a reduction of the load on the brown stock washing system. Ultimately, this change will lead to better-washed pulp entering the bleach plant for the hardwood line (B-line), or to the oxygen delignification system for the softwood line (A-line).

The last screens in the B-line digester will be replaced during the annual shut down in May 2001. During last year's annual shutdown some screens were already replaced, and an improvement in the washing was noticed. The mill has plans to install new wash screens in the A-line digester in 2002.

Down flow Cooking

Down flow cooking in the A-line is another project considered outside the XL-2 project that could have significant impact on the discharge of COD to the waste treatment plant. Down flow cooking will replace the current counter current cooking operation, and may lead to a decrease in the black liquor discharge by the mill because the digester kappa number will be lowered from about 30 to about 27. This project is being considered for the summer of 2001. Based on the decrease in the digester kappa number of 30 to 27, and assuming a constant delignification efficiency of the oxygen stage of 30%, it can be estimated that the post oxygen kappa number will decrease by 3x0.7=2 units. Using the same assumptions as those listed earlier when calculating the effect of optimizing the mini O_2 stage, the isothermal cooking process implementation will lead to a decrease in the COD discharge of 2x1.9x0.6x0.9=2.1Kg COD/MT pulp.

Black Liquor Carryover and Turpentine Recovery Projects

Flash Steam Condensate For Softwood "A".

A significant source of COD on the softwood "A" side originates from the flash steam condenser on the softwood digester (see Figure 4). The two flash tanks on the softwood digester which process black liquor from the digester pressure to atmospheric pressure are undersized which cause high vapor (steam) velocity. Consequently, black liquor is being entrained in the vapor leaving Flash Tank No. 2. This black liquor -- including significant amounts of turpentine -- is being carried over to the condenser. Non-condensable gases leaving the condenser go to the non-condensable gas system (NGS) for incineration, while condensate, including black liquor solids and turpentine, go to the sewer. It is estimated that the entrained 3 to 4 gpm of weak black liquor in the flash steam condensate contributes about $2.1x10^6$ pounds of COD per year going to the waste treatment plant. Further, it is estimated that the turpentine in the flash steam condensate contributes another 3.6 to 7.1 x 10^6 pounds COD per year, depending upon the quantity of turpentine in the wood and the method of calculation. In any event, the flash steam condensate off the softwood digester contributes significantly to the COD load on the treatment plant.

Liquor Separator. One possible solution to the flash steam condensate stream is to install a larger flash tank in the second position, or even install a third flash tank downstream of the second flash tank. Another option would be to install a liquor separator between the existing second flash tank and the total condenser (see Figure 5). The black-liquor separator could be a cyclone separator, a simple knock-out drum or a demister. Of these two options, the liquor separator option was thought to be less expensive and commensurate with available real estate by the Technical Team. A major advantage of adding the separator is that, in addition to collecting a portion of the entrained black liquor and avoiding sending it to the sewer, implementation of this project would avoid contamination of the turpentine leaving the condenser and thus could permit turpentine recovery, providing of course that the return on investment was high enough. Recovery of turpentine would also permit a revenue stream for a previously heretofore considered waste steam. The following assumptions were made to permit estimation of the impact of the liquor separator project: (1) the entrainment separator is 80% efficient for removal of black liquor, (2) the evaporators can handle 95% of the recovered black liquor and 5% of the material is discharged as foul condensate from the evaporators, and (3) the efficiency for destruction of black liquor solids in the waste treatment plant is 81%.

$$COD\ \text{Re}\,duction\,to\,effluent\ treatment = \frac{(2.1x10^{6}\ lbs\ COD/yr)x\frac{1Kg}{2.2lbs}x\frac{1Yr}{365\,Days}x0.8x0.95}{1{,}000\,ADMT/Day}$$

$$= 1.99\,Kg\,COD/ADMT$$

$$COD\ \text{Re}\,duction\,to\,Andoscoggins\,River = 1.99\,Kg\ COD/ADMT\,x\ (1-0.81)$$

$$= 0.38\,Kg\,COD/ADMT$$

The Technical Team has decided to recommend the liquid separator project to the Collaborative Team for approval.

Turpentine Recovery. Sending turpentine to the sewer represents a significant COD load on the waste treatment system. It has been estimated that 13% of the black liquor load on the waste treatment system results from the discharge of turpentine. Turpentine recovery is a project that would reduce this discharge and provide a potential income source to the mill. The Technical and Collaborative Teams have discussed turpentine recovery extensively in the XL meetings. A typical recovery system is shown schematically in Figure 6. In this system, a turpentine decanter, storage and handling facility would be added on the A. Side. To estimate the anticipated reduction in COD to the Androscoggin River, the following assumptions were made: (1) the ratio of COD to BOD is 1.7, which is the lowest multiple measured during the last round of COD testing done to develop the balance, (2) 90% of the available turpentine is recovered in the proposed system, and 81% of the discharge turpentine is destroyed in the waste treatment plant.

$$COD\ Reduction\ to\ effluent\ treatment = \frac{(4.1 x 10^6\ lbs\ BOD/yr) x (\frac{1\ Kg}{2.2\ lbs}) x (\frac{1.7\ Kg\ COD}{Kg\ BOD}\ x \frac{1}{365}\ x\ 0.90}{1{,}000\ ADMT/Day}$$

$$= 7.81\ Kg\ COD/ADMT$$

$$COD\ Reduction\ to\ Andoscoggins\ River = 7.81\ Kg\ COD/ADMT\ x\ (1-0.81) = 1.48\ Kg\ COD/ADMT$$

It has been suggested by McCubbin[5] that virtually all of the turpentine is removed in the waste treatment plant and thus does not represent a major source of COD discharge to the Androscoggin River. If turpentine is preferentially destroyed in the waste treatment plant to a greater extent than 81% (the average determined for the mill in the COD balance), then the discharge to the river would decrease accordingly. This is shown in Table 8 assuming various levels of destruction in the waste treatment system.

Table 8

Estimated COD Discharge to Androscoggin From Turpentine

Assumed Turpentine Destruction in Waste Treatment (%)	**COD Discharge to Androscoggin River Kg COD per ADMT**
81[a]	1.48
90	0.70
95	0.39
99	0.078

Although the discharge of turpentine is a significant source of COD, the cost of adding a turpentine recovery project is estimated to be approximately $2,500,000 and well beyond the monies available on the XL-2 project.

[5] McCubbins, Personal Communication, Jan. 17, 2001 XL Meeting, Jay, Maine

Projects to Reduce Evaporator Condensate Discharges

Condensate Stripping

Organic substances are volatilized during cooking and black liquor evaporation. A flowsheet of a modern black liquor evaporation plant showing the separate collection of three condensate streams of different "cleanliness" is shown in Figure 7. Typical flow rates and composition of the three condensates streams (A, B, and C) for a softwood kraft mill are listed in Table 9. At the mill in Jay, all the condensates are sewered. Based on the mill wide COD balance, the combined softwood and hardwood evaporator condensate discharge is about 12 kg COD/MT or 18% of the total pulp mill COD discharge[6]. This is somewhat smaller than the 15-22 kg COD/ADMT given in Table 9. Many mills clean the most concentrated condensate stream(s) by steam stripping, and reuse the cleaner condensates as wash water. Assuming that the stripping process has an efficiency of 80%, this operation would represent a removal of 0.8x12=9.6 kg COD/MT from the pulp mill effluent going to the waste water treatment system. After the wastewater treatment system, the COD discharge reduction to the river is calculated to be 1.8 kg COD/MT.

Reverse Osmosis on Stripped Condensates

A recent development of evaporator condensate treatment at the Irving kraft mill at St John, NB, Canada, was reported by Dube and coworkers[7]. Here the condensate originating from the 5th effect evaporator (i.e. stream B in Figure 7) was treated by reverse osmosis (RO). This led to an estimated COD discharge reduction of 5 kg/MT, and, more importantly for this mill without a wastewater treatment system, to a 100% final effluent that is non-acutely lethal to rainbow trout and Dafhnia magna. In addition, after installation of the RO system, sublethal effects of plasma hormone depressions were no longer apparent for a fish species found in the St. John River. For the kraft mill at Jay, the potential COD discharge reduction of reverse osmosis is estimated at 3-4 kg/MT, i.e. somewhat lower than that reported for the Irving mill, because the measured COD associated with the black liquor condensates at Jay is lower than that reported in Table 9.

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[6] Genco, J. M., and van Heiningen, A, Comparative Analysis of SL-2 Projects - Third Report for IP XL-2 Project, December 28, 2000.
[7] Dube, et. al., Pulp and Paper Canada, page 42, August 2000.

Table 9

Typical Flow Rates and Composition of Softwood Black Liquor Condensates[a]

Stream	Flow	COD		Methanol	TRS
	(m^3/ADMT)	(g/l)	(Kg/ADMT)	(g/l)	(mg/l)
A	5	0.2-0.5	1-2.5	0.05-0.15	5-10
B	4	1.0	4	0.4-0.9	10
C	1	10-15	10-15	5-10	1000
Total	10		15-21.5		

[a] P. Axegard, Ecocyclic pulp mill, final report (2000).

Presently the black liquor condensates are not considered as a potential XL project because they will be handled in the so-called "Hardpipe" project, whereby the condensates will be transported in a separate pipe (rather than by the regular sewer system) to the waste water treatment system.

Project Related to the Screen Room

Treatment of the Knots

Approximately 10 t/day of knots and about 15 t/day of screenings are produced at the IP Androscoggin mill. Presently, these waste streams are going to the landfill on the mill site. It is estimated by the mill that the COD content of the filtrate associated with the knots and screenings is 160,000 lb COD/year or 200 kg COD/day. This represents a discharge of approximately 0.2kg COD/ADMT pulp produced. For operational reasons, the mill personnel are reluctant to re-cook the knots and screenings in the Kamyr digesters. Also, because the knots and screenings are a relatively small discharge, treatment of the knots by pressing out the entrained liquor (about 3.5 (±1) liter liquid/kg o.d. fiber) and recycling the filtrate is not a priority item for the XL-2 project. However, the energy value of the pressed knots is significant, and therefore this project is being pursued outside the XL-2 project to improve the energy efficiency of the mill.

Summary of Potential New Projects

The impact on the pulp mill effluent of all the potential new projects in terms of reduction in Kg COD/MT pulp, or as a percentage of the total pulp mill effluent of 69 Kg COD/MT, are summarized in Table 10. The final column gives an indication of the COD reduction per $1,000 of capital cost required (Kg COD/ADMT/$1,000 investment). This measure does not take into account operating cost. It can be seen that the projects leading to the largest COD reduction in the pulp mill effluent are the turpentine recovery and those associated with the evaporator condensates. These two major streams represent about 21 Kg COD/MT or 31 % of the total COD discharge of the mill. Presently, the black liquor evaporation condensates are not considered as a potential XL project, because they will be handled in the so-called “Hardpipe” project whereby the condensates will be transported in a separate pipe (rather than by the regular sewer system) to the waste water treatment system. This leaves the turpentine recovery, representing about 11% of the total COD discharge of the mill, as the project with the largest impact. The many other listed projects combined represent 15% of the total discharge. Despite their relatively small impact in terms of percentage reduction of the pulp mill COD discharge, some of these projects are quite cost efficient when expressed in (Kg COD/(1000$xMT), because their cost is relatively small as well. However, since not all of the cost data are yet available, a complete rating of these projects cannot be made at the time of writing this report. Another important consequence of the relatively small cost of some of the listed projects is that these projects can be accommodated within the available limited budget of the XL-2 Program.

Table 10
Summary of Potential New Projects

Source	Proposed Project	Pulp Mill COD Reduction		Cost	Efficiency
		(Kg COD/MT)	**(%)**	**($1000)**	$\left(\frac{KgCOD}{1K\$.MT}\right)$
Bleach Plant	Optimize Mini O_2 System for "A" mill	1.5-2.3	2-3	70	0.02-0.03
	Improve Washing	1.3	2	170	0.008
	Kappa Number Analyzers	2.7	4	?	?
	Downflow cooking	2.1	3	?	?
Black Liquor Entrainment and Turpentine Recovery	Minimize Black Liquor Carry-Over	2.0	3	150	0.01
	Turpentine Recovery	7.8	11	2500	0.003
Evaporator Condensates	Condensate Stripping	10	15	-	-
	Reverse Osmosis on Stripped Condensate	3-4	4-6	-	-
Screen Room and Miscellaneous	Knots and Screenings Processing	0.2	0.3	~350	0.0006
	Sewer Conductivity and Flow Monitoring	---	---	?	?
	All Projects	**31.5**	**46**		
Total Effluent of Pulp Mill Black Liquor Cycle		**69**	**100**		

TESTING

Validation of effluent quality improvement

In order to document and quantify the effluent quality improvement resulting from implemented XL-2 projects, selected streams will be monitored for COD and color before and after completion of a project.

In the 1st quarter of 2001, the A-line screenings filtrate will be replaced by paper machine white water (Project no. 3), and the B-line reject cleaner will be fitted with a timer to release the rejects (Project no. 5B). In order to establish the baseline before the implementation of these two projects, samples were taken in the appropriate sewers, and the flow rate of the sewer stream was measured. The samples were sent to Acheron Environmental Laboratory for COD testing, while the mill will take new samples for color determination to be done by mill personnel. The testing will be repeated when these two projects are implemented.

COD test method

The COD of a sample is determined by titrimetric determination of the oxygen requirement to obtain complete conversion of the organics (dissolved and undissolved) to CO_2 and H_2O (EPA method 410.1). It has been discussed whether the samples should be filtered to remove the undissolved material in order to simulate the effect of the clarifier. At the previous COD mass balance, the samples were not filtered before being analyzed by Acheron Labs (Newport, Maine). Since the samples were homogenized, the analytical results include all the undissolved organics. This method may be maintained for future sample analysis in order to maintain a consistent analysis technique throughout the XL-2 project. More information is needed to evaluate whether the samples for COD testing need to be filtered prior to performing the COD test.

Whole Effluent Toxicity

The annual toxicity testing of the whole effluent of the mill for 2001 (taken during 1st quarter) has been completed. The acute and chronic No-Observed-Effect-Concentration (NOEC) toxicity tests were found to be larger than 100%, including, for the first time, the chronic water flea (Ceriodaphnia dubia) test. In comparison with 1999, and generally in previous years going back to 1995, the chronic water flea test result was 25 %, while the annual result for the year 2000 was 50%. These results may suggest that the recent improvements in the screen room as part of the XL-2 program, as well as those done recently outside the XL-2 program have led to an improvement in effluent quality, which is the underlying goal of the Program.

CONCLUSIONS

Most Significant Projects. The identified projects giving the largest COD reduction in the pulp mill effluent identified to date are turpentine recovery and those associated with the evaporator condensates, representing approximately 11% and 20% of the total COD discharge of the black liquor cycle respectively. Presently the black liquor evaporation condensates are not considered as a potential XL project, because they will be handled in the so-called "Hardpipe" project. This leaves the turpentine recovery, as the project leading to the largest reduction in COD discharge.

Smaller Projects. Seven other projects have been identified, representing a combined reduction in COD discharge of about 10 Kg COD/MT pulp, or 15% of the total discharge from the black liquor cycle. Despite their relatively small contribution in percentage reduction of COD discharge from the black liquor cycle, some of these other projects may be quite cost efficient, especially when expressed in (Kg COD/(1000$xMT) because their cost is relatively small as well. Also, these smaller projects might be accommodated within the available limited budget of the XL-2 Program. An accurate rating of these seven projects can presently not be made since some of the cost data are not yet firm. The data shown in Table 10 are preliminary, but indicate that preventing the carryover of black liquor solids with the softwood flash steam and optimization of the oxygen delignification system on the softwood side have considerable potential.

COD and Color Levels. The COD and color data for the mill have continued to increase even though we have been implementing COD reduction projects (see Figures 1 and 2). Most of this increase in COD is thought to result from discharges from the paper machines. This goes to point up the fact that each mill is different and generalities are not possible. The current XL project is concentrating on reducing COD and color from the pulp mill while the majority of the COD originates from the paper mill.

Toxicity Testing. Early toxicity testing indicate that the black liquor is considerably more toxic than discharges from the paper mill. The annual toxicity testing for 2001 (taken during 1st quarter) for the whole effluent of the mill, including for the first time, the chronic water flea (Ceriodaphnia dubia) test, were all larger than 100%. The latter result may suggest that the recent process changes in the screen room made as part of the XL-2 program, as well as those implemented outside the XL-2 program have led to an improvement in effluent quality, which is the underlying goal of the Program.

Standards Based on COD and Color. Based upon the work being done on the IP XL-2 project, the relationship between COD, color, and toxicity is quite different for pulp mill and paper machine effluent. Thus, basing standards on final effluent COD and color to control black liquor discharges may not be correct.

RECOMMENDATIONS

Evaluate Projects. It is recommended that the technical team focus on the cost benefit ratio when evaluating the newly identified projects. More precise cost data need to be developed. Using the present data, the most cost effective projects are: optimizing the oxygen delignification system, minimizing black liquor carry-over in the softwood flash-tanks that are undersized, and improving the brown stock washing.

Study on COD Test Procedure. It is also recommended that the technical team undertake a study to fully evaluate the COD test procedure to determine whether the samples for COD testing need to be filtered prior to performing the COD test. Until data become available, the unfiltered COD test procedure should be followed.

COD to Kappa Number Ratio. It would be very helpful if data were developed on the COD to Kappa number ratio. This is a critical number in the analysis for softwood and hardwood and there is considerable uncertainty regarding what number to use.

Toxicity Test. It is recommended that the samples taken from the process streams be neutralized and filtered prior to toxicity testing. For samples taken from within the kraft process, the results of the toxicity test will depend upon the pH and the suspended solids.

Repeat Mill-wide COD and Color Balance. Approximately 7 months have elapsed since the last mill-wide COD balance was conducted. During this time, both the color and COD in the mill effluent has continued to increase. Consequently, another round of mill wide COD and color testing should be done.

Oxygen Delignification. It is further recommended that the technical team determine the ultimate level of delignification obtainable from the "mini' O_2 delignification system. We wish to evaluate whether raising the temperature, improving the oxygen mixing, and determining whether adding a gamma gauge can significantly improve the level of O_2 delignification.

Paper Mill Discharges. It is imperative that the XL team stimulates actions that lead to reduction in COD and color originating from the five (5) paper machines at the Androscoggin mill. Without a reduction in COD from the paper machines the COD effluent release goals of the XL-project will not be met. It is strongly recommended that the paper mill take appropriate steps to stop discharging cloudy whitewater from the machines that are producing groundwood printing and writing grades. This will not only address the COD discharge but will also significantly reduce fiber, filler and chemical losses.

Figure 1

COD (kg COD/ADMT) Discharge in Final Mill Effluent

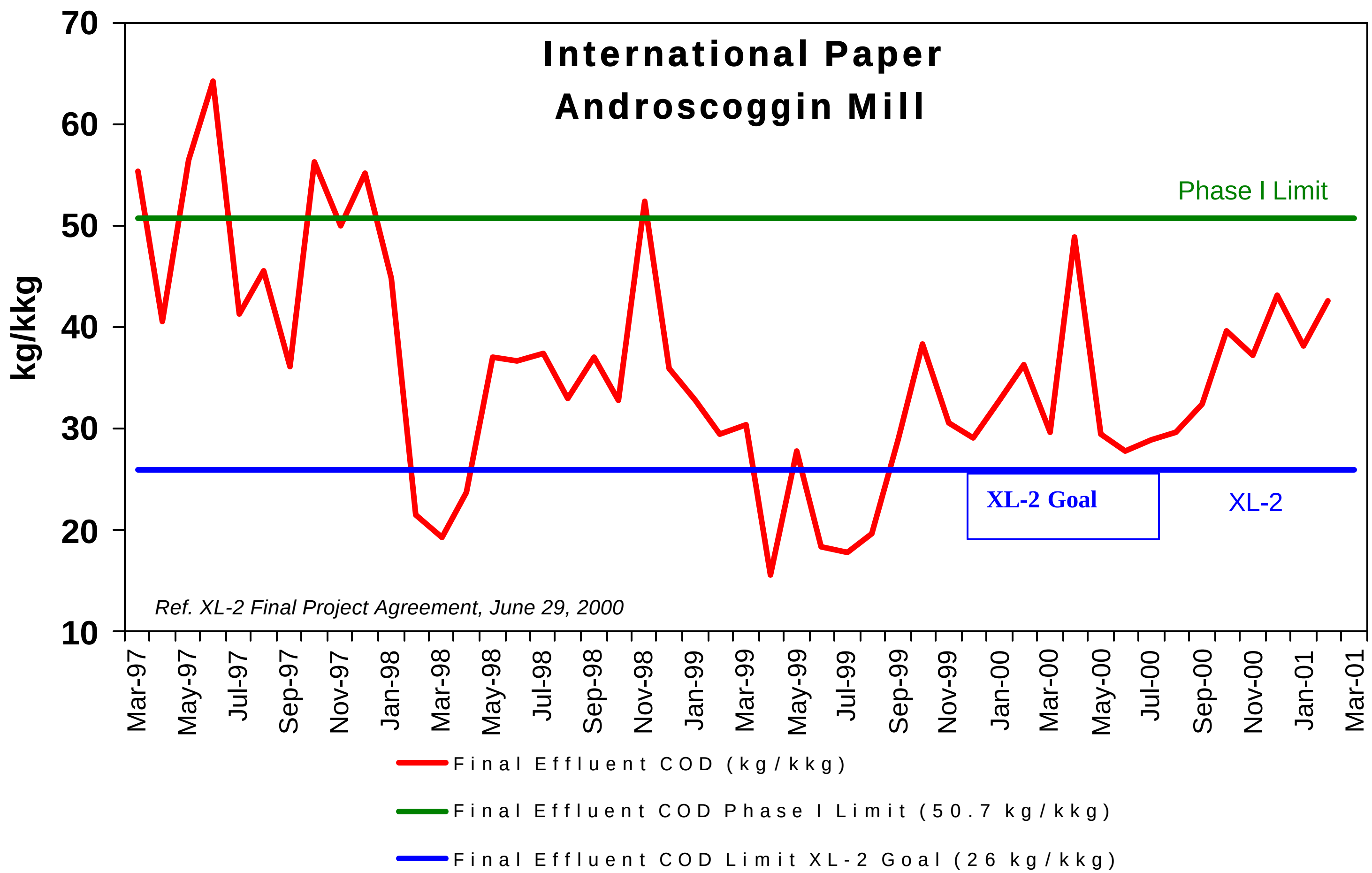

Figure 2

Quarterly Color (Lbs/AD Short Ton Pulp) Discharge in Mill Effluent

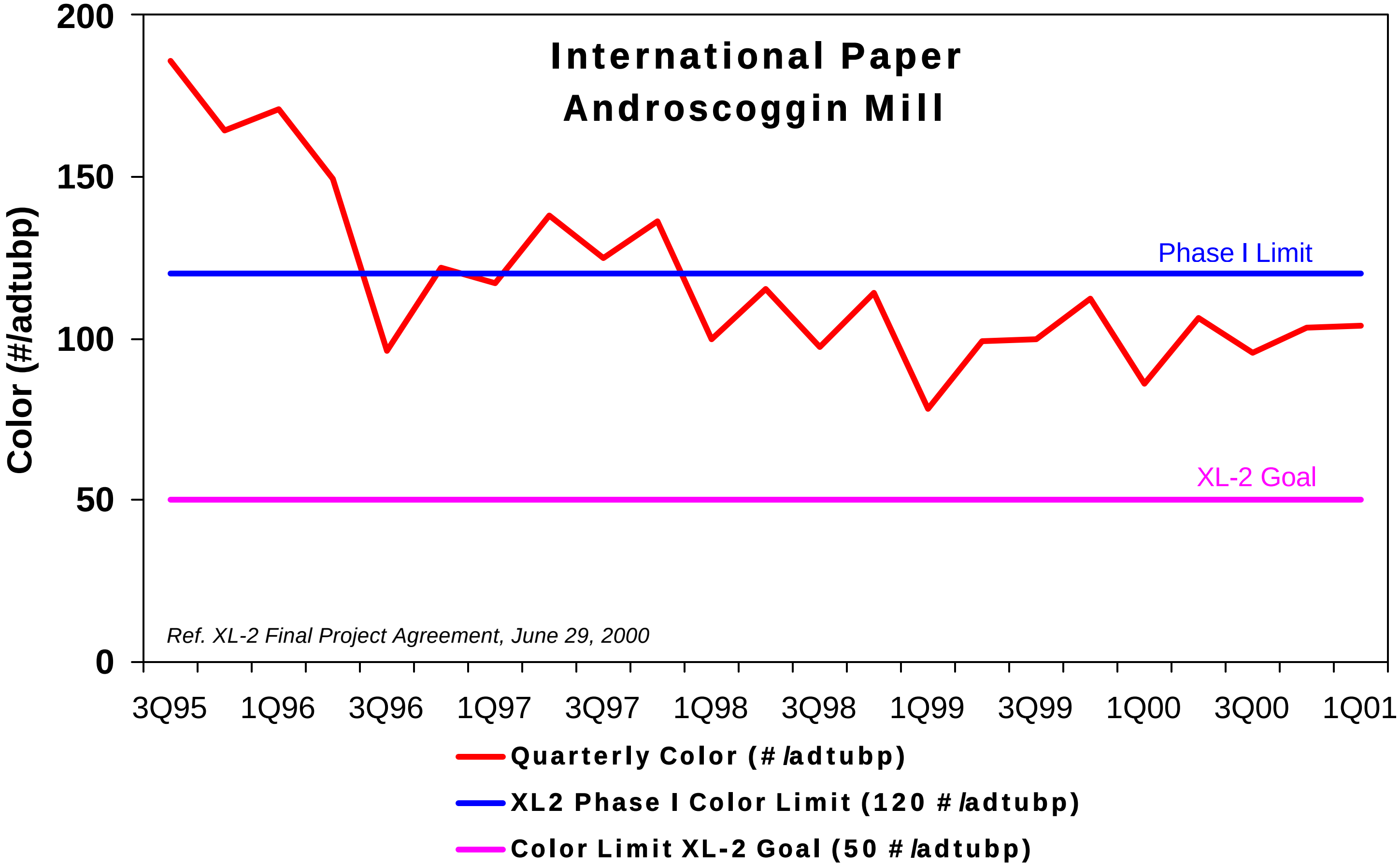

Figure 3

Softwood O_2 System at IP Androscoggin Mill

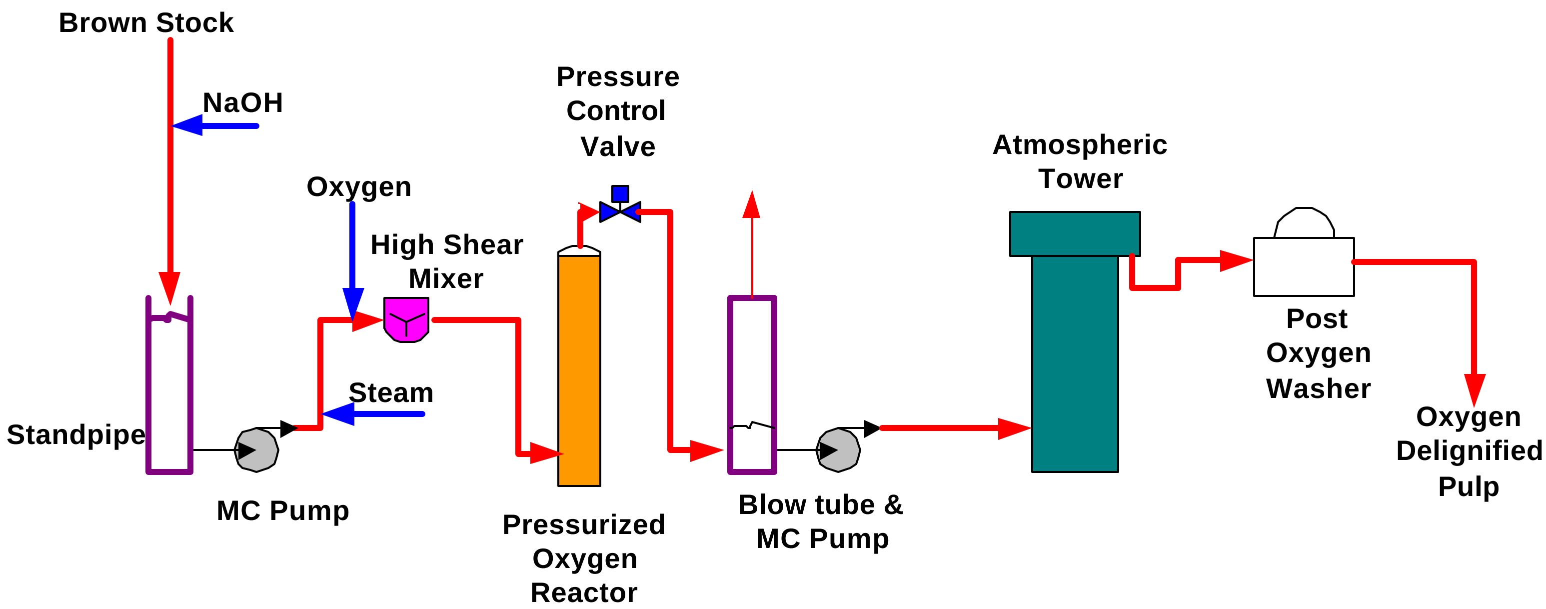

Figure 4

Current Softwood "A" Side Digester At IP Androscoggin Mill, Jay, Maine

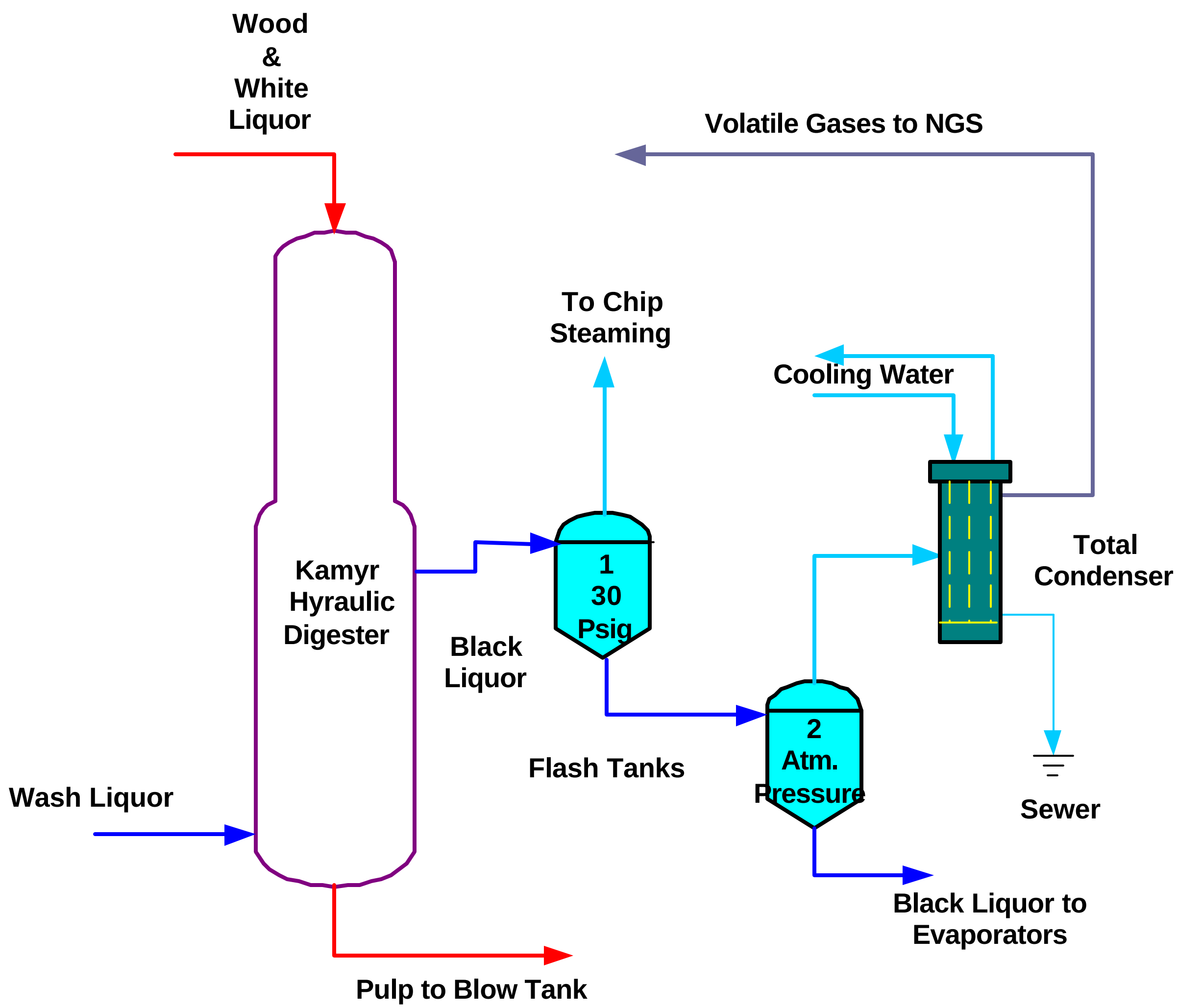

Figure 5

Proposed Entrainment Separator
Softwood "A" Side Diges ter at IP Androscoggin Mill, Jay, Maine

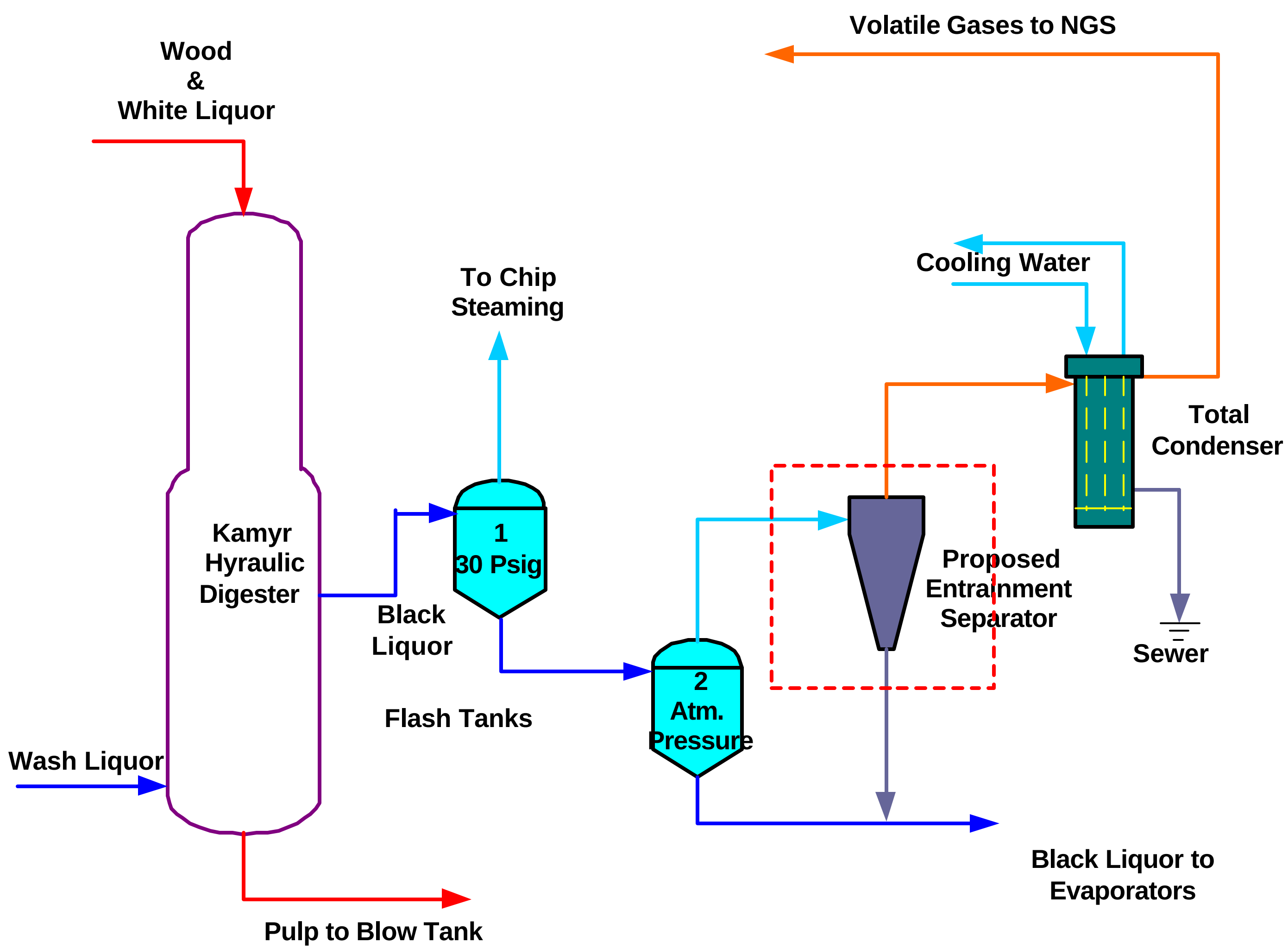

Figure 6

Softwood "A" Side Digester Showing Potential Turpentine Recovery Unit

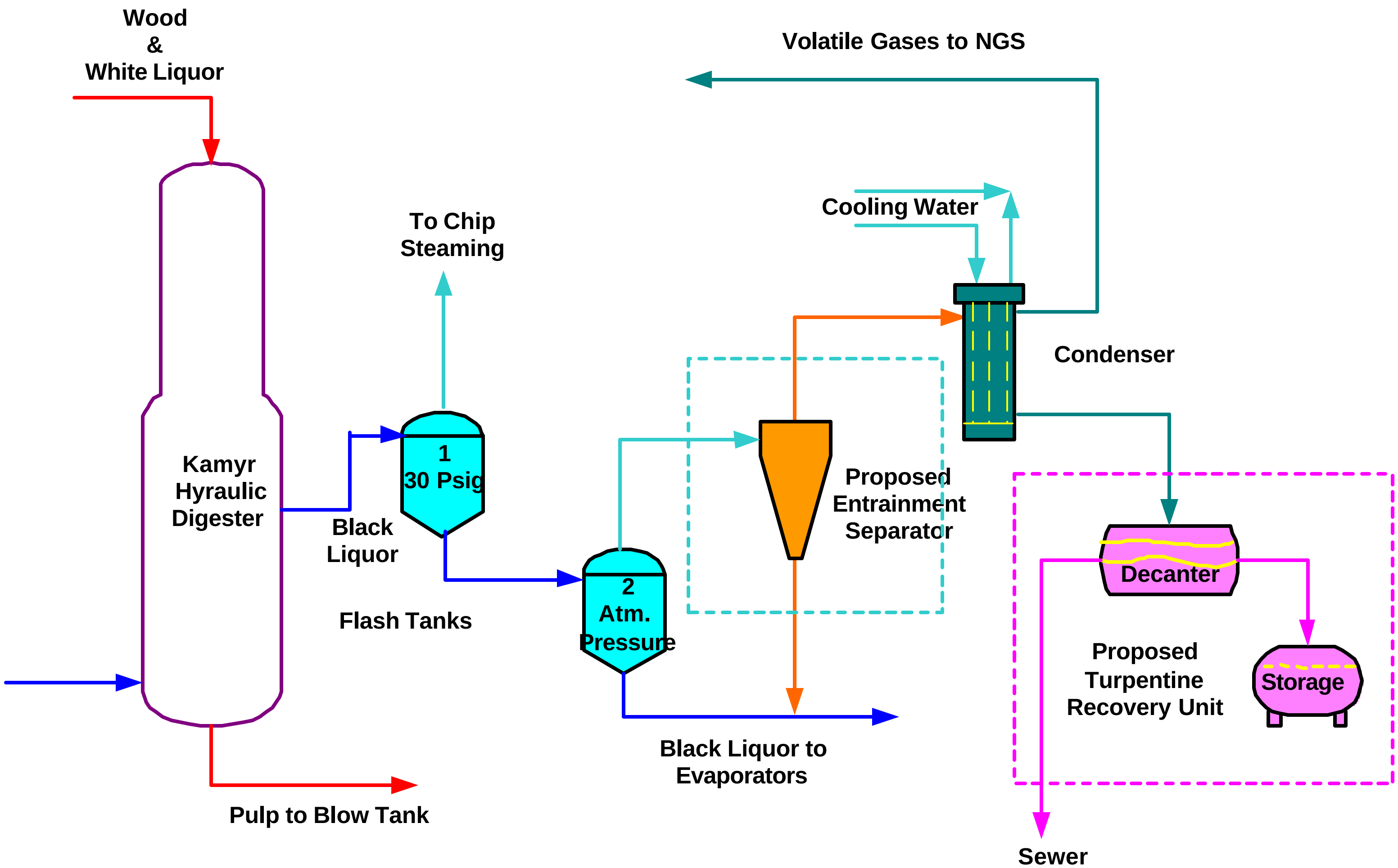

Figure 7.
Flowsheet of a modern black liquor evaporation plant [7]