FINAL REPORT ON WASHINGTON STATE DEPARTMENT OF ECOLOGY AG-BURNING PERMIT PROJECT CONTRACT NO. C0300085

FOR

LEWIS ENGINEERING CONSULTANTS

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2001-2003

Executive Summary

Environmental and population growth pressures are contributing to long range changes in forestland management practices, which reduce the harvest of wood for wood products and for pulp and paper manufacture (1). Consequently, the actual available supply for industrial purposes has declined dramatically (2). Partial replacement of domestic virgin fiber sources comes almost entirely from increased importation of wood and pulp and by enhanced recycling, particularly of old corrugated containers, old newspaper and mixed office waste. Projections show growing shortages of some of these waste paper categories in the near future (3). Consequently, manufacturers must seriously evaluate other fiber sources. Intensively managed plantations established during the last two decades will begin to replace only some of the deficit in virgin wood fibers.

Pressures to limit wood harvest from U.S. public forestland represent a significant opportunity to integrate agricultural production and pulp and paper manufacture. Thus, interest is also growing in the U.S. to find processes by which pulps from agricultural residues such as the cereal grains can be produced and blended with higher quality wood fibers for paper and paperboard production. Integration of agricultural production and pulp and paper manufacturing potentially could reduce the pressure on forest harvesting and at the same time produce added value products from underutilized residues while contributing to rural development and income. In Washington State (and the Pacific Northwest) wheat straw is the dominant agricultural residue. Consequently, this paper focuses on that material. Other residues such as other cereal grains, grass seed straw, seed alfalfa straw, and corn may also find use as pulp raw materials.

The first step in an integrated system would involve conversion of wheat straw to pulp for partial substitution into paper products. In addition, by selection of a sodium-free pulping process/s further integration may include processing of the spent pulping chemicals into a form compatible with soil application as fertilizers. These pulping chemicals are rich in carbon and sulfur and could incorporate potassium, ammonia and other nutrients. Evidence from our early laboratory and green house studies shows that soil application of sodium-free spent pulping liquors has the potential to increase soil carbon, plant growth and soil aggregation with improved resistance to soil erosion (4).

Excess straw associated with wheat in the highly productive Northwest regions poses significant management problems. The supply of straw far exceeds demand for low cost uses such as bedding or livestock feed supplement. Recycle by tillage is expensive in terms of time, machinery wear, increased nitrogen fertilizer costs and labor costs. Furthermore, the diesel fuel usage associated with tillage consumes a non-renewable resource (diesel fuel) and produces carbon dioxide as a combustion product. Conversion from tilled to No-Till systems could reduce carbon dioxide emissions associated with diesel fuel combustion by about 10 pounds of CO_2 per acre. This amounts to about 40 million pounds per year associated with Washington State wheat production. Public appreciation of such a quantity of greenhouse gas could help keep this nation on track for ratifying treaties to reduce emissions altering global and regional climate.

However, the heavy straw yield in the Northwest requires removal for successful No-Till operations. The least expensive straw removal involves field burning. Currently, about 2 million acres of wheat are grown in Washington with straw yields of 3 to 4 million tons per year. Presently about 200,000 acres of wheat stubble is burned per year in those regions. This results in atmospheric emissions of about 45,000 tons of particulates, carbon oxides and volatile carbon compounds (5).

Conversion of the residue to pulp and paper products with return of the spent pulping chemicals to the soil would be compatible with No-Till agronomic methods. Furthermore, soil carbon content could be maintained by the application of carbon-rich spent chemicals. Higher application rates could be on carbon-depleted sites such as steep hill gradients. Finally, spent pulping chemicals (described later) placed on the soil strongly aggregate soil and would retard erosion rates.

Clearly, an integrated agripulp system offers potential economic and environmental improvements to the agricultural and forest products communities as well as to our common environment. However, mechanical and chemical differences between wood and wheat straw requires some attention to technical, infrastructure and economic challenges.

Straw residue consists mostly of stems, leaves, sheaths and nodes. These materials are a heterogeneous matrix of cellulose (≈42%), hemicellulose (≈32%) and lignin (≈22%) and small amounts of extractives. Separation of the plant stem material into fibers by softening and removing a portion of the lignin results in brown colored pulp which can be used in products such as corrugated medium and liner board for boxes.

It has long been recognized that wheat straw has adequate fiber quality for a range of paper grades. The problem has been with both pulping and bleaching. The bleached and semibleached pulp demand has been for TCF pulp.

Technical barriers to economic pulp and paper production from straw include 1) control of silica in the process equipment. 2) Produce paper products with equivalent properties to wood derived papers. 3) Chlorine-free bleaching systems for straw pulps. This paper will address all of these issues.

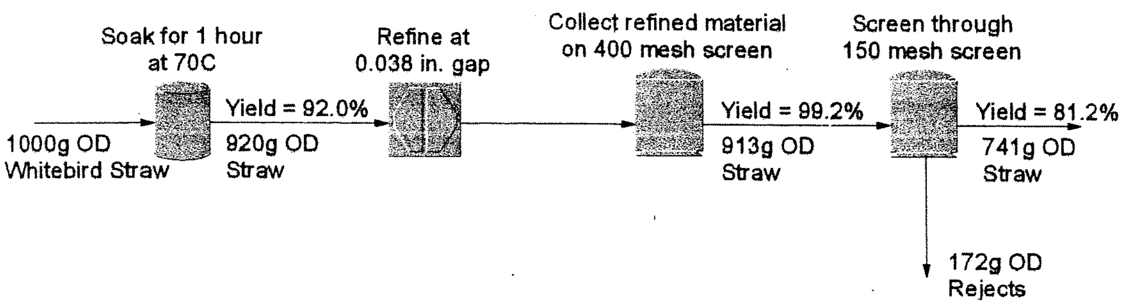
Control of Silica

Universal Pulping is a patented technology for producing bleachable and unbleached pulps. The basis of Universal Pulping is sodium hydroxide, nitric acid and alum as a catalyst. One of the benefits of UP is the ability to recycle the black liquor back into the original pulping liquor. After a series of recycles the black liquor solids and viscosity will reach equilibrium. The strength of the pulp will increase through the first few recycles before reaching equilibrium. An occasional purge of the system is required. This liquor is high in lignin, and in nitrogen. Research is ongoing into the utilization of this liquor for fertilizer, and as a soil amendment. The possible use of the liquor as a fertilizer prompted research into Potassium Hydroxide as the alkaline component.

The use of nitric acid in a pulping process may be of concern for a number of mills. With the principles of Universal Pulping, a series of cooks were done with sodium hydroxide and potassium hydroxide with peroxide. A brighter, stronger pulp with lower yield was produced under these conditions.

A series of preprocessing steps have been developed to help initially remove the silica and the nodes thereby creating a stronger cleaner pulp. Figure 1

Pre-processing of Whitebird Straw with Screening Through a 150 Mesh Screen (Overall Yield is 74.1%)



Bleaching of wheat straw

Wheat Straw that has been pulped under atmospheric conditions has a lower TCF bleached brightness due to a residual yellow color in the pulp. This yellow color is believed to be due to ferulic acid reprecipitating on the fibers. Traditional peroxide or hydrosulfite bleaching has yielded a maximum brightness in the low sixties on most wheat straw pulp. Two and three stage peroxide stages have not yielded brightness above sixty-five. These sequences required peroxide dosages of over fifteen percent.

Peracetic acid was used as a first stage bleach application. The peracetic acid had removed a degree of yellow color as a pretreatment in the pulping.

Treatment	Brightness	L	a	b
15% NaOH 10% H2O2 DTPA	33	81.2	-2.2	30.5
Paa(90) 15% NaOH, 5% H2O2	31.9	79.2	-1.2	28.8
Paa(90) 10% NaOH, 5% H2O2	31.9	81	-2.8	32
Paa(50) 15% NaOH, 5% H2O2	31.6	81	-3	32.2
15% NaOH 10% H2O2	31	80.5	-2.9	32.1
10% NaOH, 10% H2O2, DTPA	28.9	78.6	-2.3	32
15% NaOH, 5% H2O2, DTPA	28.2	79.3	-2.8	34.2
10% NaOH, 10% H2O2,	27.9	77.5	-2.2	31.8

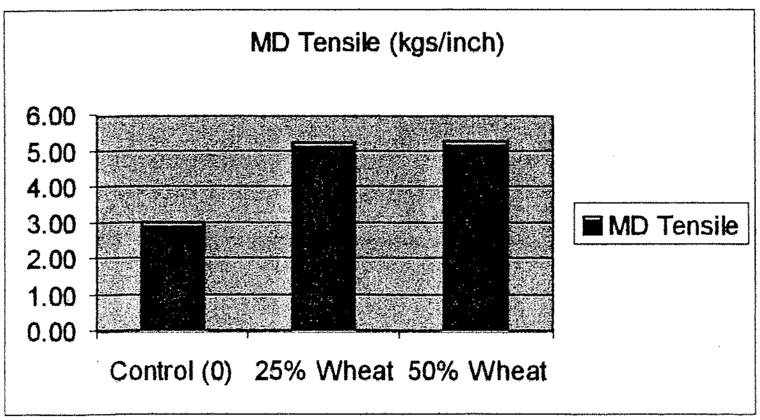
Further fractionation work yielded improved initial brightness after pulping with KOH and Peroxide

Production of Paper Products

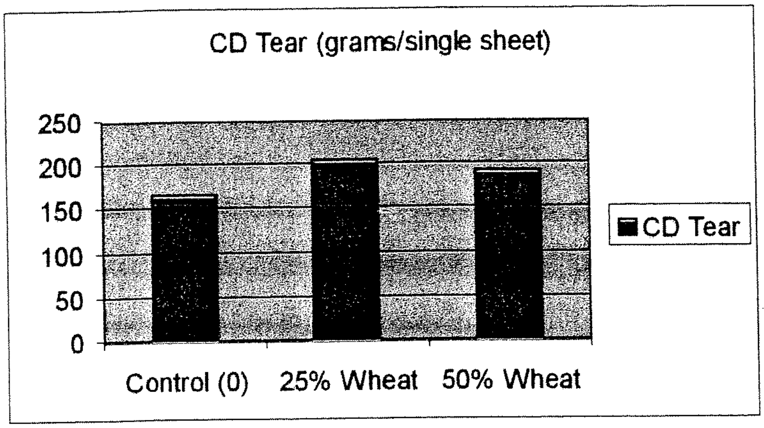
The majority of the wheat straw produced in the world is used in the production of Liner and medium. The North American Liner market requires a higher surface quality than does the Southeast Asian market.

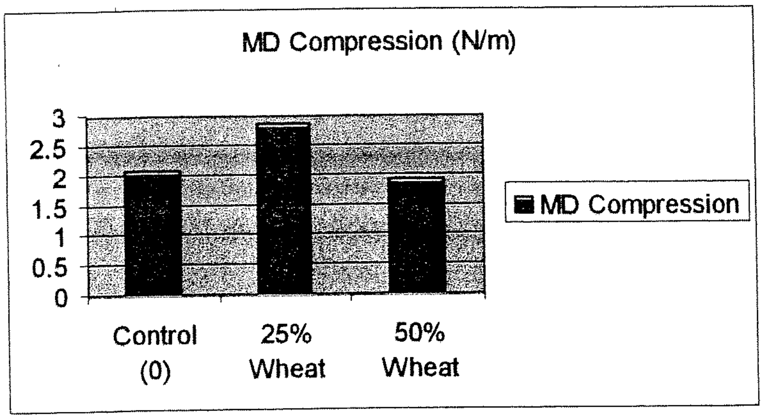
Papermachine trials were run with increasing percentages of wheat straw pulp substitution on a 137 gram per square meter medium. Papermaking conditions are in Table

Tensile strength was shown to increase with the increase in wheat straw percentage. Graph



Tear and compression strength increased at the 25% substitution level but then dropped back to levels similar to the control. This decreasing strength at the 505 level is due to the shorter fiber length.





The tensile properties are more influenced by the Relative Bonded Area. The tear and compressive strength will increase to an extent with and increased RBA but the intrinsic fiber strength has a greater influence on these properties.

Conclusions from papermaking trials:

50% wheat straw sheet has a greater than or equal strength to that of the control.

25% wheat straw pulp medium has significantly higher tensile, tear, and short span compression strength.

Newsprint

At the time of this writing, a newsprint trial was recently completed with 30 % wheat straw substitution into a sheet with deinked ONP and Kraft cooked Arundo donax. The sheet has five percent PCC filler added. The newsprint is stronger than TMP/DIP that was previously run on the machine. (Results will be available at the conference)

OTHER FIBERS

Blue grass straw fibers are similar to rye grass straw that was used in the development of the Weyerhaeuser straw mill in Springfield Oregon. This straw is much finer than that of wheat. It has fewer nodes, less silica, and doesn't require the preprocessing of the heavier straw. It does contain shorter fibers, more fines and isn't as strong. Previous work with kraft cooking has produced a very weak low freeness pulp.

Pulping of Blue grass under atmospheric conditions have produced a good filler type fiber with appreciable strength.

Sample	Conditions	Freeness	Tensile (Std.dev)	Burst (Std.dev)	S.S. Comp (Std.dev)
		ml	(Nm/g)	(Kpa m^2/g)	(KN/m)
bluegrass	1.5%HNO_3/15%KOH	546	43.58 (6.13)	2.71 (0.47)	1.11 (0.13)
bluegrass	1.5%HNO_3/15%KOH /1%alum	524	40.28 (3.73)	3.27 (0.34)	1.16 (0.19
bluegrass	1.5%HNO_3/15%KOH /1%alum	529	43.13 (2.45)	2.71 (0.45)	1.03 (0.17)
bluegrass	1.5%HNO_3/15%KOH	386	43.7 (5.00)	2.70 (0.43)	1.11 (0.12)

Seed alfalfa straw is a by-product of seed production for the alfalfa growers. It is a low growing vine type of straw. It produces approximately 3-4 tons per acre per year of straw. It is not a very high biomass producer, but currently the only option for removal is by burning it. There is approximately 25,000 acres of seed alfalfa in south central Washington, most in close proximity to the Boise Wallula mill. Preliminary work on seed alfalfa showed good results. The pulping under atmospheric conditions produced a brighter stronger pulp than wheat straw. More work needs to be done with this fiber source.

9% Peroxide, 12% KOH, Wheat Straw	average	stdv
Basis Weight (g/m^2)	67.09	
Brightness (ISO)	37.0	
Tensile Index (N-m/g)	71.1	1.0
Tear Index (mN-m^2/g)	4.7	0.05
Burst Index (psi)	3.7	0.2

9% Peroxide, 12% KOH, Seed Alfalfa	average	stdv
Basis Weight (g/m^2)	62.53	
Brightness (ISO)	42.5	
Tensile Index (N-m/g)	77.1	5.2
Tear Index (mN-m^2/g)	5.7	0.28
Burst Index (psi)	4.3	0.2

Conclusions and Recommendations

There is enough straw fiber in Washington to supply all the pulp and paper mills in Washington. Though this is not a viable idea, with new technology in atmospheric pulping conditions fiber from straw can be economically produced and can be used as a filler fiber in some situations, and as a finer papermaking fiber in others.

A 25 percent wheat straw fiber based medium has superior properties to a NSSC/OCC blend.

20 percent bleached wheat straw produces a stronger better printing sheet than does a TMP/ONP blend.

Grass straw pulp can be blended with secondary fiber to produce molded pulp products.

Other lesser-known fiber types such as seed alfalfa need to continue to be explored for specialty grades of paper, or for commercial communication grades.

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Progress Report on Washgton State DOE Ag Burning Project
DOE Agreement Number C0300085
March 10, 2003

Phase 1 Wheat Straw Medium Production

This phase of the project was to evaluate different pulping processes that could be used at either the Boise Wallula mill, or the recently closed Ponderosa Fibers Mill to make pulp for medium. Medium is the grade of paper that is the fluted material in the middle of a cardboard box.

Boise at Wallula manufactures approximately 375 tons of medium paper a day. This is shipped to a variety of box plants all over the west. Medium paper does not require a nice appearance, so fleck of wheat straw would not have any influence on the sheet.

The University of Washington has been studying wheat straw for many years, and only recently has determined that wheat can be pulped under non-pressurized conditions and give an acceptable quality of pulp to be blended with virgin or recycled pulp to make paper. The first part of this phase was to determine which pulping conditions would yield the best pulp properties for boxes. The second, a more work intensive phase, was to pulp fifty pounds of wheat straw. Third was to turn it into paper on the University of Washington Paper Machine. Finally the paper was tested to find an optimum level of wheat straw pulp addition.

EXPERIMENTAL:

250-gram batches of preprocessed straw were cooked under a variety of conditions. These pulps were then formed into handsheets and tested for physical properties. The pulping conditions used were a traditional Neutral Sulfite Semi-chemical (NSSC) cook using Sodium Hydroxide and Sodium Sulfite. An alternative non-pressurized method known as Universal Pulping which uses Sodium Hydroxide and Nitric Acid was also evaluated.

The batches were cooked in thermal resistant plastic bags and then refined in a Sprout Waldron refiner. Handsheets were made and tested according to TAPPI T-220 with a slightly heavier medium-like basis weight. All of the physical testing was done according to TAPPI standards.

TABLE 1
I/ Pulping Conditions:

Sample ID	L : W Ratio	NaOH (%)	Na2SO3 (%)	HNO3 (%)	Alum (%)	Temp (C)	Time (min)
NSSC 5K*	9 to 1	4.08	40.8	0	0	95	60
NSSC 8K	9 to 1	4.08	40.8	0	0	95	60
NSSC 8K*	9 to 1	4.08	40.8	0	0	95	60
NSSC 12K	9 to 1	4.08	40.8	0	0	95	60
UP 5K*	6 to 1	10	2	1	0.1	95	60
UP 8K	6 to 1	10	1	1	0.1	95	60
UP 8K*	6 to 1	10	2	1	0.1	95	60
UP 12K	6 to 1	10	1	1	0.1	95	60

It was decided to do the pulping with Universal Pulping conditions, which could be used in the Ponderosa Fibers Mill. The properties were better than the NSSC, and would function much better in that mill.

The paper was made on a Noble and Wood Formar at standard medium conditions and a basis weight of 127 grams per square meter. The wheat straw pulp was blended with old corrugated containers (OCC) pulp at 25 and 50% substitution. Earlier work was done at 5, 10 and 15 % and properties continued to increase. It was decided to push the percentage substitution to 50%

RESULTS:

Table 2 shows the results of the handsheets made from 100% wheat straw cooked and refined under different conditions. All of the strength properties for the UP cooked straw are higher than the NSSC pulp. The NSSC is brighter, but that is not needed for medium. It will be explored again in newsprint pulp production.

All of the strength results are normalized for basis weight.

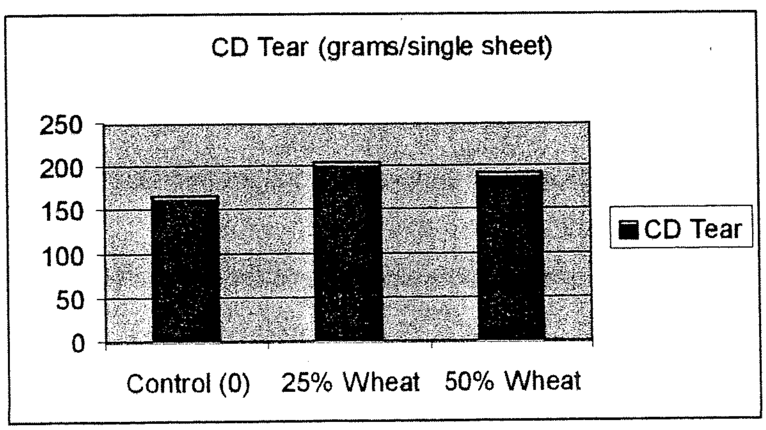
TABLE 2
II/ Handsheets Testing Results:

Sample ID	Basis Wt (g/m^2)	Caliper (mm)	Bulk (cm^3/g)	Density (g/cm^3)	Tear Index (mN*m^2/g)	Burst Index (kPa*m^2/g)	STFI Index (mN/g)	Brightness (% ISO)
NSSC 5K*	134.50	386.80	2.88	0.35	2.24	0.63	16.00	34.84
NSSC 8K	138.40	299.70	2.17	0.46	5.27	1.32	20.90	32.82
NSSC 8K*	--	--	--	--	--	--	--	--
NSSC 12K	148.30	447.80	3.02	0.33	7.62	1.01	19.60	32.00
UP 5K*	129.60	268.40	2.07	0.48	3.33	2.50	25.60	26.14
UP 8K	150.80	288.30	1.91	0.52	6.04	2.91	29.90	24.64
UP 8K*	123.20	277.90	2.26	0.44	5.35	2.59	25.60	26.10
UP 12K	150.80	317.20	2.10	0.48	8.38	2.43	24.90	24.90

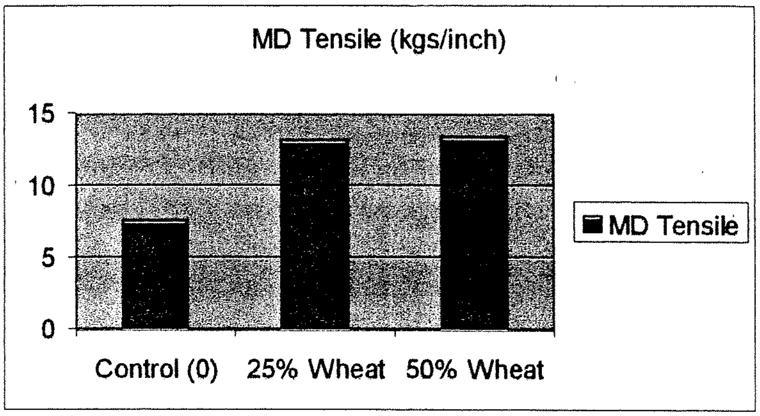
Note: 1/ The * samples were cooked in the jars.
2/ The NSSC 8K*'s fibers handsheets were not formed well. Not enough handsheets available for testing.

The paper made was tested for physical properties and samples were fluted and combined with commercial linerboard to check for combined board integrity. The paper was made to a 127-gram per square meter basis weight with a 25, and 50 percent substitution. Critical properties are cross direction tear for combined board integrity, Machine direction tensile for runnability through a high-speed corrugator, and machine direction compression, which is a predictor of how good a box, will resist compression. Graphs 1-3 show that the 25 percent substitution was superior.

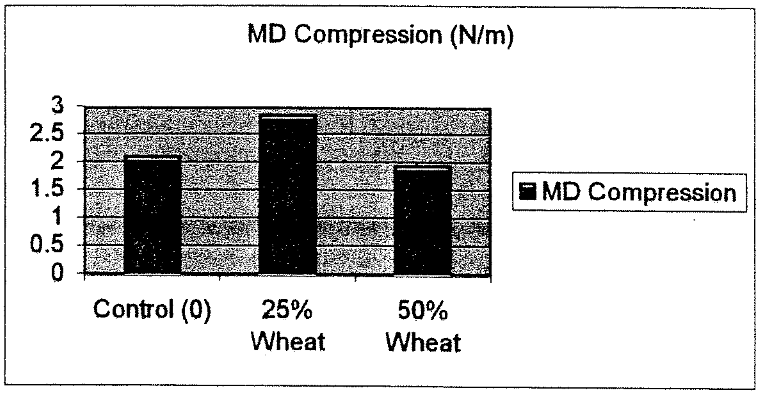
Graph 1



Graph 2



Graph 3



A 50 percent substitution is possible for 2 and 3 ply combined board, but may have some issues with traditional combined board. A heavier weight medium may be used with a higher percentage of wheat straw.

CONCLUSIONS

This phase of the project proves that medium can be successfully made with high percentages of wheat straw. This is common in China, but what is different with this work is the high percentage of straw, and that the straw pulp is from an unpressurized reactor. This pulping chemistry could be effectively used in the Ponderosa Fibers mill in Wallula, or other non-traditional pulping reactors.

Phase II

The objectives for Phase II of this project were to:

1. Evaluate seed alfalfa, grass, and barley straw for strength properties.
2. Determine an optimum bleaching sequence for each of these straws.
3. Determine a match for each straw type and a corresponding paper grade.

The bleaching of wheat straw to a level of 62 requires a different pulping scenario than that to make unbleached medium or liner. It also requires a bleaching sequence to minimize cost. To fit existing newsprint mills in eastern Washington, or the secondary fiber mill at Wallula a peroxide bleaching sequence is required.

Straw Type	Cooking Conditions	Tensile Index	Burst Index	Brightness
Ken Blue Bluegrass	15% KOH/1.5%HNO3	43.6	2.71	
Plush Bluegrass	15% KOH/1.5%HNO3	43.7	2.7	
Seed Alfalfa	12%KOH/9% H2O2	77.1	4.3	42.5
Madsen Wheat	12%KOH/9% H2O2	71.1	3.7	37
Barley	12% NaOH/10% H202	56.2	3.1	33.8
Oat	12% NaOH/10% H202	51.2	3.2	35.6

Peroxide bleaching of wheat straw has a couple of issues regarding a residual yellow color left to the pulp. Yellow color leads to a much lower brightness. This is due to ferrulic acid in the wheat straw lignin. Peracetic acid has been found to cleave ferrulic acid thus improve brightness. A series of bleaching experiments were designed to evaluate the effectiveness of peracetic acid as a bleaching agent as well as a pretreatment to pulping. The effectiveness of the peracetic acid as a residual yellow remover is measured by the b value in L a b color space. Table _ shows various pulping conditions and pretreatments for wheat straw in an attempt to reduce the yellow color in wheat straw pulp. The lower the b value the less yellow the pulp.

Table X

Treatment	Brightness	L	a	B
15% NaOH 10% H2O2 DTPA	33	81.2	-2.2	30.5
Paa(90) 15% NaOH, 5% H2O2	31.9	79.2	-1.2	28.8
Paa(90) 10% NaOH, 5% H2O2	31.9	81	-2.8	32
Paa(50) 15% NaOH, 5% H2O2	31.6	81	-3	32.2
15% NaOH 10% H2O2	31	80.5	-2.9	32.1
10% NaOH, 10% H2O2, DTPA	28.9	78.6	-2.3	32
15% NaOH, 5% H2O2, DTPA	28.2	79.3	-2.8	34.2
10% NaOH, 10% H2O2,	27.9	77.5	-2.2	31.8

A series of bleaching trials on wheat, blue grass and seed alfalfa were run with peracetic acid and peroxide. The trials were designed to attempt to get to a high newsprint brightness level (greater than 65 ISO brightness).

Table Y

Straw Type	Peracetic Acid	Peroxide	Peracetic Acid	Brightness
Wheat	0.5	5	1	53.7
	1	3	0.5	57.3
	2	3	0.5	65.4
	2	5	1	74.2
Blue Grass	0.5	5	1	47.2
	1	3	0.5	48.7
	2	3	0.5	51.6
Alfalfa	0.5	5	1	54.3
	1	3	0.5	59.7
	2	3	0.5	67.9

Blue grass and barley straw do not bleach as easily as wheat straw and seed alfalfa. Wheat straw can be bleached to a 70+ brightness economically. Alfalfa bleached under the same conditions as the wheat straw had higher brightness than the wheat straw.

The brightness limitations and lower strength of the blue grass as compared with wheat and alfalfa, limits the use possibilities. Barley and oat straw have comparable strength properties but do not have the initial brightness of wheat and alfalfa.

Table Z shows the pulp and paper mills in the northwest and the types of paper that are manufactured. Table Z also shows the types of straw that can be used in those mills. Mills producing grades of brown paper can utilize higher levels of straw. More work needs to be completed on the printing and writing grades, including newsprint.

City	Company	PMS	Grade	Tons	Straw	% Sub
Bellingham	Georgia Pac	5	Tissue	260	1, 2	to 20
Camas	Georgia Pac	10	Various	1500	1, 2	to 25
Cosmopolis	Weyerhaeuser	1	Mkt Pulp	400		
Longview						
	Weyerhaeuser	1	Liquid Packaging	800	1	to 10
	Longview Fibre	12	Various Brown	3500	1, 3	to 40
	Norpac	3	Newsprint	2000	1, 2	to 25
Everett	Kimberly-Clark	5	Tissue	580	1,2	to 20
Hoquiam	Grays Harbor	2	Fine	400	1, 2	to 20
Pt. Angeles	Daishowa	2	Directory	550	1, 2	to 25
Pt. Townsend	Pt. Townsend	1	Linerboard/Bag	400	1, 2	to 40
Inland Empire	Spokane	1	Newsprint	550	1, 2	to 25
Sonoco Products	Sumner	1	Chipboard	125	1, 2, 3	to 40
Simpson	Tacoma	2	Linerboard/Bag	850	1, 2	to 40
Carastar	Tacoma	1	Tube/Core	150	1, 2 , 3	to 40
Usk	Bowater	1	Newsprint	720	1, 2	to 25
Boise Cascade	Wallula	1	Medium	350	1, 2	to 40
		1	Copy	450	1, 2	to 20
		1	Mkt Pulp	550		
Wenatchee	Keyes Fiber	1	Molded	80	1, 2, 3	to 50
Yakima	Michelsen	1	Molded	40	1, 2, 3	to 50

1	Wheat
2	Seed Alfalfa
3	Blue Grass

Conclusion

There is approximately 15,000 tons of pulp and paper produced every day in Washington. Straw can be utilized in many of these grades. Work is ongoing to make mills aware of the capabilities of straw pulp. As secondary fiber prices on the west coast continue to rise. Manufacturers are starting to look at straw as an alternative. Molded pulp mills such as Keyes Fiber, and 100 percent recycle mills such as Sonoco and Caraustar are likely candidates for straw trials.

Cereal Straw Utilization for Paper

Phase III Report

Pre-commercialization Trial Planning

Michael Jackson

Consultant

Final June 25, 2003

Summary

Alternative means of producing semi-commercial quantities, 20-200 t, of straw pulp using the processes identified in the pilot laboratory phases of this study are reviewed. The idle Ponderosa Fibers mill in Wallula, WA, has an excellent capability of being able to process straw in the required manner with minor, low cost modifications.

A demonstration of straw pulping on this scale would enable papermaking trials to be made by several Northwest paper producers to confirm the feasibility of the processes. This would allow final evaluation of the conversion of straw to paper to be made prior to full commercialization of the opportunity. The ability to utilize straw in paper products would stabilize the raw material supply to the pulp and paper industry in the Northwest and would be beneficial to farmers with excess straw.

Several alternative process flows in the Ponderosa mill are identified and costs for the modifications that would be required are estimated. Overall trial cost to produce 100 t of unbleached straw pulp is estimated to be $110,000. Cost for the production of a semi-bleached grade using a Total Chlorine Free (TCF) bleach sequence is estimated to be $130,000.

It is recommended that an agreement be sought to run the trial and funding obtained.

Index

Introduction

An ongoing program at the University of Washington Pulp and Paper Center has identified opportunities for the utilization of cereal straw and other agricultural residual materials for the production of paper. The work has demonstrated, on a laboratory and small pilot scale, several approaches that could be successful. Phase I of this study investigates on a pilot laboratory scale the process details and papermaking performance of two of these processes with wheat straw to produce an unbleached fiber. Phase II evaluates other agricultural residuals and looks at the opportunity to produce bleached pulp for an extended range of paper applications.

Phase III of the study, presented in this report, is aimed at moving the development towards commercialization. The step from pilot laboratory work producing a few pounds of pulp and paper to commercial production that may range from producing one hundred to one thousand tons per day is a large one. Typically, intermediate tests and trials need to be conducted. These pre-commercial trials are usually made by producing sufficient pulp to run small commercial paper machines for several hours. The quantities of material required are in the ten to one hundred ton range. The goal of Phase III is to evaluate an approach to pre-commercial trials that could be undertaken prior to full commercialization in order to reduce the risk of the necessary investment involved. Means of producing quantities of pulp for tests on commercial paper machines are identified, cost estimates made and a preliminary trial plan outlined.

Objective

The objective of Phase III of the study is to evaluate alternative approaches to pilot and pre-commercial testing of agricultural residual for utilization in paper and board products in the Pacific Northwest. Plans and cost for trials that would produce sufficient quantities of straw pulp for test runs on commercial paper machines and a mill at which these trials potentially could be made are identified.

Expected Benefits

The availability of wood chips as a resource for the pulp and paper industry in the Pacific Northwest is becoming more and more restricted by environmental, ecological and social pressures. The cost of wood chips for pulping is currently relatively low following a period of high cost. Future projections indicate that significantly higher costs will return. Straw is a fiber resource available in significant quantities in Washington and Oregon. Development of a low cost means of utilization of the straw resource could provide a stabilizing influence on the raw material supply for the industry, resulting in long term economic viability.

This report presents a route from laboratory development work to full commercialization of the use of agricultural residual material for papermaking.

Background

Pacific Northwest Raw Material Supply

The pulp and paper industry in the US Pacific Northwest was initially based on use of wood from the abundant coniferous forests, utilizing logs directly chipped at the pulp mills and some residual chips from sawmills. Subsequently, restrictions on burning waste wood at the sawmills and recognition of the economic benefits of using chipped sawmill residual material led the pulp industry to being over 70% reliant on sawmill chips for its raw material supply. The remaining supply came mostly from chipping low quality whole logs.

The high proportion of raw material originating from sawmills linked the pulp industry strongly to lumber production with which these residual chips are directly associated. This resulted in fluctuations in the supply based on lumber demand. Severe swings in chip prices have been experienced due to this relationship between lumber production and chip availability.

Over the last two decades, the raw material supply to the pulp mills has been modified as increasing amounts of waste paper have been brought into the production of paper and board. Waste paper and board recycling and deinking plants have been established at unbleached board mill, newsprint and tissue mills. This new supply of raw material has alleviated the reduced availability of wood chips caused by forestry restrictions due to environmental and societal pressures. However, the cost and availability of waste paper of the correct type and quality has become a new issue. The pulp industry still experiences wide fluctuations in the cost of raw materials, both wood chips and recycled waste paper.

Wheat straw, seed grass straw, alfalfa and other agricultural waste materials have a fibrous nature and can be used in full or partial replacement for wood fibers in paper manufacture. In the Pacific Northwest considerable quantities of these materials are generated each year and to some extent represent a significant disposal problem. The utilization of straw materials for papermaking has a long history and is still practiced on a large scale in many countries. North American use of straw was discontinued shortly after the end of World War II; the availability of low cost, high quality wood material, especially residual material from sawmills, resulted in the use of annual agricultural crop residuals being discontinued. Economics made straw utilization valuable in tree scarce countries a viable undertaking.

Agricultural crop residuals can present problems in their collection, storage and in some aspects of pulp processing but their utilization in paper products is confirmed by the large quantity of these materials used in paper worldwide. They have advantages in uniform cost and availability and can enhance certain properties of specific papers and boards. However, the technology of their earlier use by the US paper industry is essentially lost due to the time lapse and the constant improvement in wood processing and paper quality achieved over the years. Thus, it has been necessary to rework technology for processing agricultural residuals and to develop new technology to make their utilization in the present industry successful.

Atmospheric Pulping Process

The process conditions established by the work at the University of Washington are based on the "Universal Pulping" (U-P) process patented by Eric Prior and on other processes that use conditions not requiring pressurized equipment. The processes produce a high yield, semi-chemical pulp suitable for the production of container board, linerboard and corrugating medium. One of the goals of the U-P process is to recycle the spent liquors from the digestion stage for reuse in the digestion of subsequent batches of raw material after fortification with the necessary fresh chemicals. The excess liquors can be compatible with dispersion for their fertilizer value and other attributes; they are being tested for soil application by Washington State University.

Systems to collect, store and preprocess straw for use in pulping have been developed as part of the Weyerhaeuser, Springfield, Oregon pulp and paper mill straw utilization project. The possibility of utilizing the preprocessing system to prepare clean, opened straw for the trials is being considered.

Development Steps

Evaluation of the steps necessary for scale-up to commercial production is the objective of this present study. Process development and trial production are the methods by which an idea, developed initially on a laboratory scale, is moved forward towards commercialization. The techniques use the development of specific information to provide models, written, drawn, physical or computer, of the process system in increasingly more detailed form. A series of information development steps are taken that reduce the risk of undertaking the ultimate investment in the commercial operation. Typically each step towards commercialization is more costly with the final commercialization step the most costly.

Typical pulp and paper mills range in the $250 million to $1 billion capital investment for a greenfield manufacturing facility. Even incremental expansion of production typically costs in the tens to hundreds of million dollar range. Such investments are not undertaken unless the successful operation of the new plant is highly assured. The development process is the means to make this assurance for a process that has not previously been commercialized.

In North America, with its heavily forested areas, wood has been the economical source of fiber, particularly wood chips from residual material from sawmills. The Ponderosa Fibers deinking plant has equipment that is considered suitable to effect the conditions required to pulp straw by the U-P process. It is proposed that a 200 T quantity of straw be processed in the plant to produce approximately 100 T of unbleached pulp suitable for inclusion in the production of corrugated medium. Trial quantities are planned for evaluation at several locations in the Pacific Northwest.

Survey of Northwest Mills

A review of the pulp and paper mills in Washington State was made to establish a listing of their potential for trial facilities and for the use of the straw pulp in their paper products. Summary information for each mill is given in Appendix I.

Production of paper and board grades applicable to this project in Washington State is as follows:

- Corrugating medium and related grades 1300 t/d
- Linerboard and related unbleached 1295 t/d
- Newsprint production (semibleached) 3720 t/d.
- Tissue production (bleached and semibleached) 1340 t/d

Several mills in adjacent states are potential customers for pulp produced from straw in the eastern Washington area; in particular:

Potlatch at Lewiston, ID:	tissue
Smurfit-Stone mill at Missoula, MT:	linerboard
Blue Heron Paper at Oregon City, OR:	newsprint

Facilities Available for Trials

Facilities that could be used to process straw in semi-commercial quantities using the atmospheric pressure processes need to have processing equipment that could easily be adapted to the conditions of the process, could handle straw rather than wood, and could treat the resulting pulp by refining, screening, cleaning and dewatering. It is also desirable that the facility be idle as the cost of suspending normal production can be high. These considerations brought the focus to the idle Ponderosa deinking plant at Wallula as offering the most promising opportunity.

Other options considered included the idle semi-chemical digester at Bellingham. However, this unit has been idle for 8-10 years and would be difficult to restart. In addition, Georgia Pacific permanently closed the pulp mill portion of the plant in 2002. The shut down newsprint mill at Steilacoom does not offer any suitable pulping capacity as it has a thermomechanical system that uses refiners rather than digesters for pulping.

In 1997-98 Weyerhaeuser operated a 20 t/d pilot facility at its Springfield, Oregon, mill to process grass straw to an unbleached pulp suitable for linerboard and corrugating medium. This unit operated for about nine months and produced pulp of good quality. The process used, however, required a specialized high pressure digester that would not be suitable for the atmospheric pressure systems that are the focus of this study.

Trial Plan Development

Trial Objectives

Overall objective of the trial is to facilitate the development of straw utilization for paper and board production in the Pacific Northwest by producing pulp in sufficient quantities for commercial paper machine runs.

Specifically, the objective of the initial trial is to use an atmospheric pressure process pulping process, defined by work in other phases of this study, in the facilities of the Ponderosa Fibers, Wallula, deinking plant, to provide 100 T pulp for papermaking runs at commercial operations.

A second trial is also defined in which a semibleached pulp is produced for inclusion in newsprint production.

Trial Criteria

In order to complete a successful trial pulping straw with the atmospheric pressure process and fulfill the objectives the following criteria must be met:

1. Providing a supply of straw to the mill site
2. Opening the bales
3. Removing gross heavy contaminants
4. Cutting and 'opening' of the straw stalks with destruction of nodes to allow rapid liquor penetration
5. Removing of fines material (optional but desirable for quality)
6. Cooking the straw at 90-95°C for 45-60 minutes in the presence of sodium (or potassium) hydroxide and other chemicals according to the process conditions specified by the laboratory work

7. Removing a substantial portion of the spent cooking liquor after the cook and recycling this liquor for treatment of subsequent raw material
8. Removing some portion of the recycling liquor from the cycle for off-site evaluation
9. Washing the cooked pulp after spent liquor separation to reduce entrained dissolved material
10. Lightly refining to control freeness to a level suitable for board production
11. Dewatering the refined pulp to a shippable form
12. Shipping to mills for papermaking trials

Straw Supply

In addition to wheat straw several alternative materials have been evaluated under Phase II of this study. A final selection of the material that would be used for the initial pulping trial has not been made. For the purposes of this phase of the study it is assumed that wheat straw would be used. Other alternatives could be substituted with only minor changes in the plan.

Wheat straw is normally available in bales made directly in the field from straw discharged from the harvesting machine. Various sized bales are made depending on the baling machine used. Standard 18"x18"x36" bales have been the most common but larger 36"x36"x72" bales are beginning to be used more frequently. Rolled bales are common for grass straw. It is anticipated that the raw material for a pre-commercial trial would be obtained from a farmer cooperating with the development process. A nominal cost has been included for the straw and an estimated transportation cost made based on typical trucking costs and truck loading.

Straw Preprocessing

Baled agricultural residual materials typically have contaminants, rock, sand, dirt, that must be removed before the material can be fed into the pulping process. If this is not done then equipment damage, rapid wear and low quality product can result.

Two preprocessing systems have been selected as alternatives for the proposed trial and they are compared in the analysis. The simplest system would be to feed the straw bales to a tub grinder that would break open the bales and cut the straw to short lengths suitable for the pulping stage (1 to 4 inches). After opening and cutting fines could be screened out to remove sand, grit and some leaf material. To separate the larger heavy contaminants either an air density separation system could be used or the heavy materials could be left in the straw and separated as heavy junk material in the first stage of pulp processing system.

Another system for preprocessing would be to use the plant set up by Phalen Company for Weyerhaeuser Company during their trials utilizing grass straw. This plant has been idle for several years but according to the Phalen people could be brought back into operation relatively easily. The plant system takes bales, opens them and removes gross contaminants then mills the straw to a relatively short length (½ to 1½ inch) and destroys most nodes. The resulting cut straw is fine screened to remove dust that includes most of the leaves and node material. The preprocessed straw is then transported in live bottom bulk trailers. This system would be preferred if the alternative pulping approach, using the peroxide bleach system' were used as the well-cleaned nature of the straw would provide good equipment protection. The major disadvantage would be the transportation cost.

Ponderosa Mill Description

The Ponderosa mill was built in 1998 adjacent to the Wallula pulp and paper mill of Boise Cascade Corp. The objective was to provide the Boise mill with high quality bleached recycled fiber to be included in the production of copy and printing paper produced by Boise. Problems in achieving the target quality at economic cost and a significant upswing in the price of waste paper of the necessary quality drove the operation into uneconomical operation and the facility was closed despite extensive improvements that were incorporated in the process.

The mill is sited on land owned by Boise Cascade and Boise's Wallula operation processes the effluent from the deinking mill and provides steam and water for its operation. A description of the process and equipment at the Ponderosa mill is presented in Appendix II. A general lay out of the mill system is shown in Figure 1, Appendix IV. A process flow diagram is shown in Figure 2, Appendix IV.

Observations on the Ponderosa Mill

The process equipment in the Ponderosa mill has many features that would be suitable for the processing of pulp from straw or other agricultural residuals. There is a large degree of flexibility in the system to reconfigure the sequence of the processing steps and to omit some, as necessary.

Evaluation of the Ponderosa system and equipment shows that there are two alternatives for the atmospheric pulping stage required for straw. The pulping stage could be made in the mill's Pulper with some changers in the liquor heating and pulp discharge or the Peroxide Bleach system could be used without modification if the straw could be successfully fed to the system.

Digesting in Pulper

The Ponderosa Pulper ability to handle raw chopped straw rests on two points. One is the need to apply the pulping chemicals at close to 100°C (212°F). The operation was using only a low temperature of 35° C (95°F) without applying any extra heat at the point that the operation closed. To reach the desired minimum temperature of 95°C (203°F) a heating system will have to be installed on the liquor line leading to the Pulper. Recirculation of the spent liquors, which will be hot, will reduce the heating need after the first few batches. There is a possibly that such a system was in place when the mill started up but was discontinued. Further investigation of this point is needed.

It has not yet been determined what consistency (or liquor to straw ratio) could be mixed in the system as the agitation is a low intensity one. Fluidization of the chopped straw charge may be difficult except at low consistencies. Pretrial tests would need to be made to determine possible operational conditions.

A second problem with the Pulper system is that the extraction of pulped material is through the small holes of the extraction plate where the accepted pulp normally discharges. In the proposed pulping method, the straw is not completely defibered at the end of the cook and it is desirable to maintain this incompletely defibered state for washing. It is expected that at the end of the pulping cycle the straw will not be defibered enough to pass through the extraction plate holes. The Pulper does have a large discharge for contaminant materials and probably this could be rearranged with some new piping to discharge the whole of the digestion charge.

The required separation of the spent cooking liquors after the cooking stage will have to be made in the second Fluidized Drum Washer and Screw Wash presses by-passing the coarse screening and cleaning systems. The pulp would then be defibered in the Shinhama Kneader and be screened and cleaned in the fine screens and small cleaners system before either passing to the peroxide bleach system or being transferred after thickening to the HD storage chest.

Schematic diagrams of the alternative feed systems to the Pulper are shown in Figures 3 and 4, Appendix IV. A diagram of the process flow for the Pulper alternatives is shown in Figure 6, Appendix IV.

Digesting in Peroxide Bleach System

The alternative to using the Pulper for the atmospheric pulping is the Peroxide Bleach system. This system can provide conditions required for the atmospheric cook. A good heating system is available in the Peroxide system. The main difficulty would be providing feed access for the raw material to enter the system at this stage. A new or temporary conveying system would need to be established to take cut and cleaned straw from ground level to the top of the building where the input system for the peroxide system is located. It would be desirable to use pre-clean straw raw material to ensure the process equipment was not damaged by rocks and tramp metal that might be in the straw bales and that might not be removed with a simple tub grinding system.

The ease of feeding the straw through the plug screw feeders would also need to be checked as these units are notorious for plugging except with the material they were designed for.

The Peroxide Bleach system does provide good heating capability, good chemical mixing, retention at high liquor to straw ration and a liquor separation stage. After washing, the pulped material would need to be transferred back to the Kneader thickening system for liquor separation and defibering.

A schematic diagram of the feed system for the Peroxide Bleach is shown in Figures 5, Appendix IV. A diagram of the process flow for the Peroxide Bleach alternative is shown in Figures 7, Appendix IV.

Pretrial Tests and Actions

Recommended pretrial tests and actions are as follows:

1. Get one truck load of straw into the plant
2. Rent a tub grinder and test bale opening and straw chopping
3. Make one charge of the Pulper
4. Locate a blower – chip blower from Radar?
5. Check temporary storage of chemicals:
    - Caustic (sodium, potassium)
    - Alum
    - Nitric acid
6. Check mixing facilities and heat of reaction when nitric is added to caustic
7. Develop data to satisfy environmental agency approval of any trial.

Trial Execution

Major steps in putting this trial plan into action are:

1. Bring together the main actors in the plan: farmers, Ponderosa mill, Boise mill, papermakers
2. Complete planning details, quantities and funding
3. Make modifications to Ponderosa mill as required
4. Acquire chemicals and other materials needed for trial
5. Make pretrial run with a small amount of material
6. Make trial run
7. Ship trial product
8. Papermakers use trial material
9. Assess product quality
10. Reassess economics of full commercialization

Critical Issues

1. Straw Opening and Feed to Process

Opening of the straw bales is necessary to obtain a flow of chopped straw and to 'open' the straw stalks to chemical penetration. A tub grinder is a suitable machine for this opening operation but would not allow any cleaning in terms of tramp metal and rock removal. The tub grinder could probably be arranged to drop the opened straw onto the existing weight belt feeder to the Pulper.

A wood waste reclaimer has been proposed as an alternative. This equipment could break the bales, wash the straw to remove heavy contaminants and dewater. A blower system might be needed to transport the opened straw to the process system.

A further alternative is to preprocess the straw in the Weyerhaeuser/Phelan system at Tangent. This system opens bales, grinds the straw for node reduction and screens for fines removal. The resulting material has essentially all the nodes removed and the straw stems are in 0.5-1.5 inch lengths.

The wet system would avoid excessive dust generation. Using off-site preprocessing would eliminate dust problems at the Wallula site but high transportation costs would be incurred.

2. Suitability of the Existing Bleach System to Process Straw

   The individual pieces of equipment need to be evaluated for their capability to process straw. The Plug Screw Feeder needs to be evaluated as to its capability of processing straw.

3. Liquor Recycle

   A system needs to be put in place to allow the press filtrate to be isolated and pumped to the incoming straw for recycle. A system to collect a portion of the liquor for off-site treatment is needed.

4. Heat Balance

   A preliminary heat balance needs to be calculated once liquor flows and feasible consistencies have been established.

5. Effluent

   Calculations need to be made of the amount of BOD and other dissolved solids expected to be washed from the pulp and sent to effluent treatment.

Trial Process Conditions

Process conditions for the pulping treatment, calculated quantities of materials and expected spent liquor recycle are listed in Appendix III, Table 2.

Schedule and Expected Completion

The major steps in running this trial are listed in Table 3, Appendix III.

An expected time schedule for pretrial planning is shown in Table 1 below. A detailed time sequence for the actual mill trial is shown in Table 2 below.

Table 1

Time Schedule for Trial Set-up

Action	By	Month 1	Month 2	Month 3	Month 4
Source straw		XXXXXXX			
Straw preprocess		XXXXXXX			
Boise specs/cost		XXX	XXXXX		
Other users					
Identify		XXX	XXXXXXX		
Agreements			XXX		
Contract with mill		XXX			
ID extra equipment			XXXXXXX		
Approve trial plan				XXXXX	
Trial funding			XXX	XXXXXXX	
Set trial conditions and controls			XXXXX	XXX	

Table 2

Specific Time Sequence for Trial at Mill

Action	By	Week 1	Week 2	Week 3	Week 4/5
Order chemicals		XX			
Safety review		XX			
Complete mill mods		XXXXXXX			
Ship straw to prep		XXX			
Preprocessing			XXXXX		
Prep straw to mill			XXX		
Run trial				XXXX	
Test product				XXX	
Ship product				XX	
Receive evaluation					XXX
Review mill op					XX
Conclusions					X

Trial Cost Estimate

Equipment changes determined to be necessary in the Ponderosa mill for various alternative trial schemes were listed and costs estimated. Wherever possible equipment would be rented on a temporary basis or purchased used. Details of these estimates are given in Appendix V.

Table 3 below summaries the estimated costs.

Table 3

Summary of Equipment Modification and Additions

Appendix V Table	System Alternative	Cost
1	Bales to Pulper	$8,000
2	Preprocessed Straw to Pulper	$4,500
3	Bales to Peroxide System	$31,500
4	Preprocessed Straw to Peroxide System	$21,500
5	Pulper System Modifications	$38,000
6	Peroxide System Modifications	$3,000
7	Pulping Chemicals Supply	$0
8	Bleaching Chemicals Supply	$2,000

Preliminary costs for a trial using straw bales fed to the Pulper are shown in Table 4, below. The diagram in Figure 9, Appendix IV shows the process flow for this alternative.

Table 4

Cost Estimate for Trial Using Bales going to Pulper

Item	Amount	Unit Cost	Total Cost
Straw bales delivered	200T	$50/T	$10,000
Bale handling	3 men at 16 hours	$45.00/hour	$2,160
Pulping & processing	20T raw/hour	$3500/hour	$35,000
Shipping	100T	$50/ as is T	$5,000
Preparation work	Manpower-80 hours	$100/hour	$8,000
Process modifications	Table 3, Items 1, 5 & 7		$46,000

Effluent treatment	By Boise Cascade		?
Spent liquor Transportation	One tank truck, 150 miles	$5.00/ml	$750
Off-site testing	40 hours	$50/hour	2,000
	TOTAL		**$108,910**

Bleached Pulp Trial

The second objective of the overall study was to define the process conditions for production of a semi-bleached pulp suitable for use in newsprint. The process selected in Phase II uses a three-stage Total Chlorine Free (TCF) bleach involving an acid/alkali/acid sequence with peroxide bleach chemicals. The Ponderosa mill system was evaluated to determine how this sequence could be made using existing equipment.

The Ponderosa system has a high consistency alkali peroxide bleach followed by a reductive bleach at medium consistency that was used for bleaching recycled pulp. This part of the Ponderosa mill process is ideal to run the second two parts of the acid/alkali/acid sequence for the straw pulp. The first acid stage will have to be run in one of the mill's retention or dilution tanks. The process conditions required for the first acid stage are:

Table 5

Conditions required for first stage of bleach

Item	**Units**	**Value**
Temperature	°C	50
Time	Minutes	30-60
Consistency	%	5-10

The retention tank following the Third Thickening stage has a consistency of about 6.0%. At this time information is not available on it size and therefore retention time cannot be estimated.

The proposed bleach process flow is shown in Figure 8, Appendix IV.

Estimated cost for bleached pulp trial production is shown in Table 6, below.

Table 6

Cost Estimate for a Bleached Pulp Trial Using Bales Going to Pulper

Item	Amount	Unit Cost	Total Cost
Straw bales delivered	200T	$50/T	$10,000
Bale handling	3 men at 16 hours	$45.00/hour	$2,160
Pulping & processing	20T raw/hour + 50%	$3500/hour	$52,500
Bleach chemicals			$3,930
Shipping	100T	$50/ as is T	$5,000
Preparation work	Manpower-80 hours	$100/hour	$8,000
Process modifications	Table 3, Items 1, 5 & 7		$46,000
Effluent treatment	By Boise Cascade		?
Spent liquor Transportation	One tank truck, 150 miles	$5.00/ml	$750
Off-site testing	40 hours	$50/hour	$2,000
	TOTAL		**$130,340**

Conclusions

1. The idle Ponderosa Fibers mill in Wallula, WA, has an excellent capability of processing straw in the required manner with minor, low cost modifications.

2. Straw could be processed directly from bales if the proper modifications were made to ensure that dirt, grit, rock and other tram material was removed early in the pulping process to protect equipment from damage. Alternatively, the straw could be preprocessed at an existing facility that would ensure the supply of a well-cleaned material.

3. Cost for production of 100 t unbleached straw pulp is estimated at $110,000.

4. Cost for the production of 100 t semi-bleached straw is estimated at $130,000.

Recommendations

It is recommended that efforts move ahead to develop the trial plan outlined, with initial identification of participants and source of funding for the project.

APPENDIX I

Washington Pulp and Paper Mills

Georgia Pacific Corporation
Bellingham

General Manager:	James Cunningham
Tissue Operations Manager:	Dave Jarrett
Pulp Mill:	Closed 2002
Pulp Source:	Market pulp
Paper Machines:	Four Fourdriniers One Twin wire
Products:	Tissue
Production:	260 T/D

Georgia Pacific Corporation
Camas

V.P. Resident Manager:	J.F. Koeppel
Fiber Processing:	C.AQ. Strawn
Technical:	T.L. Wolford
Pulp Mill:	
Kraft:	Batch digesters Continuous (sawdust)
Sulfite:	Closed 2000
Paper Machines:	Ten
Products:	Tissue/toweling Specialty papers
Production:	1500 T/D

Weyerhaeuser Company
Cosmopolis

General Manager:	Dave Walseth
Pulp Mill Super.:	C.D. Kramer
Technical:	S. Martinis
Raw Material:	Wood chips
Pulp Mill:	Sulfite
Paper Machines:	One Fourdrinier
Products:	Market pulp
Production:	400 T/D

Weyerhaeuser Company
Longview

V.P. Mill Manager:	John Walkush
Raw Material:	Wood chips
Pulp Mill:	
Kraft:	One Kamyr digester
Paper Machines:	Two Fourdriniers One Board Fourdrinier
Products:	Copy and printing papers Bleached liquid packaging board
Production:	1200 T/D

North Pacific Paper Company (Weyerhaeuser)
Longview

V.P. Mill Manager:	Harrison
Raw materials:	Wood chips ONP/OMG
Pulp Mill:	TMP Deinked ONP
Paper Machines:	Three Twin wire formers
Products:	Newsprint
Production:	2000 T/D

Kimberly-Clark Corporation
Everett

V.P. Operations: Mill Manager:	Mike Holcomb Richard Abrams
Raw Materials:	Wood chips Market pulp
Pulp Mill: Sulfite:	 Batch digesters
Paper Machines:	Four Yankee Fourdriniers One special
Products:	Tissue/Toweling
Production:	580 T/D

Grays Harbor Paper, LLP
Hoquiam

President:	William Quigg
Mill Manager:	Keith Folkers
Pulp Mill:	No pulp mill
Pulp Source:	Market pulp
Paper Machines:	Two Fourdriniers
Products:	Copy and printing papers
Production:	400 T/D

Longview Fiber Company
Longview

Sr. V.P./Mill Manager:	R.J. Parker
V.P./Ass. Mill Manager:	T.E. Stacie
Technical Dir.:	M.E. Haas
Raw Materials:	Wood chips OCC
Pulp Mill:	
Kraft:	Batch digesters Kamyr digesters M&D Digesters
Recycled OCC	
Paper Machines:	Twelve Fourdriniers
Products:	Linerboard Converting papers Corrugating medium
Production:	3800 T/D

Daishowa America Co. Ltd.
Port Angeles

Resident Manager:	Mark Hannah
Raw Materials:	Wood chips Old directories ONP
Pulp Mill:	TMP/RMP Deinked ONP/directories
Paper Machines:	Two Fourdriniers with top wires
Products:	Directory paper
Production:	450 T/D

Port Townsend Paper Corporation
Port Townsend

Mill Manager: David Hartley
Pulp Mill Manager: Bruce McComas
Technical Director: Ev Muehlethaler

Raw Material:	Wood chips Sawdust OCC
Pulp Mill: Kraft:	Batch digesters M&D continuous sawdust
Paper Machines:	One Fourdrinier
Products:	Unbleached kraft papers Linerboard Unbleached market pulp
Production:	375 T/D

Inland Empire Paper Company
Spokane

President/Gen. Manager:	Wayne Andersen
Production Manager:	Kevin Rasler
Technical Super.:	Rick Fink
Raw Materials:	Wood chips ONP
Pulp Mill:	TMP Deinked ONP
Paper Machines:	One twin wire former One Fourdrinier
Products:	Newsprint
Production:	550 T/D

Sonoco Products Company
Sumner

Plant Manager:	J.P. Kicklighter
Raw Materials:	OCC Mixed waste
Pulp Mill:	Recycled OCC/waste paper
Paper Machines:	One Cylinder machine
Products:	Chip board Boxboard Tube stock
Production:	115 T/D

Simpson Tacoma Kraft Company
Tacoma

V.P./Gen. Manager:	Donald Johnson
Pulp Mill Manager:	John Conkle
Paper Mill Manager:	Tim Jaeger
Raw Materials:	Wood chips OCC
Pulp Mill:	
Kraft:	Batch digesters Two Kamyr digesters
Recycled OCC	
Bleach Plant	
Paper Machines:	Two Fourdrinier machines
Products:	Linerboard Kraft paper (bleached/unbleached) Bag paper
Production:	850 T/D

Carasatar Northwest LLC
Tacoma

General Manager:	William Henry
Mill Manager:	Gary Moll
Raw Material:	OCC
Pulp Mill:	Recycled OCC/waste paper
Paper Machines:	One Cylinder machine
Products:	Chip board Can/core stock Linerboard
Production:	150 T/D

Boise Cascade Company
Wallula

Resident Manager:	Miles Hewitt
Pulp Prod Super:	Todd Pierce
Paper Prod Super:	Derrick McCain
Technical Dir.:	Kevin Scott
Raw materials:	Wood chips Sawdust OCC
Pulp Mill:	Kamyr continuous digester Three M&D digesters Recycled OCC
Paper Machines:	Two Fourdrinier machines One Twin wire former
Products:	Corrugating medium Copy/printing papers Market pulp
Production:	1350 T/D

The Chinet Company
Wenatchee

General Manager:	Ted Smith
Production Manager:	David Farendon
Raw Materials:	Waste papers/board
Mill:	Molding machines
Products:	Fruit packaging trays
Production:	80 T/D

APPENDIX II

Ponderosa Mill Description

A diagram of the general plant layout is shown in Figure 1, Appendix IV.

A diagram of the process flow is shown in Figure 2, Appendix IV.

Raw Material Receipt

Waste paper bales are received by truck, off-loaded and stored in a warehouse that houses the feed conveyor to the deinking system. Waste paper bales are manually dewired and placed onto a Weight Conveyor which feeds a batch Pulper. The Pulper is equipped with load cells to help control the loading sequence. Weight capacity of the conveyer is 15 tons. A typical Pulper batch is 10 tons.

Main Pulp Flow

The Pulper is the first stage of the deinking system. The Pulper is a low intensity system using a helical screw type impeller. Discharge from Pulper is through an extraction plate with 5mm holes and 8.5% open area. The capacity of the Pulper is 10.5 to 11 tons of dry paper – with pulping at 14 to 16% consistency. The Pulper operates at 95°F, cycle time is 40 minutes, with loading and dumping taking 15-20 minutes and actual pulping time being about 16 minutes.

The consistency range used, the low temperature and neutral pH are considered optimum for waste paper defibering, preliminary ink dispersion and minimum contaminant attrition. There are presently no provisions for addition of chemicals or heat to the Pulper. Originally, there may have been a system to heat the Pulper batch.

At the end of the pulping cycle the batch is diluted to approximately 4.5% by the addition of water as the dump begins and the defibered pulp is removed through the holes in the extraction plates with the assistance of the impeller's wiper blades. The accepted discharged pulp is pumped to the Dump Tank. Most of the large trash is retained in the Pulper.

The materials remaining in the Pulper at the end of the dump are fed directly into a reversing drum Trash Screen for further separation and fiber recovery – drum screen holes are slightly larger (5/16th versus 3/16th) than the Pulper discharge screen holes. The recovered fiber which has been separated from the contaminants is pumped to the Off-Grade Tank. The contaminants are discharged to the trash compactor.

The Dump Tank serves as the source for the continuous flow of stock through the rest of the plant and its discharge pump controls the production rate.

Pulp from the Dump Tank is pumped to the Coarse Screens that are fed at 3.3% consistency (this could be reduced to as low as 2.0%). The screens are in-flow type Ahlstrom Moduscreens, two primary screens and one secondary. They have 24 mm holes (0.094") in the primary and 20 mm (0.078") holes in the secondary, secondary accepts feed forward. The screens are inward flow vertical screens with a spinning basket and a stationary foil on the screen housing. There are heavies junk traps on the screens with Larox pinch valves. The heavies traps reject to a heavy reject conveyer that feeds to a sand separator. There is a tertiary stage Escher Wyss reject sorter.

The coarse screening is followed by centrifugal cleaning in a five stage CLP 700 Cleaner system, fed by a fan pump at 1.0% consistency. Four of the stages have lightweight removal as well as heavies removal.

Cleaned stock is 0.7-0.9% consistency and is thickened in two Fluidized Drum Thickeners (FDT). These are underflow drums, 3.4 m diameter, one is 4.5 m in width, the other 7.5 m. The drums have polypropylene fabric wires with 0.4 mm holes. Pulp discharge consistency is 6%. The thickeners also effect a deinking action but the present system returns the filtrate water to the Pulper via the Surge Tank and Pulper Head Tank.

Thickened stock falls into an agitated tank and is then pumped, with consistency controlled to 1.5-1.8%, to feed three primary Gault 1100 Micro Screens fitted with 4 thou inch slots baskets. The screen system has five total stages. The rejects from the final stage flow to the Sludge Press Feed Tank.

Screen accepts are washed and thickened in a single Fluidized Drum Washer (polypropylene wire) discharging at 4.5-5.0% consistency. The filtrate is pumped to Spraydisc Filters for fiber recovery. The thickened stock from the washer is pressed in two Screw Wash Presses to 28-32% consistency. The stock from the Drum Washer can be pumped back to the Dump Chest if required. Filtrate from the Screw Presses is fed to the Spraydiscs.

The thickened stock at 30% consistency is treated in a Shinhama Kneader having a 1500 HP drive (with specific energy control). The discharged stock is diluted in a stock tank and pumped to feed the Flotation Cells with dilution controlled to 0.9% consistency. There are four primary flotation cells in series. Rejects flow to the single secondary cell. Rejects from this cell flow to the sludge tank. Accepts are pumped to the four stage set of Forward Fine 270 Cleaners separating small heavy materials.

The accept stock is thickened on a Disc Filter to 20% consistency and discharged to a stock tank where the stock is pumped at 5.5-6.0% consistency to a Screw Press. Filtrate from the Disc Thickener is used for dilution in the pulping and screening stages with excess of the cloudy portion going to the DAF Clarifier. The Screw Wash Press #3 discharges at 26-28% consistency and is fed by a Plug Screw Feeder to a pressurized steam heater, rated at 28 psig with temperatures to 295°F.

The steam heater discharges through a Plug Screw Discharge to a Disc Disperser with 900 HP drive to enter the top of the HC Peroxide Bleach Tower. Bleach chemicals are added at the Disperser. The Bleach Tower discharge needs to be maintained above 22% consistency at the bottom of the tower for steady operation. Retention is up to 2 hours. Minimum measurable retention time is about 30 minutes. Discharge consistency after dilution is 6%.

A Screw Wash Press, #4, follows the Bleach Tower, with a feed of 6% and discharge of 14-18%. The stock is then pumped by an MC Pump to an Up-Flow Bleach Tower with chemical addition for a reductive type bleach using Direct Borol Injection (DBI). The bleached stock then flows to the HD Storage Chest that has capacity for about 300 tons pulp.

Pulp is discharged from the HD Storage Chest with dilution to 3.5-4.5% and is pumped to the Andritz Twin Wire Former. The Former produces wet-lap sheet at 50% consistency. The sheet is cut and formed into bales on a Cutter-Layboy as approximately 2000 lb lots for storage or immediate shipment.

Water

Fresh water use in the mill is solely for seal water, equipment cooling and chemicals make down. More fresh water can be used – in that case it goes as make up to the clearwell. Shower waters are clear water from the Dissolved Air Flotation (DAF) Clarifier. All other dilution water is recycled from the DAF clarifier or directly recycled without clarification.

Filtrates from the washing stages are pumped to a Spraydisc for fiber recovery. The filtrate then goes to the DAF clarifier. Other filtrates flow directly to the clarifier. Clarifier water is treated in a sand float clarifier for further clarification. The various press and thickener filtrates are not collected in separate tanks but flow through a central system for clarification (the fluidized drum thickener filtrate is a partially closed loop).

Effluent

Clarified waste water is pumped to Boise Cascade's effluent treatment system. The amount is determined, in part, by the need to control dissolved solids.

A Nano Filtration system installed at the mill which has been started up but not brought to fully satisfactory operation. This system was planned to treat part of the effluent to reduce BOD load on the Boise mill system.

Solid Rejects

The rejects from various points in the system are collected and thickened in central systems for disposal. Heavy rejects from drum screen, junk traps from Moduscreens system and HD cleaners are fed to a compactor for shipment to landfill.

The floated and settled solids from the clarifiers are pumped to a Gravity Belt Sludge Thickener then to Sludge Presses for dewatering before shipment to landfill. Other high contaminant streams are also directed to the sludge presses.

APPENDIX III

Trial Planning Details

Table 1

Trial Steps

200 T Straw to 100 T Corrugating Medium Pulp.

Straw received by Truck in bale form

200 T as is (350 x 1200 lb bales)

Unloaded to Holding Area

Fork or Clamp Truck

Bales lifted into Tub Grinder

Tub Grinder – run continuously or just on Repulper fill?

Opened Straw conveyed to Repulper

Chemicals addition
Heat and hold

Cook in Repulper

Pump out to Dump Tank (What capacity?)

Pumped to Centrifugal Cleaners

By pass primary screens

Thickened in Primary Thickeners

Screw presses

Dispersed/Kneaded to separate fibers

Dilution for Screen Feed

Screening to removed shives

Wash press to remove fines (?)

Final Thickener

Hi D Storage

Wet Lap Machine

Ship

Store in Cold Storage (if necessary)

Table 2

Trial Operating Conditions and Calculations

Item	**Units**	**Amount**
Production		
Target Trial Production	BDST	100
Average Production Rate	BDST/hr	3.0
Total Operational Time	Hours	33.3
Overall Yield	%, BD to BD	70.5
Straw Required	as is ST	2
Straw Moisture Content	%	15
Straw Supply		
Bale Size	inch	18x18x36
Bale Weight	lb	85
Bales Required		39
Truck Deliveries		12
Digestion Stage		
Straw Feed Rate	BDT/hr	4.26
Bale Feed Rate	bales/hour	100
Liquor to Straw Ratio	:1	3

Digestion Liquor Charge		
Total Cooking Liquor Flow	Gal/min	64.7
Recycle Liquor Flow Rate	Gal/min	33
Fresh Liquor Flow	Gal/min	32
Nitric Acid Charge	% on BD Straw	1.0
Nitric In Fresh Liquor	%	0.528
Alum Charge	% on BD Straw	0.1
Alum in Liquor	%	0.053
NaOH (or KOH) Required	% on BD Straw	8.0
NaOH (or KOH) (or KOH) Required in Liquor	%	4.22
NaOH (or KOH) in Recycle Liquor	%	2.11
NaOH (or KOH) Required in Fresh Liquor	%	2.11
Cooking Conditions		
Maximum Temperature	°C	95
Retention Time	minutes	45
End Cook Consistency	%	18
Tower Discharge		
Diluted Consistency	%	5
Dilution Filtrate Flow	Gal/min	169
Discharge Rate	Gal/min	235
Water Soluble Material Loss	% on BD Straw	25
Fines and Dirt Loss	% on BD Straw	6.0
Overall Yield	% on BD Straw	70.5
Thickening		
Thickener Feed Consistency	%	5.0
Thickener Feed Flow	Gal/min	235
Thickener Discharge Consistency	%	35
Thickener Filtrate Flow	Gal/min	202
Liquor Available for Recycle	Gal/min	33

Refining/Kneading/Dispersing		
Wash Press Feed Consistency	%	5
Wash Press Discharge Cons.	%	35
Fines Loss	% on BD Straw	4.0
Wet Lap Machine		
Feed Consistency	%	5
Feed Flow	Gal/min	235
Discharge Consistency	%	50
Production	BDT/Hr	3.0
Production	as is T/Hr	6.0
Liquor Recycle		
Sodium Hydroxide Consumed	%	50.0
NaOH (or KOH) conc. In cooking liquor	%	4.223
NaOH (or KOH) conc. in spent liquor	%	2.112
Yield Summary		
Pulping	%	75
Fines and Dirt		6.0
Overall	%	70.5
Chemicals Usage		
Straw	BDT/BDT pulp	1.42
Sodium Hydroxide (or Potassium Hydroxide), with recycle	lb/BDT pulp	113
Sodium Hydroxide (or Potassium Hydroxide), no recycle	lb/BDT pulp	227
Nitric Acid	lb/BDTpulp	28
Alum	lb/BDTpulp	3
For 100 T Pulp Production Trial		
Straw	T	142
Sodium Hydroxide (or Potassium	lb at 100%	11348

Hydroxide), with recycle		
Sodium Hydroxide (or Potassium Hydroxide), no recycle	lb at 100%	22695
Nitric Acid	lb at 100%	2837
Alum	lb at 100%	284

Table 1

Step	Completion Date	Responsibility
Establish availability of straw supply		
Assemble straw opening equipment or use of Tangent facility		
Obtain agreement with Boise for use of trial pulp, quantity, specification, and price.		
Identify other companies interested in trail pulp		
Establish trial date and mill costs with Ponderosa		
Complete trial funding		
Order and schedule delivery of chemicals		
Obtain necessary extra mill equipment		
Complete safety review		
Make necessary Ponderosa mill changes		
Complete trial and in process testing plan		
Run trial		
Complete testing of pulp produced		
Obtain Boise approval to ship trail pulp		
Ship trial pulp to other companies		
Prepare trial run report		
Obtain feed back from		

pulp use runs		
Complete overview report		
Next steps as appropriate		

APPENDIX IV

Figures

Figure 1

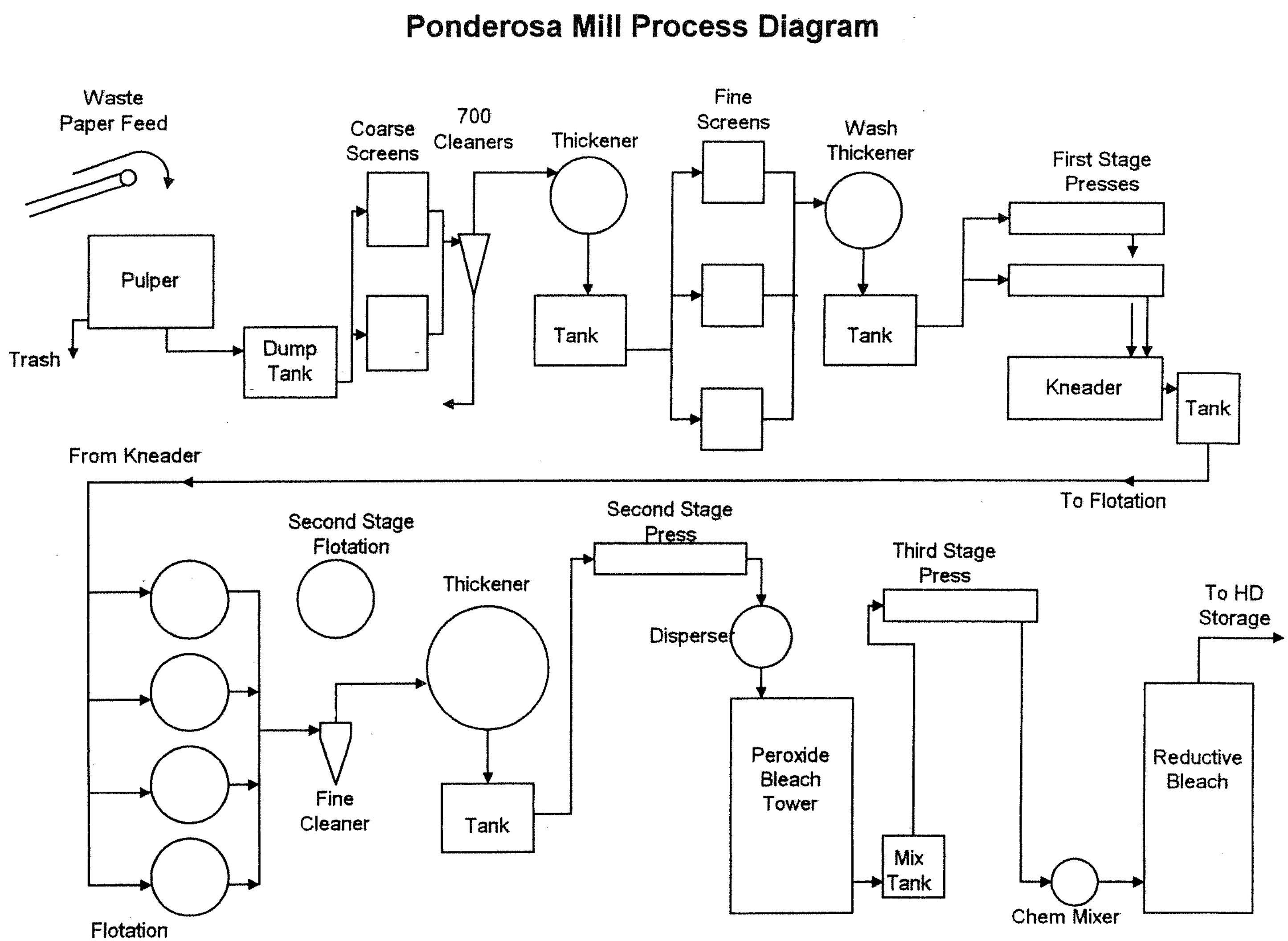

Ponderosa Mill Process Diagram
Waste Paper Feed
Pulper
Trash
Dump Tank
Coarse Screens
700 Cleaners
Thickener
Tank
Fine Screens
Wash Thickener
Tank
First Stage Presses
Kneader
Tank
From Kneader
To Flotation
Flotation
Second Stage Flotation
Fine Cleaner
Thickener
Tank
Second Stage Press
Disperser
Peroxide Bleach Tower
Mix Tank
Third Stage Press
Chem Mixer
Reductive Bleach
To HD Storage

Figure 2

Ponderosa Mill General Layout

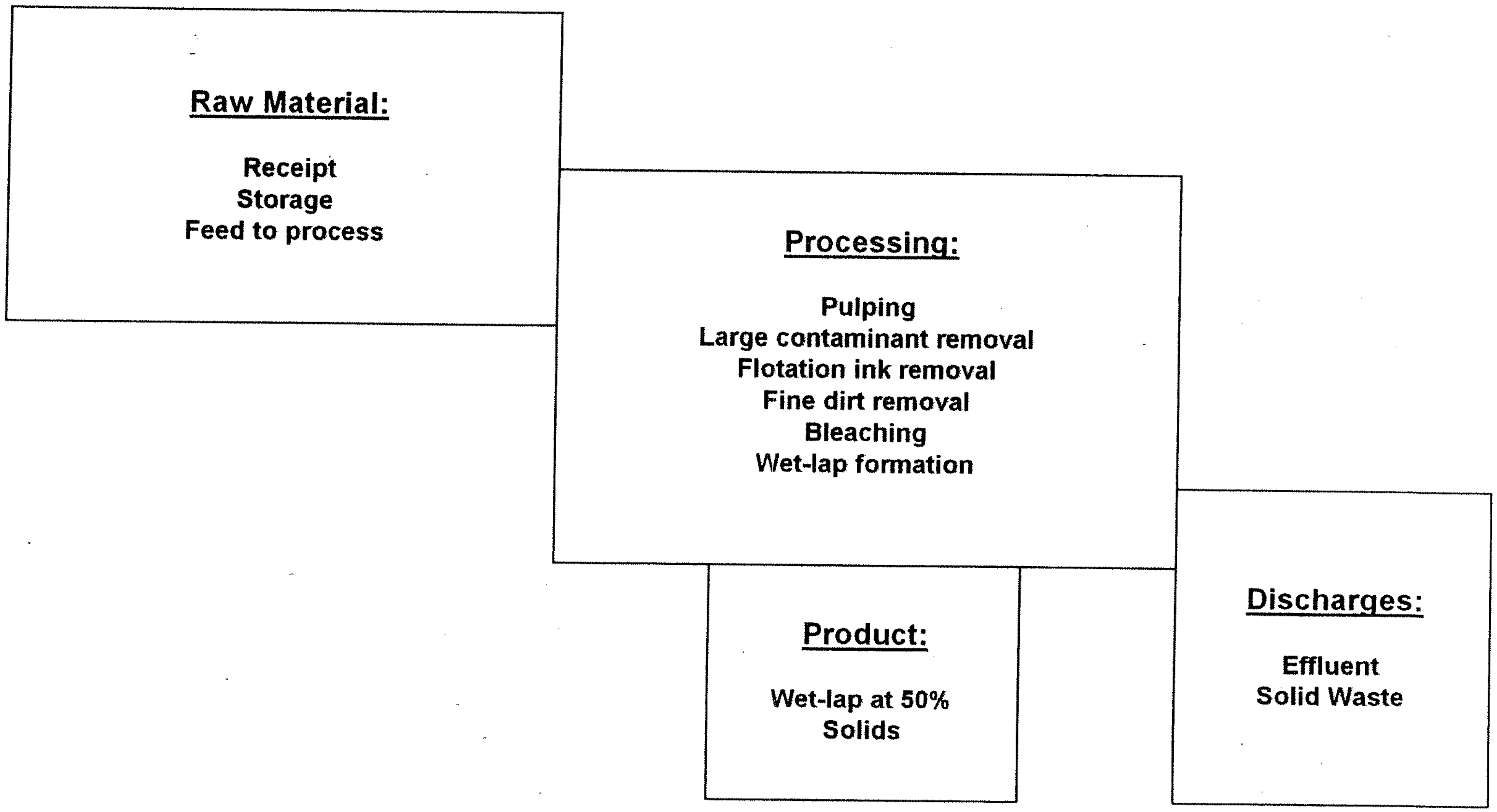


Figure 3

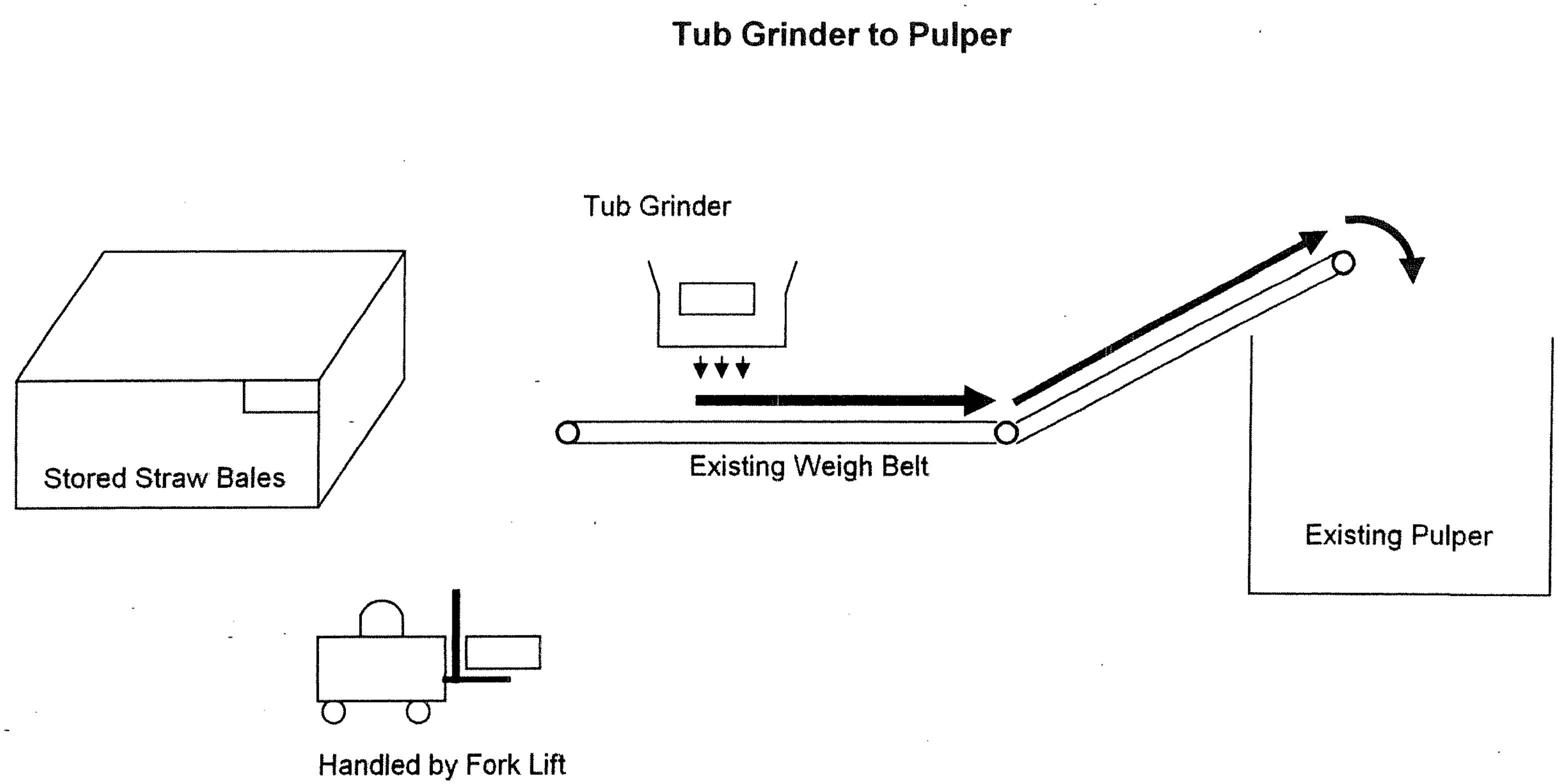

Tub Grinder to Pulper
Tub Grinder
Stored Straw Bales
Existing Weigh Belt
Existing Pulper
Handled by Fork Lift

Figure 4

Preprocessed Straw to Pulper

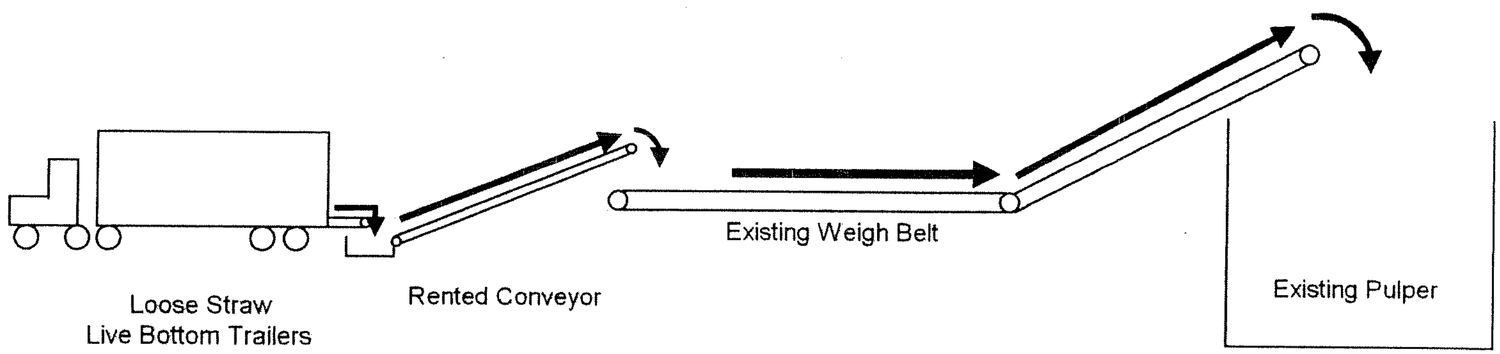


Figure 5

Preprocessed Straw to Peroxide Bleach System

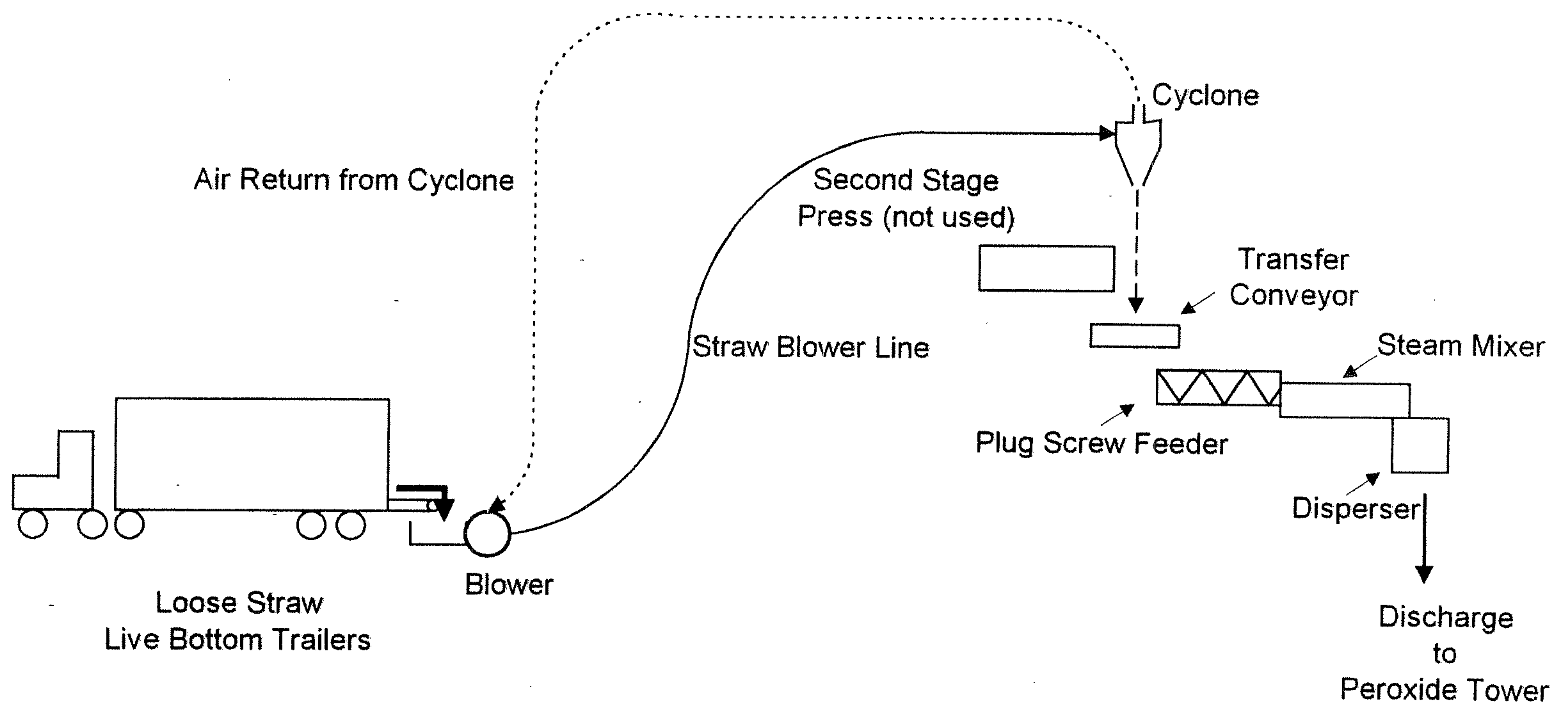


Figure 6

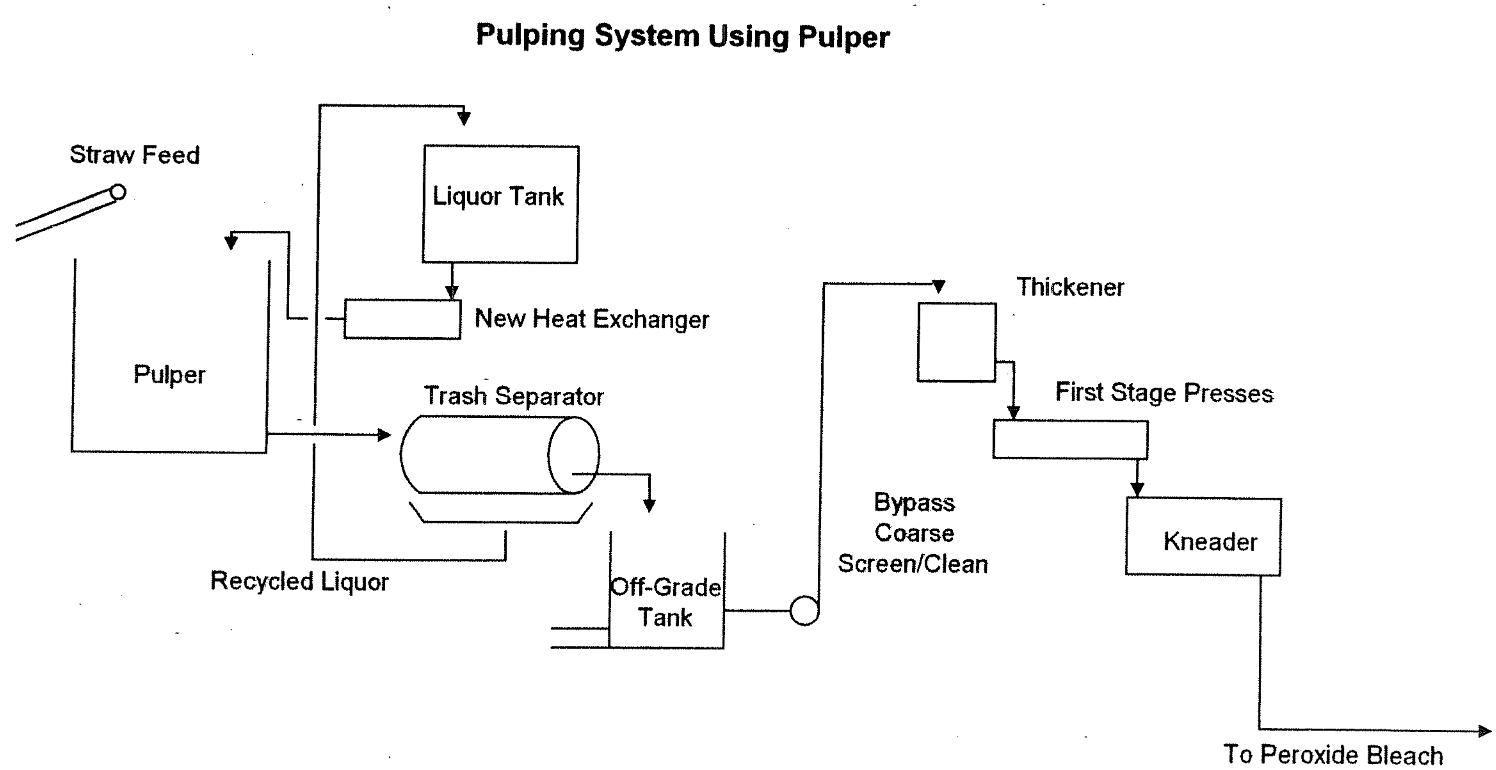

Pulping System Using Pulper
Straw Feed
Liquor Tank
New Heat Exchanger
Pulper
Trash Separator
Recycled Liquor
Off-Grade
Tank
Bypass
Coarse
Screen/Clean
Thickener
First Stage Presses
Kneader
To Peroxide Bleach

Figure 7

Straw Pulping Using The Peroxide Bleach System

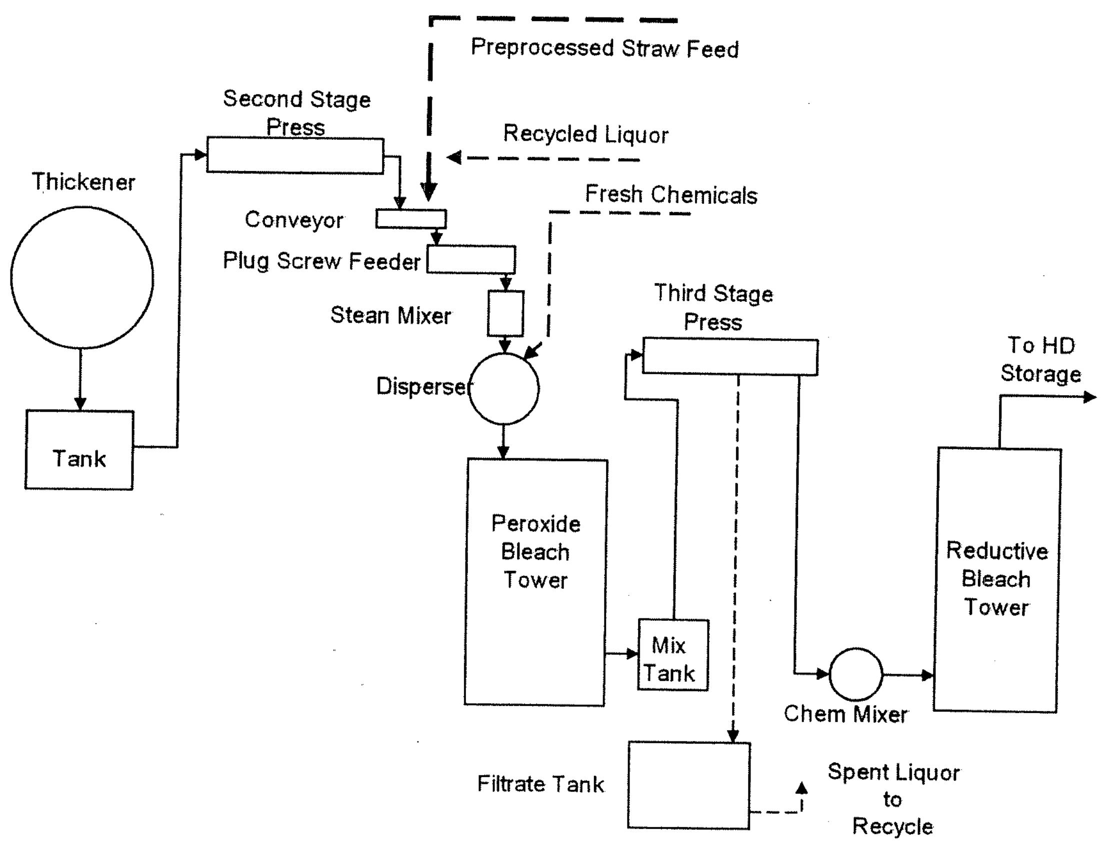


Figure 8

Bleach Sequence for Semi-Bleached Newsprint Grade

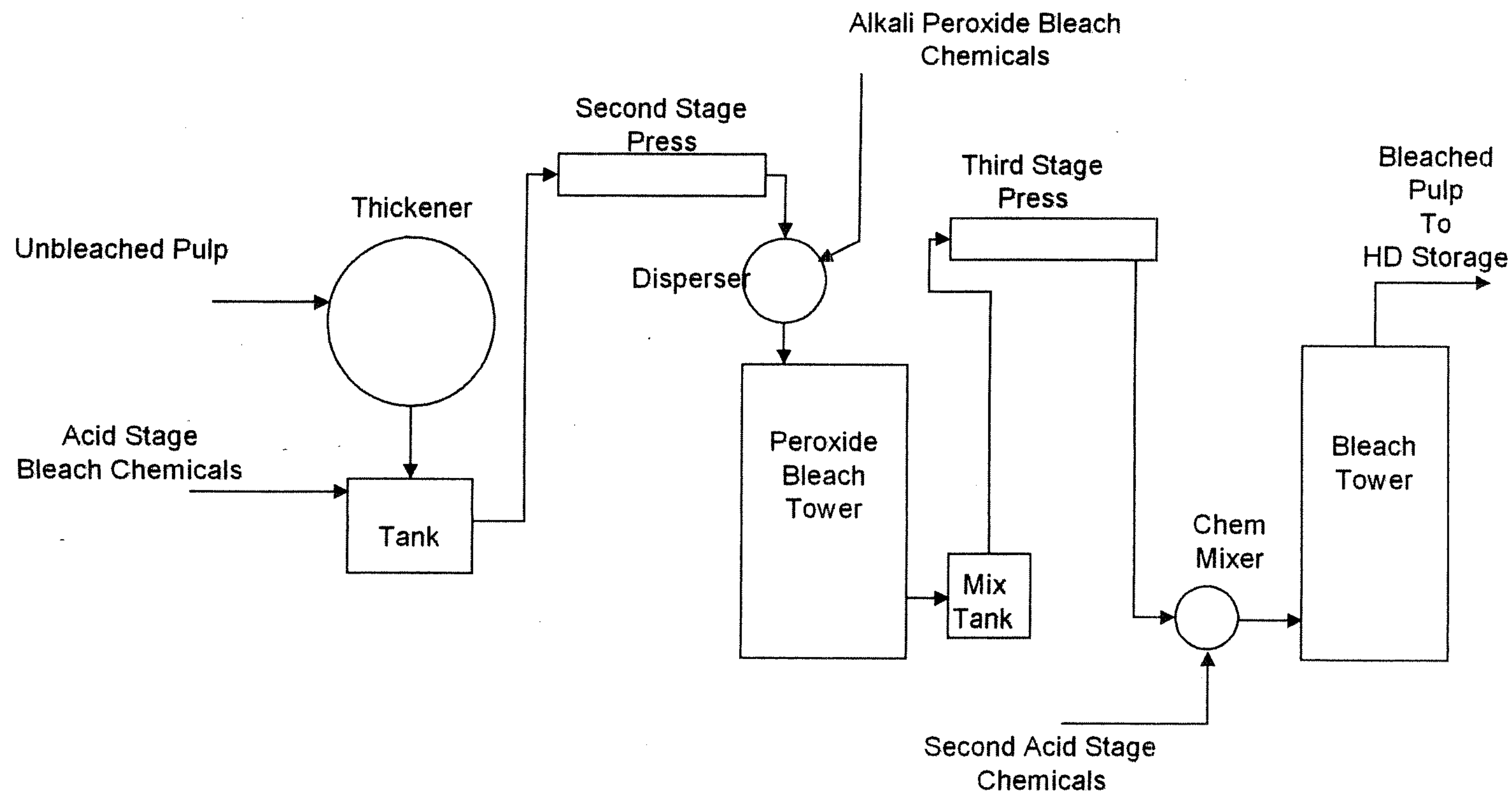
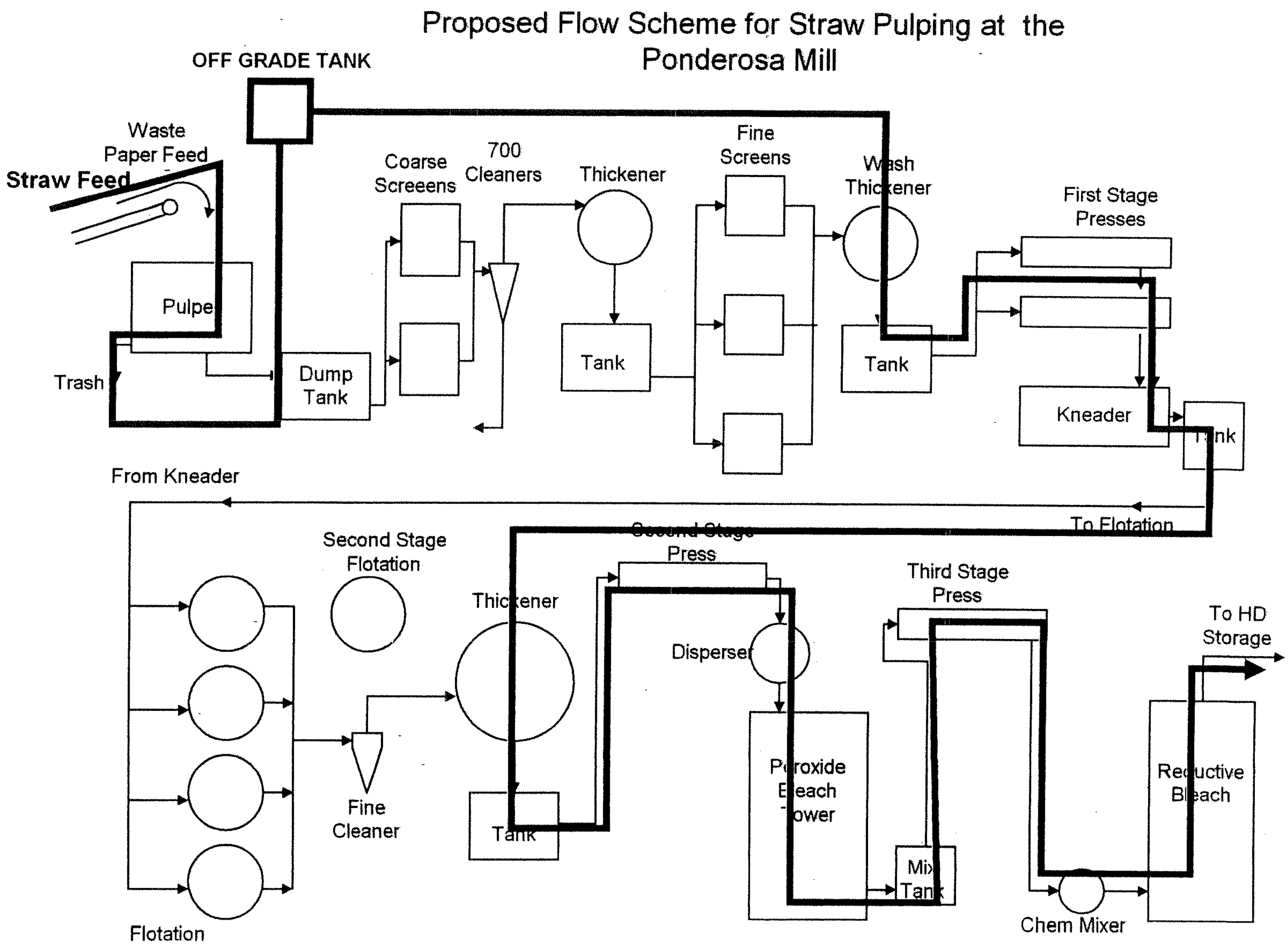


Figure 9


Proposed Flow Scheme for Straw Pulping at the Ponderosa Mill
OFF GRADE TANK
Waste Paper Feed
Straw Feed
Pulpe
Trash
Dump Tank
Coarse Screeens
700 Cleaners
Thickener
Tank
Fine Screens
Thickener
Tank
First Stage Presses
Kneader
From Kneader
To Flotation
Second Stage Flotation
Press
Third Stage Press
To HD Storage
Thickener
Tank
Disperse
Fine Cleaner
Flotation
Chem Mixer

APPENDIX V

Cost Estimates for Equipment Modifications and Additions

Table 1

Straw Bales to Pulper

Item	By	Size	Existing	Source	Cost
Fork Lift			yes	Mill	$0
Tub Grinder		10 t/hr		rental	$3,500
Support for Tub Grinder				construct	$3,000
Electrical Supply		10 kW		construct	$1,500
TOTAL					**$8,000**

Table 2

Preprocessed Straw to Pulper

Item	By	Size	Existing	Source	Cost
Conveyor, truck to feed conveyor		30 ft		rental	$3,500
Electrical Supply		5 kW			$1,000
TOTAL					**$4,500**

Table 3

Straw Bales to Peroxide System

Item	By	Size	Existing	Source	Cost
Tub Grinder				rental	$3,500
Blower		10 t straw/hr		rental	$4,500
Air Density Separator				loan	$5,000
Blow Line		6"x50ft			$6,000
Cyclone					$10,000
Electrical Supply		5 kW			$2,500
TOTAL					**$31,500**

Table 4

Preprocessed Straw to Peroxide System

Item	By	Size	Existing	Source	Cost
Blower		10 t straw/hr		rental	$4,500
Blow Line		6"x50ft		construct	$6,000
Cyclone				purchase	$10,000
Electrical Supply		5 kW			$1,000
TOTAL					**$21,500**

Table 5

Pulper Modifications

Item	By	Size	Existing	Source	Cost
Add Liquor Heater				construct	$20,000
Discharge by Junk System				modify	$6,000
Modify Off-Grade Tank to Separate Heavy Material				modify	$10,000
Collect liquor from Trash Screen				modify	$2,000
TOTAL					**$38,000**

Table 6

Peroxide System Modifications

Item	By	Size	Existing	Source	Cost
Spent Liquor Lines				modify	$3,000
TOTAL					**$3,000**

Table 7

Chemicals Supply for Pulping

Item	By	Size	Existing	Source	Cost
Caustic Soda		20,000 lb @100%	yes		$0
Potassium hydroxide		28,000 lb @100%	Storage by chem. supplier		$0
Nitric acid		5,000 lb @100%	Storage by chem. supplier		$0
Alum		500 lb @100%	yes		$0
TOTAL					**$0**

Table 8

Chemicals Supply for Bleaching

Item	By	Size	Existing	Source	Cost
Peroxide		4,000 lb @100%			$0
Caustic soda		4,000 lb @100%			$0
Acid stage bleach agent		3,000 lb @100%		Metering pump	$2,000
TOTAL					**$2,000**

Report to Lewis Consulting on
Black Liquor Soil Amendment Field Experiment
C. Xiao, W. L. Pan, M. Fauci, D. F. Bezdicek
May 30, 2003

A field experiment was conducted to evaluate the effect of wheat straw pulping black liquor in (1) improving soil quality parameters of soil aggregation, microbial biomass and microbial activities and (2) as a potassium source for improving potassium availability in crop production. A complete randomized block experiment was established with 7 soil amendment treatments and four replicates. Sweet corn was tested for black liquor as a K source. The experiment was established in a grower's pivot irrigated field near Quincy WA. There were two potassium sources as KCl and black liquor with two application times (December 19, 2002 and March 14, 2003) at a rate of 150 and 300 K 1bs/acre, respectively. Individual plots were 35' x 15'. The treatments are shown in the Table 1.

Table 1. The field experimental design

Treatment ID	K sources	Application Timing	K rates (1bs/acre)	KCl or BL rates (gallons/acre)
1	Control		0	0
2	KCl	December	150	285
3	KCl	December	300	570
4	Black liquor	December	150	1200
5	Black liquor	December	300	2400
6	Black liquor	March	150	1200
7	Black liquor	March	300	2400

The amounts of black liquor for corresponding treatments were calculated based on the K contents of the two black liquors generated by M. Lewis at UW. Their characteristics are shown in Table 2. K concentrations of two black liquor for December 19,2002, and March 14, 2003 application was different, therefore, the black liquor application rates for corresponding treatments differed between the December and March applications (Table 2).. The black liquor was homogenously sprayed into soil surface with a pump-driven liquid spray applicator. Soil samples were taken from each replicate for the determination of organic C, total N, NO_3-N and NH_4-N, available K, CEC etc before black liquors were sprayed into the surface of plots. Plots were not cultivated after application of black liquor until sweet corn was planted.

Table 2. Selected characteristics of black liquors used for the field trial

Black liquor application timing	pH	EC (ds/m)	Solid content (g/100 ml)	K (g/L)	NO3-N (ppm)	NH4-N (ppm)	Polysaccharides (g/100 ml)	Lignin (g/100 ml)	Total C (% on wet)	Total N (% on wet)
December 2002	8.81	27.1	6.84	15	1.68	5.53	0.82	1.52	2.62	0.0814
March 2003	6.87	20.55	4.65	11	0	7.3	0.83	0.47	2.12	0.0614

* The other element will be determined by ICP (digestate was stored under refrigeration)

(3) Analysis of soil and plant samples

Soil samples were taken from plots at two depths (0 – 2 inches, and 2 inches to 1 foot) on March 14, and April 14, 2003 separately. The samples at a depth of 0-2 inches were run for the determination of soil microbial biomass C by the method of fumigation incubation (Vance et al., 1987), microbial activities (dehydrogenase, ß-glucosidase and arylsufatase) by the method of Tabatabai (1994), soil aggregate stability by the method of Elliott (1986), NaHCO3 extractable K by the method of Schoenan and Karamanos (2000), soil pH and electrical conductivity by the method of Jansen (1993). The samples at depth 2 inches to 1 foot were analyzed for NaHCO3 extractable K.

Soil samples were gently passed through a 2 mm sieve in air dried state and stored at room temperature. Three 50-g subsamples were submersed in water on a 250 μm sieve for 5 minutes before sieving started. Soils were sieved under water by gently moved the sieve 3 cm vertically 50 times over a period of 2 minutes through *water contained in a shallow pan. Soils remaining on the 250 µm were transferred to a forced air oven at 105 °C for 10 minutes. The macroaggregate stability was calculated based on the equation:

Wet macroaggregate stability (%) =100 x soils remaining on the 250 µm (g)/50 g subsamples .

Results

Soil samples are currently being processed and and the data will be statistically analyzed. Preliminary results suggest that black liquor applications increased microbial activity and soil aggregate stability.