PROCEEDINGS OF THE WORKSHOP ON ASPEN PULP, PAPER AND CHEMICALS

20

Editors:
Al Wong and Ted Szabo[1]

1987

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[1] Edmonton, Alberta

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DISCLAIMER

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WELCOME AND INTRODUCTION

Welcome to Edmonton and the workshop of aspen pulp, paper and chemicals. Over the next two days you will see and hear a number of internationally recognized people on these important subject areas.

This workshop is sponsored by the newly-created Forest Industry Development Division of the Alberta Department of Forestry, Lands and Wildlife, and the Northern Forestry Research Centre of the Canadian Forestry Service in Edmonton. The sponsoring of seminars such as this is an important function, to provide an interface amongst the researcher, the investor, the manager, and the government in order to achieve greater utilization and development of Alberta's forest.

The funding for the Workshop is provided by the $23 million Canada-Alberta Forest Resource Development Agreement. This Agreement is a very comprehensive one. It includes major programs in reforestation, public communication and forestry awareness, but most importantly; a very major component dealing with forest products development.

The aspen resource in Alberta comprises about 40% of the total wood volume. It is essentially aspen rather than a wide range of different hardwood species.

Until a few years ago, only 2% of this total resource was utilized. Today, it is about 10%, ie., 10% of the total allowable annual cut. Thus, there has been a 4- to 5-fold increase in just a few short years. The potential for additional large-scale utilization is very apparent. The realization of the full potential of this under-utilized resource would make a major contribution to the diversification of the forest products industry, and hence to the rejuvenation and diversification of the Provincial economy as well.

The opportunities and constraints associated with greater utilization of the resource are addressed under the $10 million Sub-program of the aforementioned Federal-Provincial Agreement.

The aim of the Sub-program is to provide improved methods and new technologies in aspen management, utilization, product development and processing, and marketing. Achievements to date include:

* Development of the forest products research and panel board testing laboratory at the Alberta Research Council.

* Assessment of the feasibility of producing chemical feedstock for further processing to value-added products.

* Development of laminated beams by using Alberta spruce/fir as opposed to imported Douglas fir.

* Several state-of-the-art literature reviews.

* Special seminars to identify hardwood utilization opportunities.

On-going and future priorities to be addressed under this Sub-program include studies on the assessment of aspen decay at tree and stand levels, and marketing and promotion related to industry investment and diversification. In general, the Sub-program is dedicated to stimulate research and technological innovation.

Alberta firmly believes that the timing is right to provide the opportunity for development with aspen/poplar. This can be substantiated by the successfull projects on the three oriented strandboard plants and a chemi-thermo mechanical pulp mill.

Great opportunities also exist in softwood utilization for pulp, lumber, fibreboard paper and secondary manufacturing.

At present there's a very significant demand wtih respect to pulps and papers, with price increases occurring in the past year or so and projected to increase again for the next year at least.

Alberta's greatest challenge of all is trying to develop greater utilization of aspen/poplar resource which now represents about 13 million cubic meters allowable cut, of which only about, oh, 15 to 20 percent at the maximum is being allocated.

The purpose of the present Workshop is to focus attention on processes related to aspen pulp, paper and chemicals, and to identify needs and opportunities for future research, development and investment in support of primary and value-added products from the Alberta aspen/poplar resource particularly.

J.A. Brennan
Executive Officer
Forest Industry Development Division
Alberta Department of
Forestry, Lands and Wildlife

A.D. Kiil
Director
Northern Forestry Research Centre
Canadian Forestry Service

PROGRAM AGENDA

WORKSHOP

ON

ASPEN PULP, PAPER AND CHEMICALS

March 25, 1987

9:00	Registration
10:00	Welcome and Introduction by the Moderator - A.D. Kiil - Canadian Forestry Service Edmonton, Alberta
10:15	Alberta's Aspen/Poplar Resource - D. Morgan - Alberta Forest Service Department of Forestry, Lands and Wildlife Edmonton, Alberta
11:00	Hardwood Pulp Production: Threats and Opportunities - D. Breck - Woodbridge, Reed & Associates Vancouver, B.C.
12:00	LUNCH
13:15	Chemical Pulping of Aspen: Possibilities and Realities - M. Macleod - Pulp and Paper Research Institute of Canada Point Claire, P.Q.
13:45	Overview of Highyield Pulping of Aspen - M. Lapointe - University Du Quebec a Trois Rivierers, Trois Rivieres, P.Q.
14:15	Innovations for Hardwood Utilization: Catalized Organosolv of Pulping and Saccharification - P. Cho - University of British Columbia Vancouver, B.C.
15:00	COFFEE

15:30	Pitch Control During the Production of Aspen Kraft Pulp - L. Allen - Pulp and Paper Research Institute of Canada Pointe Claire, P.Q.
16:00	Tour of Alberta Research Council - Forest Products Laboratory - Biotechnology Laboratory

<u>March 26, 1987</u>

9:00	Welcome and Introduction by the Moderator - J.A. Brennan - Forest Industry Development Division Edmonton, Alberta
9:15	Aspen Chemi-thermo Mechanical Pulp Production - M. Jackson - Sunds Defibrator Vancouver, B.C.
9:45	COFFEE
10:15	Aspen Pressurized Goundwood Pulp - G. Mitchell - Tampella Inc. Atlanta, GA. U.S.A.
10:45	Mill Experiences in the use of Aspen Mechanical Pulps - R. Leask - Consultant St. Catherines, Ontario
11:15	Explosion Pulping of Aspen - B.V. Kokta - Universite due Quebec a Trois Rivieres Trois Rivieres, P.Q.
11:45	LUNCH
13:15	Neutral Sulphite - Anthraquinone Pulping of Aspen - A. Wong - Arbokem, Inc. Montreal, P.Q.
13:45	Ester Pulping of Aspen - D. Smith - Biodyne Chemicals Inc. Neenah, WI., U.S.A.

14:15	Solvent Pulping of Aspen - K. Sarkanen - University of Washington Seattle, WA., U.S.A.
14:45	Aspen Based Chemicals - J. Saddler - Forintek Canada Corp. Ottawa, Ontario
15:15	COFFEE
15:30	Closing Remarks by the Program Planning/ Organization Committee

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Some of the Participants at
The Aspen Pulp, Paper and Chemicals Workshop

ALBERTA'S ASPEN/POPLAR RESOURCE

David Morgan
Head, Forest Measurement Section
Timber Management Branch
Alberta Forest Service
Edmonton, Alberta, CANADA

The fact that this Workshop is being held today, and that so many of you have attended, is a reflection of the growing interest in Alberta's aspen and poplar resources. An Aspen Quality Workshop was held at this same location scarcely one month ago. Clearly our neglected hardwood resources are coming of age.

I am going to divide my address into four parts:

First: a short description of the current level of aspen and poplar utilization;

Second: a brief description of the resource;

Third: a listing of Alberta Government activities done to support use of the resource; and

Fourth: some problems with resource utilization from a forest manager's perspective.

The attendance at this Workshop is a reflection of the increasing level of commercial utilization of the Populus species in Alberta. As recently as the early 1970s they were viewed by Alberta forest managers as a "weed" species, useful only for log fills and similar purposes on which useful material shouldn't be wasted. In short, deciduous species were seen as an obstacle to forest management, since only coniferous species were viewed as potentially useful. A certain percentage of the forestry community still, I am sure, views our hardwoods in that way today.

Alberta's aspen resource in the near future will support in whole or in part five major manufacturing facilities. These are owned by Pelican Spruce Mills, Ltd., Weldwood of Canada Ltd., Proctor and Gamble Cellulose Ltd., and Millar Western Pulp Ltd.

Pelican Spruce Mills Ltd. established Canada's first oriented strand board or OSB plant in Edson west of Edmonton. Production began in 1983. That mill's planned capacity is 250 million $ft.^2$ of panel products (3/8" basis).

Pelican Spruce Mills Ltd. recently opened a second OSB plant southwest of Edmonton at Drayton Valley. That mill also has a planned yearly capacity of 250 million $ft.^2$ of panel products (3/8" basis) based on an expected input of 350,000 m^3/year of aspen roundwood. Associated with the OSB plant is a dimension lumber sawmill which will begin production later this year. It will produce 20 million fbm of coniferous lumber annually. When this complex is in full operation, Pelican Spruce Mills Ltd. will be the first company in Alberta to utilize the total merchantable coniferous and hardwood resources from a given portion of the Province.

Weldwood of Canada Ltd. recently converted their waferborad mill at Slave Lake (north of Edmonton) to produce 170 million $ft.^2$ (3/8" equivalent) of OSB from a projected input of 300,000 m^3/year of aspen roundwood.

The Proctor and Gamble Cellulose Ltd. kraft pulp mill, located at Grande Prairie, northwest of Edmonton, is being upgraded to produce deciduous kraft pulp as well as the coniferous pulp already being produced at the mill.

Millar Western Industries located at Whitecourt, west of Edmonton, recently announced their intention to build a CTMP mill by the fall of 1988, capable of producing 177,500 air dry metric tonnes annually of bleached chemithermo-mechanical pulp (CTMP). Fifty percent of the input will come from chipping 250,000 m^3/year of aspen roundwood. The rest will come from softwood chips produced by lumber mills including that belonging to the Company.

Smaller hardwood mills also utilize significant wood volumes. During the 1985/86 fiscal year, they produced approximately 16 million fbm of aspen and poplar dimension lumber. More than half of that lumber is remanufactured into other products.

Not to be neglected in any summary of poplar and aspen use in the Province are the secondary industries' use of that hardwood lumber. A diversity of products are being made including furniture, doors and windows, pallets, trailer decking, feature walls, dunnage, tongue and groove paneling and flooring.

As Mr. Kiil mentioned, I work for the Timber Management Branch. If the number of requests for information on the aspen resource our Branch receives yearly is any indication, I expect that more production facilities utilizing Alberta hardwoods will be announced shortly.

The second topic of my address is the current state of the resource. Approximately 60% of Alberta is forested, making this the fourth ranking Canadian province in terms of forest land. This resource is currently underutilized, representing one of the few areas left in North America with the potential for major expansion of its forest industry for both coniferous and deciduous species. Even when all of the mills I mentioned reach full production, likely no more than 10% of the province's estimated 11.6 million m^3 annual allowable cut (AAC) of deciduous timber will be utilized. This chart graphically illustrates the situation.

Alberta's Hardwood Resource on Crown Lands

Current level of harvest	0.7 million m^3 (6%)
Commitments not being harvested	2.9 million m^3 (25%)
Uncommitted hardwood AAC	8.0 million m^3 (69%)
Total estimated deciduous AAC	11.6 million m^3 (100%)

Of course, some of this resource is not economically useable at this time due to accessibility, size or condition. Nevertheless, a considerable volume of harvestable aspen currently remains uncommitted. For this reason, the Alberta Forest Service strongly supports the convening of this workshop.

At this point, I would like to describe, for the benefit of those from outside of our Province, the timber disposition system used in Alberta.

Three major inventories of our timber resources have been completed, the last in 1984. That inventory information was used to calculate annual allowable cuts (AACs), the level of harvest by forest management unit that could be sustained on a perpetual basis from the Crown land base while maintaining a quality forest environment.

Commercial harvesting rights to a portion of that AAC may be obtained under one of three types of allocations:

1. Forest Management Agreement

A forest management agreement (FMA) is a long-term (twenty year, renewable) agreement the terms of which are fully negotiated and approved by the Alberta Cabinet as an Order-in-Council. A forest management agreement grants to a company the right to manage, on a sustained yield basis, the timber within the agreement area. This includes the rights and obligations of the company to establish, grow and harvest the timber according to a management plan approved by the Minister. The company carries out, at its own cost, all the inventory studies, planning, logging, road development and regeneration of the area. The Forest Service retains the authority to approve all plans and surveys carried out by the company in order to fulfill agreement requirements.

The company is required to deposit, with the Minister, a predetermined sum and to pay annually a holding and protection charge for each square kilometer within the FMA. Crown dues are paid on the amount of timber harvested.

2. <u>Timber Quota Certificate</u>

The quota system provides timber operators without an FMA with a secure, long-term wood supply. This security enables industry to make capital investments in facilities such as roads and manufacturing plants.

In return for a secure wood supply, the quota holder accepts responsibility for reforestation of lands he harvests timber from. A quota holder with a total authorized annual volume of 34,000 m^3 or greater is obligated to do the reforestation himself. One with an authorized volume less than 34,000 m^3 has the option of doing reforestation himself or of paying the Forest Service to do it.

Quotas are sold by public tender or by auction. A quota certificate is a long-term (up to twenty years) right to harvest a share of the AAC for a forest management unit.

The Forest Service is responsible for developing five- to ten-year forest management plans and for laying out the cutting sequence for the operator in accordance with those plans. The quota holder must prepare, for Forest Service approval, an annual operating plan. Timber licences are issued to the quota holder to authorize harvest and to specify where the timber is to be cut, as described in his approved annual operating plan.

A quota holder is required to pay holding and protection charges based on his authorized annual allowable cut.

3. <u>Commercial Timber Permit</u>

A commercial timber permit (CTP) is a short-term (one- to five-year) disposition which authorizes the harvest of coniferous or deciduous timber. These permits are sold at public auction. The successful bidder must deposit a performance guarantee and pay annual holding and protection charges. A reforestation levy must also be paid.

Harvesting can only commence following Forest Service approval of the permittee's annual operating plan.

The Alberta approach to forest management has been very effective. Our reforestation record is one of the best in Canada. Not that aspen regeneration is normally a problem.

The third section of my address concerns government support for hardwood utilization. A number of government initiatives have been taken in this area. These include publicizing the resource and supporting research into its use.

The availability of the resource has been publicized in several ways. A new division within Alberta Forestry, Lands and Wildlife, called the Forest Industry Development Division, has been formed. It is headed by Mr. J.A. Brennan, the moderator for tomorrow's session. A prime objective of the new Division is the promotion and enhancement of the development of Alberta's forest resources including hardwoods. Staff of this group maintain a direct, on-going contact with major North American forest industry company executives. Mr. Brennan will probably provide you with more information on the Division he heads tomorrow.

A series of informational pamphlets were published and distributed. Individual pamphlets described important features in one of four timber development areas, each seen as logical supply areas for a major wood processing firm. Two of the reports concerned hardwood areas. These pamphlets are currently being revised.

Advertisements have also been placed in forest industry trade publications.

A second initiative involved the addition of a major panel testing laboratory to the modern forest research facilities already resident at the Alberta Research Council (i.e., in this building). A tour of this facility is included in today's agenda.

This research initiative has also included a number of short-term product research projects funded under the Canada Alberta Forest Resources Development Agreement. This Agreement was signed in October, 1984, between the governments of Canada and Alberta. During the five years it will run, the Agreement will fund $23 million worth of programs in the areas of reforestation, applied research, technology transfer, opportunity identification and public information related to forest lands. Support for better hardwood utilization was identified as a major feature of the Agreement. This Workshop is one of the projects funded by the Agreement.

This level of support would not be provided if there were no problems with the utilization and assessment of the aspen and poplar resource. Many of these problems relate to the fact that we're just beginning the first harvest of this resource. We have to accept the condition of the resource this first round as nature provided it. I will mention a few problems which are relevant to the topics future speakers will be addressing.

1. Traditional forest inventory methods which rely on stratification of the resource on aerial photographs followed by field sampling in selected strata, do not work well with hardwoods. Our three Alberta hardwoods, aspen, poplar and birch, look much the same on a photograph. This was not a problem in past Alberta inventories where the concern was the separation of hardwood from coniferous species. Research is proceeding in this area.

   In the northern part of the province, aspen and poplar tend to occur on different sites, and can often be separated on that basis. Unfortunately, in the central portion of Alberta where ease of access encourages hardwood utilization, aspen and poplar tend to grow in mixed wood stands which we have difficulty describing accurately from photointerpretation alone. Because poplar (Populus balsamifera L.) is not currently in commercial demand, expensive field checking is required to determine the species mix in each stand and hence its potential harvestability. Stands which have a high poplar content are currently uneconomical to harvest. Alberta Forest Service policy also forbids logging of such stands due to the waste of poplar that would necessarily occur.

2. Assessing hardwood quality is another inventory problem. Most work to date has been done on aspen. While general trends have been noted, the large variability within and between stands due to as yet unpredictable causes has made the

assessment of current decay levels and the prediction of future decay levels difficult. The Aspen Quality Workshop held here last month demonstrated that no easy answers to these problems are known at this time.

We are also not certain what defect information is required by the hardwood industry. Defects like stain and incipient rot are almost ignored by one type of processing plant, while the success or failure of another hinges on keeping those components below critical levels. You could help us to improve the inventory information we provide to industry if you could define for each aspen manufacturing process the type and level of resource information required.

Allied to this quality problem is that of aspen age determination. In aspen, spring and summer wood are not obviously different as with coniferous species. False growth rings are common. In older trees, bole centres, especially at ground and stump level, are often rotten. The need for accuracy in aspen age determination was also not stressed during past inventories. This has led to an obvious weakness in our inventory which affects planning and harvest scheduling. The saving point, perhaps, is that we have tended to over-estimate ages of deciduous trees in past inventories, especially of older trees. Since the amount of decay is somewhat correlated to age, tree and stand conditions may be better than one would infer simply from inventory records.

3. Many Populus stands contain a softwood understory, usually white spruce. The coniferous and deciduous components of such stands mature at quite different times, the conifers taking almost half again as long as the hardwoods. A choice must therefore be made to harvest the hardwoods, destroying most of the potential conifer resource in the process, or to await maturity of the conifers. By that time, the hardwoods may be too decadent to use. New harvesting methods that allow the hardwood to be removed without undue damage to the softwoods, or new wood processing techniques that enable the older hardwoods to be utilized, are required. Perhaps this Workshop will lead to development of the latter.

4. A related problem is the presence of hardwood stands beyond the age of maturity. The level of decay in many of these stands makes their harvest and utilization uneconomic. Again you may be able to help solve this problem.

5. Some stands do contain both hardwood and softwood trees large enough that both can be harvested economically. Usually these stands are harvested in two passes because harvesting firms usually specialize in taking only one of the two types of trees. Integrated harvesting methods could solve this problem. An example of this is the new Pelican Spruce Mills Ltd. complex at Drayton Valley, where both hardwood and softwood species will be utilized.

When I read the list of other topics and speakers scheduled to be heard at this Workshop, I was impressed by both the level of expertise represented and the breadth of topics to be addressed. Here in Alberta, we are still in the pioneer stage of aspen development. I am sure that the Proceedings from this Workshop will help us to begin to solve one or more of the problems I have just outlined. I can promise, on behalf of the Alberta Forest Service, that what you say will be carefully reviewed and applied where appropriate. I am sure, too, that industry representatives who are here today will benefit from the information exchange to come, both formal and informal. I hope that the other speakers will also benefit from such exchanges.

ASPEN UTILIZATION IN CANADA
- THREATS AND OPPORTUNITIES

Daniel H. Breck
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The development of aspen utilization in Canada lies in recognizing the potentials offered by the international market place and taking advantage of our natural assets to capitalize on them. A key market area for development is in pulp and paper.

Demand for paper and paperboard is projected to increase from 200 million tonnes in 1987 to from 250 to 300 million tonnes by the year 2000. A realistic demand is about 270 million tonnes. This incremental growth of 70 million tonnes will consist of 28 million tonnes of virgin fibre, 7 million tonnes of filler and 35 million tonnes of secondary fibre. Based on trends in fibre usage and new technologies of pulping and papermaking, an increasing percentage of the incremental pulp will be from hardwoods and high yield pulps.

The world's forests must supply an additional 310 million m^3 of wood to meet this demand. Based upon FAO inventory studies, about 70 per cent of this must be supplied from existing plantations while the remainder will come from indigenous forests, primarily in the Southern U.S. and in the Soviet Union. All of the wood required to meet this demand is already in the ground and, assuming proper maintenance, the existing plantations should be able to meet the 28 million tonne figure.

Wood costs are expected to increase in real terms as more readily accessible reserves are used and hauling and felling costs increase. This will result in a real increase of paper and paperboard and increased substitution by cheaper products or other fibre. The amount of increase will depend on the growth of high yield pulps and more efficient use of fibre.

Assuming a demand for 28 million tonnes, 40 per cent being high yield and 60 per cent low yield and economy of scale mills and paper machines, the industry must build an equivalent of 56 high yield mills, 34 low yield mills and 187 paper machines by 2000. The associated capital cost will be in the order of $59 billion in 1986 U.S. dollars.

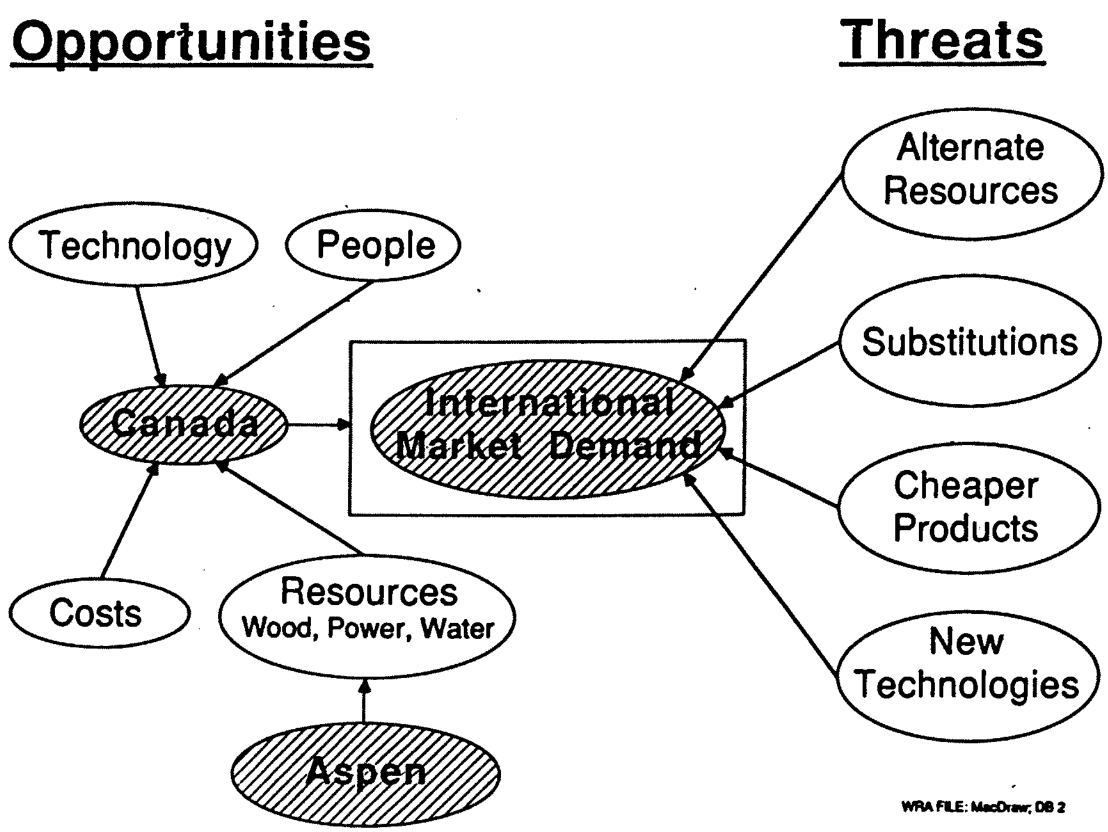
In addition, a normal expenditure of about 3 per cent of capital assets will be required to maintain existing production.

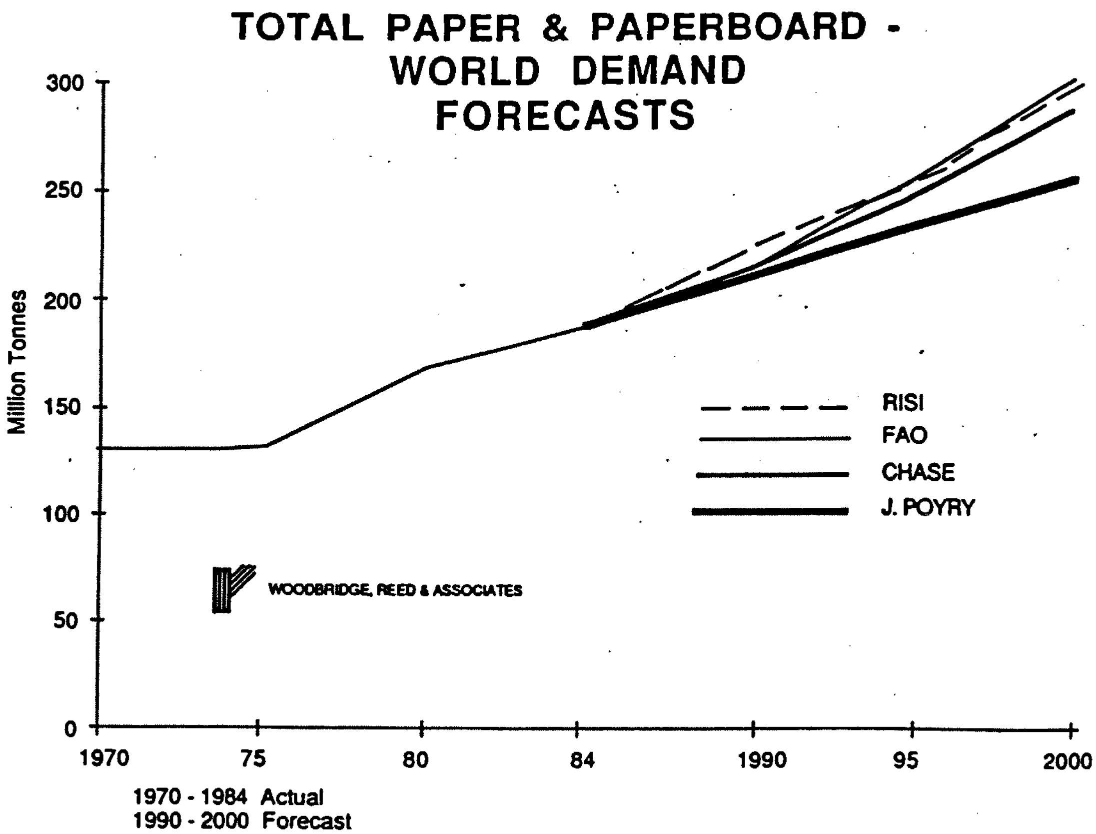
The ability of the industry to meet these challenges will depend upon the cost of capital and associated return on investment, the cost of fibre and its quality.

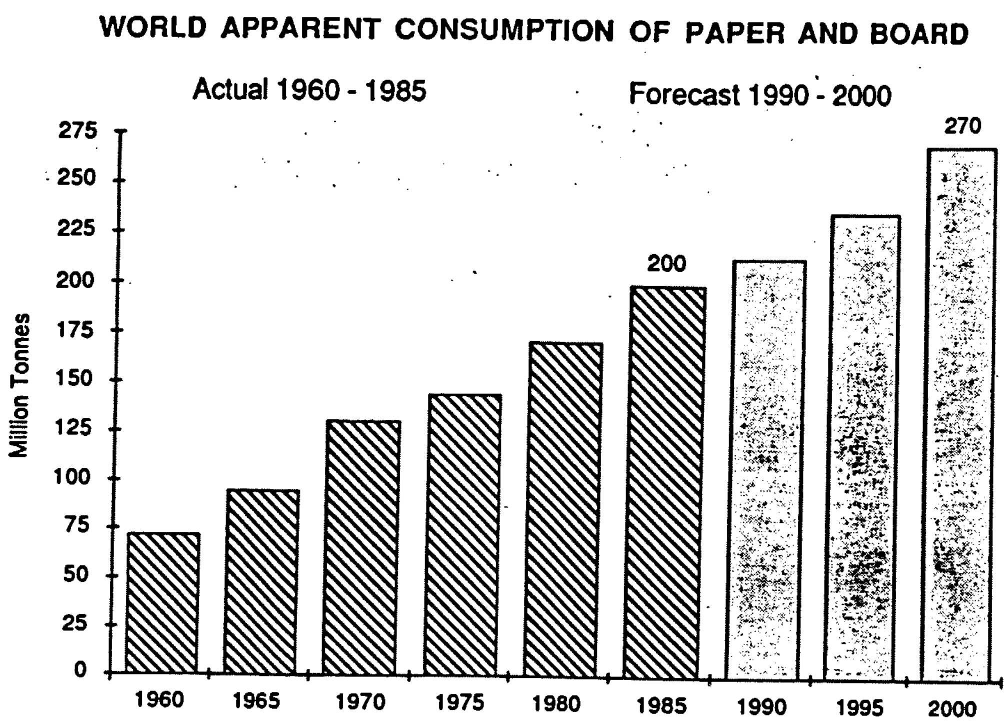
Canada is ideally situated to take advantage of these opportunities. Its abundant aspen, power and water resources can be used for both chemical and mechanical pulp. For chemical pulp, aspen has established a good reputation in certain products. On a global sense, aspen quality falls below that of plantation eucalyptus and birch/maple, but well above the mixed hardwoods from the Southern U.S. For mechanical pulp, there is none better.

The demand for fibre will be there. Whether or not Canada is able to capitalize on the potential will depend on:

- Increasing the value of aspen by:
  - technical innovation
  - low wood costs
  - integration with energy, water and manpower resources
  - aspen quality improvement
- Establishing a reputation of high quality and dependability
- Being aggressive in attracting capital and in marketing.



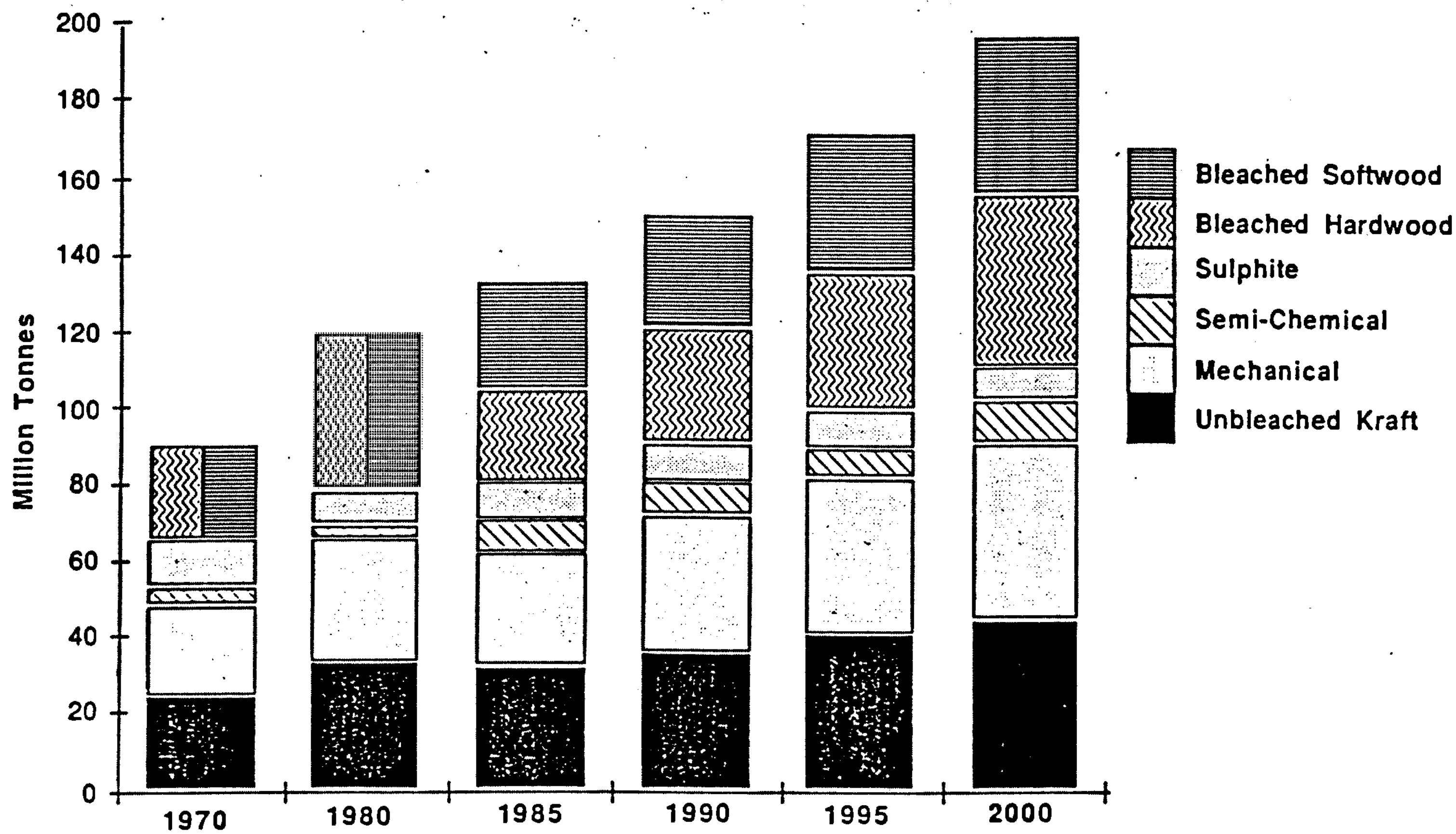




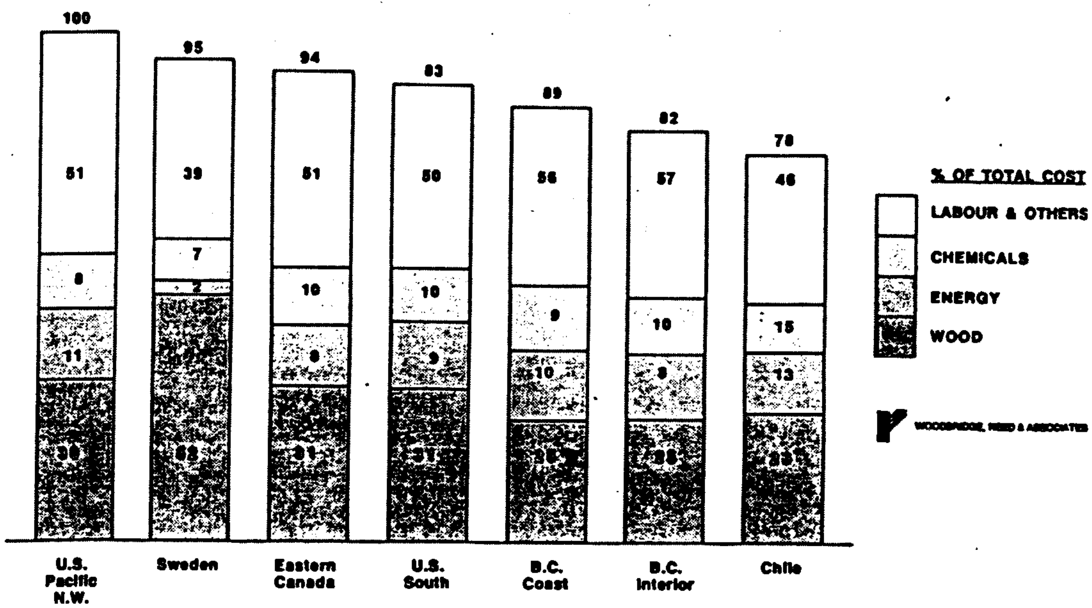
N.B.: The tonnage shown for 1975 is the average of 1974 and 1975

WRA FILE: MacDraw; DB 6

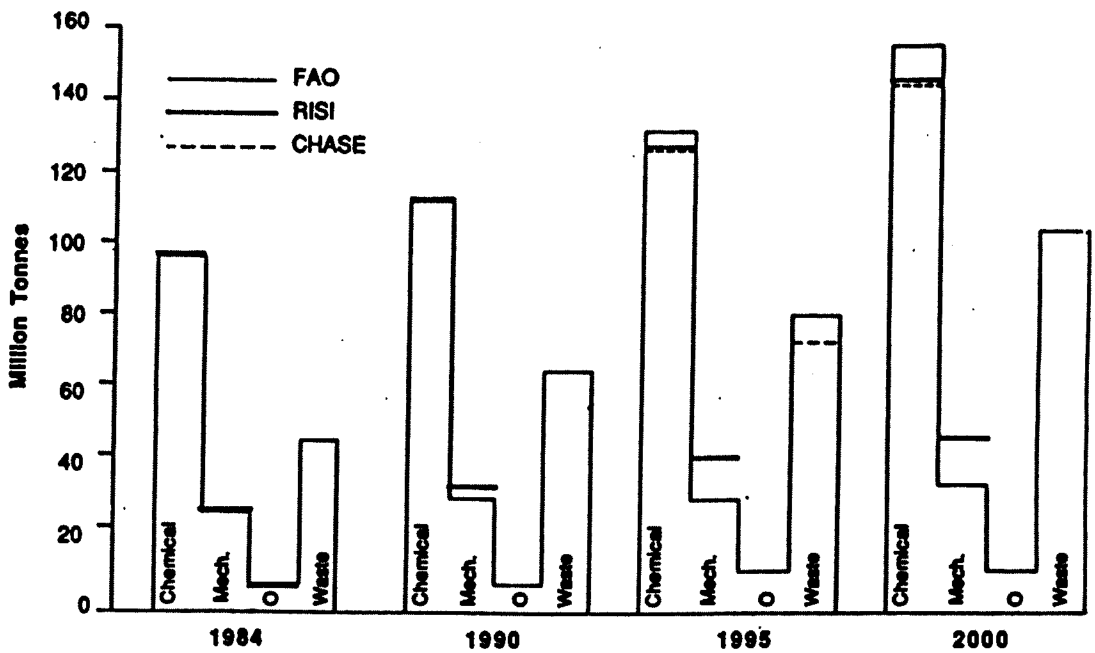
TOTAL PAPER GRADE PULP - CONSUMPTION
1970 - 2000



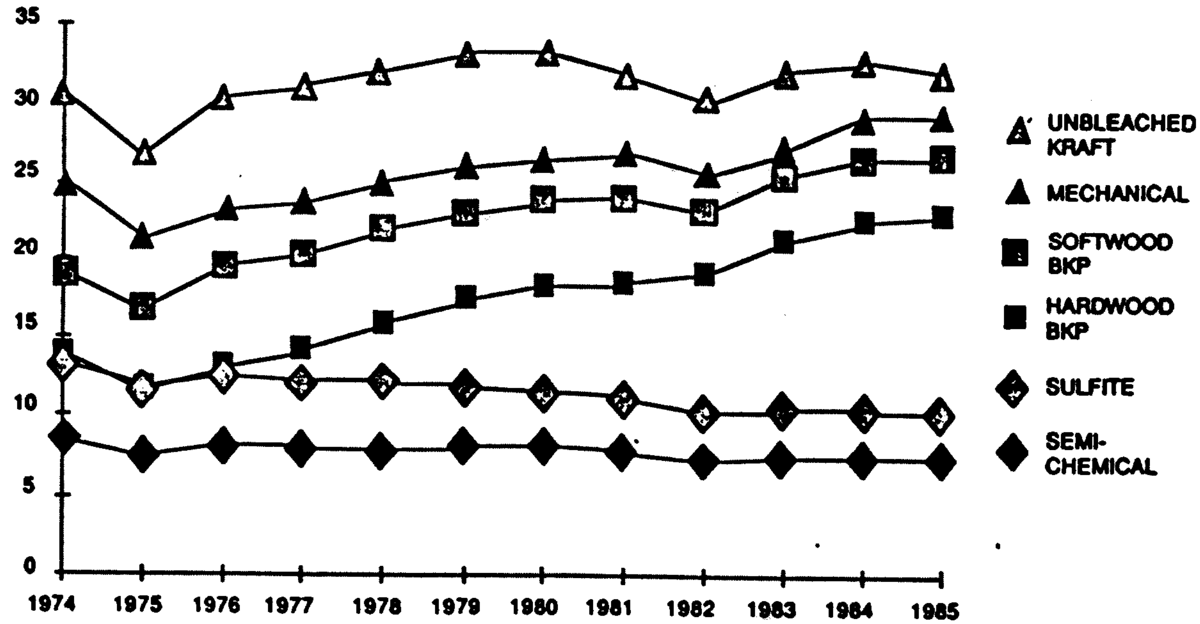
SOFTWOOD BLEACHED KRAFT PULP - COMPARATIVE COST
FOB MILL
1986 ESTIMATE
(EQUIVALENT CURRENCY - CDN FUNDS)



WORLD FURNISH CONSUMPTION
BY PRODUCT
1984 - 2000



WORLD WOODPULP APPARENT CONSUMPTION 1970-1985 (million tonnes)



Source: DRI

Incremental Demand by Component - 2000

	%	Million t/a
Virgin Fibre	40	28
Fillers	10	7
Secondary Fibre	50	35
Total		70

WRA FILE: MacDraw; DB 10

Hurdles ...

- Capital Availability
- Fibre Quality
- Fibre Availability / Cost

WRA FILE: MacDraw; DB 14

IF

40% of Growth is in High Yield Pulp

60% of Growth is in Low Yield Pulp

Avg Production High Yield = 200,000 t/a

Avg Production Low Yield = 350,000 t/a

Avg Production Paper/Board Machine = 150,000 t/a

WRA FILE: MacDraw; DB 11

THEN

70 Million t/a = 56	+	34	+	187
High Yield Pulp Mills		Low Yield Pulp Mills		Paper Machines

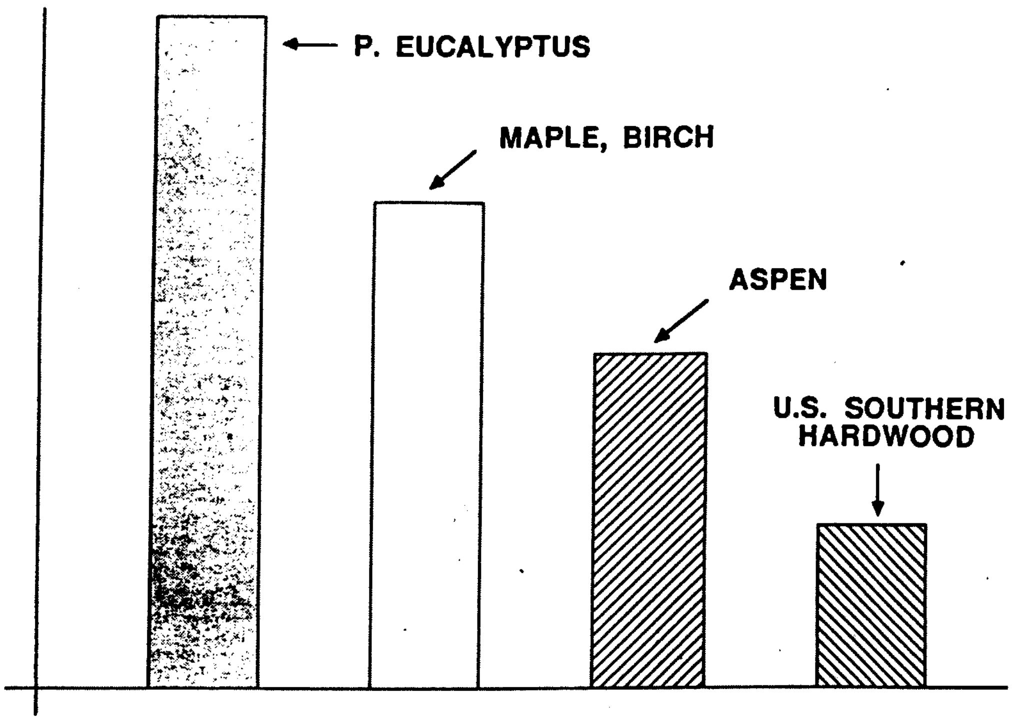
WRA FILE: MacDraw; DB 12

New Capital Requirements

56		34		187
High Yield	+	Low Yield	+	Paper
Pulp Mills		Pulp Mills		Machines
($130 million)		($500 million)		($150 million)

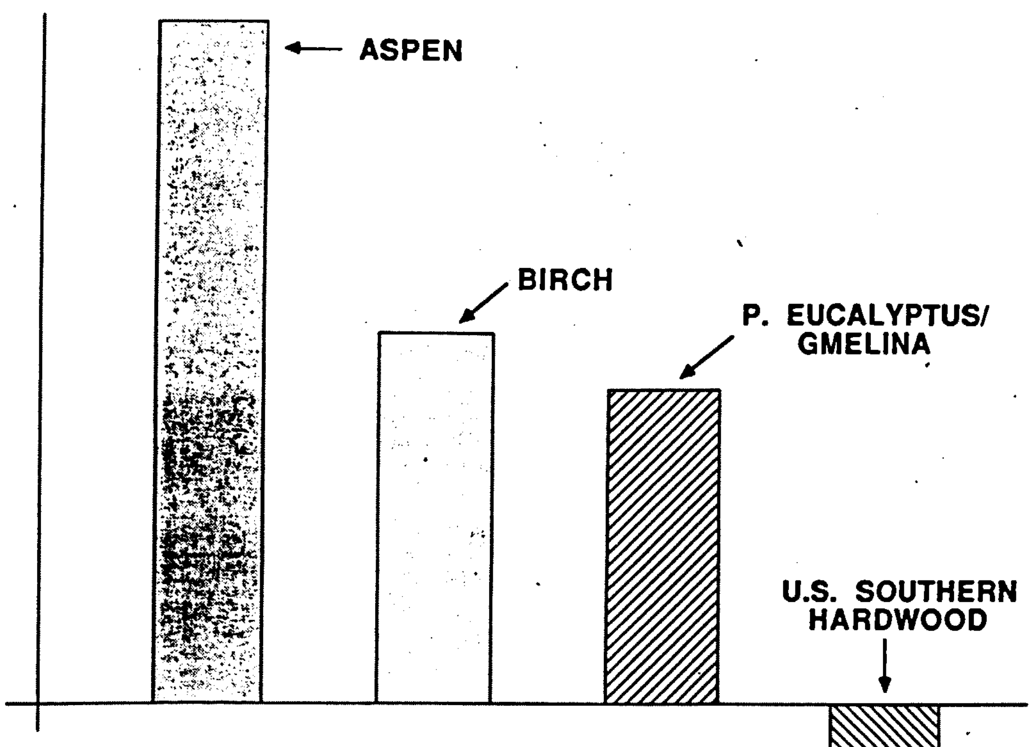
= $ 59 Billion

WRA FILE: MacDraw; DB 13



Fibre Quality H.W. Chemical Pulp

WRA FILE: MacDraw; DB 15

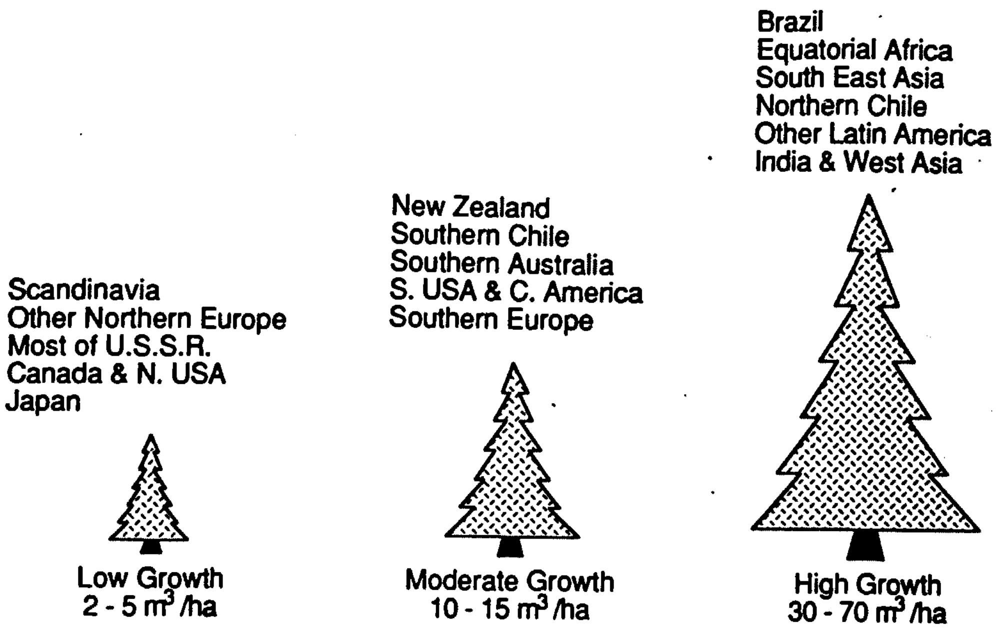


Fibre Quality H.W. High Yield Pulp

WRA FILE: MacDraw; DB 16

AVERAGE ANNUAL GROWTH RATES OF TIMBER

(assuming equal forest management practices
and equivalent site conditions)



WRA FILE: MacDraw; DB 18

Fibre Availability/Cost

Need 310 million m^3 more!
There is enough
but ...

Cost is proportional
to Growth.

70 percent of wood requirement will
come from existing plantation in:

- Southern U.S.
- Southern Hemisphere

WRA FILE: MacDraw; DB 17

Capital Availability

- High Capital Requirement will limit Growth to most Secure Investments

- Real Cost of Capital /ROI will restrict Supply,drive up Prices and invite Substitution

WRA FILE: MacDraw; DB 19

PAPER AND PAPERBOARD HAVE FEW

LONG-LASTING UNIQUE CHARACTERISTICS

.......MANY SUBSTITUTES ARE AVAILABLE

..... OR POTENTIALLY AVAILABLE

SHORT-TERM

IF YOU CAN'T MAKE IT UNIQUE

.... MAKE IT CHEAPLY

LONGER-TERM

HOW CAN YOU MAKE IT UNIQUE, OR CONVINCE CONSUMERS THAT IT IS UNIQUE?

..... TECHNOLOGY (PROCESS, PRODUCT & MARKETING) IS THE KEY.

Challenges to Canada

- Increase the value of Aspen by:
  - Technical Innovation
  - Cost Reduction
  - Integrating it with other Resources
  - Quality Improvement
- Establish a Reputation of high Quality and Dependability in the Market Place
- Be aggressive in Attracting Capital and Marketing

WRA FILE: MacDraw; DB 20

CHEMICAL PULPING OF ASPEN: POSSIBILITIES AND REALITIES

J. Martin MacLeod
Supervisor, Chemical Pulping Group
Pulp and Paper Research Institute of Canada
Pointe Claire, Quebec, CANADA

ABSTRACT

Trees of the Populus family abound in Canada, and trembling aspen is foremost among them. Unusually high in polysaccharide content and low in lignin, aspen wood is ideal in many chemical pulping processes because it offers the advantages of comparatively high pulp yield and rapid delignification. Only in recent years have these advantages been recognized and exploited on a large scale, primarily in the kraft mills of central and eastern Canada. Aspen also has some idiosyncracies, including difficult bark removal from logs and high susceptibility to early decay in standing timber. Practical solutions to some of these problems are already in daily use. It appears increasingly likely that in the chemical pulping world, aspen's time has finally come.

INTRODUCTION

> "In Manayunk, Pa., the American Wood Paper Company makes 18-20 tons of fine pulp every 24 hours. The product is highly esteemed ... for its superior quality."
>
> Scientific American, November, 1881 (1)

Is nothing new? This quotation describes a mill making chemical pulp from poplar more than 100 years ago. The cooking process was soda pulping-- delignification of the wood chips in aqueous sodium hydroxide. It was a logical progression from soda pulping (or steeping) of cotton linters or rages to produce papermaking pulps.

Why poplar? It was readily available in Pennsylvania, the wood was easy to delignify in soda liquor, and the process made bright-enough pulp to be acceptable in days long preceding the bleaching advances which gave us today's super-white pulps.

Since 1881, much has been accomplished in terms of the operating size of chemical pulp mills, but rather less progress has been made in extensive commercial use of aspen in a broad range of pulping processes.

The title of this paper sets a deliberate perspective. "Chemical pulping" means delignifying the wood chemically, usually to the point of fibre liberation. "Aspen" means Populus tremuloides", commonly called poplar in central and eastern Canada. "Possibilities" are those things which can be done with aspen wood in any imaginable chemistry of pulping, without consideration of such practicalities as making money at it. "Realities" are the means by which it is done for financial profit.

The focal points are these:

* The aspen resource: How big is it in terms of standing timber? How extensive is it geographically? How efficiently is it used?

* Wood chemistry: This is the real key to aspen-- its unusual chemistry makes aspen unique among major Canadian wood species.

* Chemical pulping: What can be accomplished when aspen is used in a variety of chemical pulping processes? Further, which of these processes are realities, and why?

The Wood Resource

In a volume of standing timber, Canada's Populus resource is very large: about 2.2 billion cubic metres [2]. That is more than twice the volume of birches, the Number 2 hardwood family, and almost five times the volume of maples. To recognize this fact, we ought to fly the flag shown in Figure 1. It should be green, or perhaps yellow.

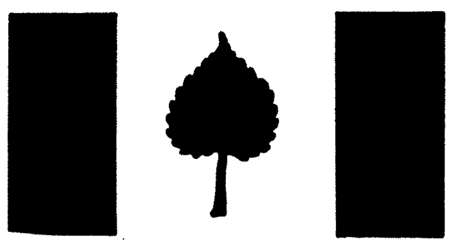


FIGURE 1. Poplars, not maples, are Canada's most abundant hardwoods.

Figure 2 illustrates the widespread distribution of aspen across Canada [3]. Trembling aspen represents about three-quarters of the country's stock of poplars. Aspen growth is particularly dense in a wide diagonal band from northeastern British Columbia to northern Ontario. Alberta and Ontario have large amounts of aspen. So does British Columbia, where aspen timber is most readily accessible in the northeastern secotr, east of the Continental Divide. In the northern parts of the prairie provinces, aspen grows very densely in what sometimes approaches a monoculture forest.

Alberta has about 30% of Canada's total aspen resource. This is a kind of athabasca oil sands of Canadian forests-- a huge natural resource, largely unused. It is, however, renewable. Alberta's aspen stock is approximately equal to that of the entire United States. Currently, however, the yearly harvest of aspen is a very small fraction ot the annual allowable cut.

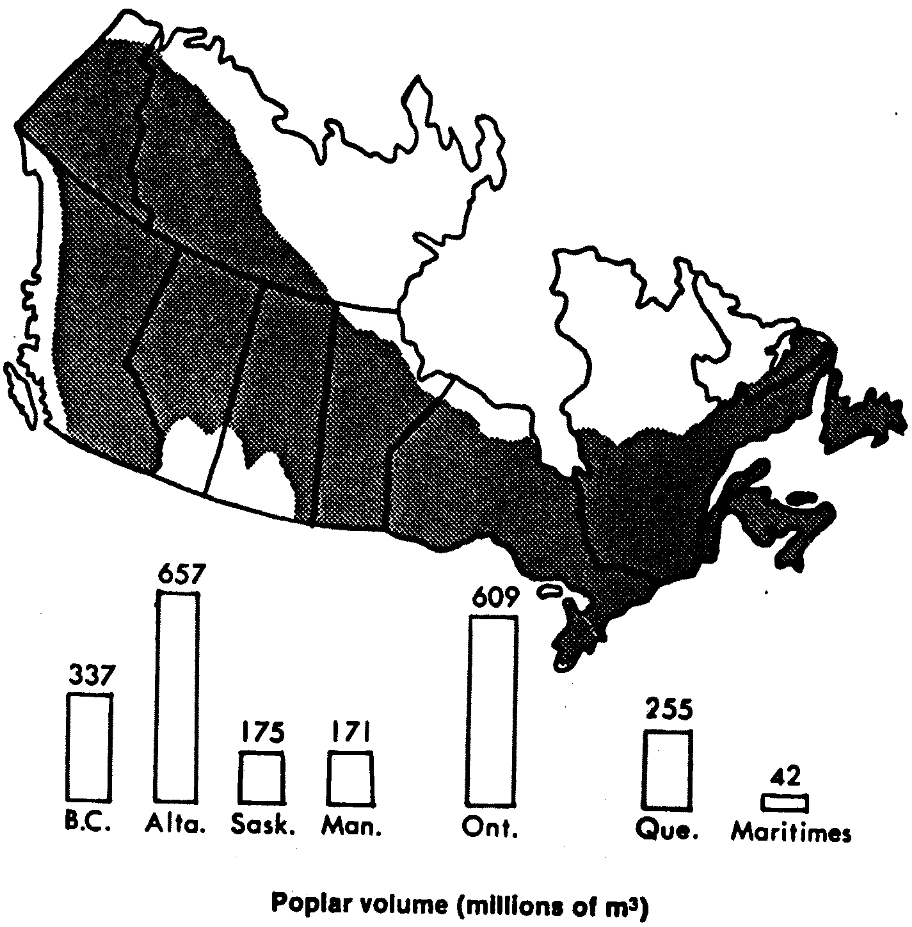


FIGURE 2. Trembling aspen grows almost everywhere in the country. Each bar represents the volume of standing aspen timber in the province above it [3].

WOOD CHEMISTRY

Unusual wood chemistry is the feature which distinguishes aspen (in fact, poplars in general) from all the other important wood species in Canada. Figure 3 shows that in general terms, cellulose accounts for more than 50% of aspen wood, and lignin content is typically 20% or less. Total hemicellulose content is about 30%, of which xylan is a large proportion. The corresponding values of several other common wood species are listed in Table I, from which it is apparent that, in chemical terms, aspen is in a league of its own [4].

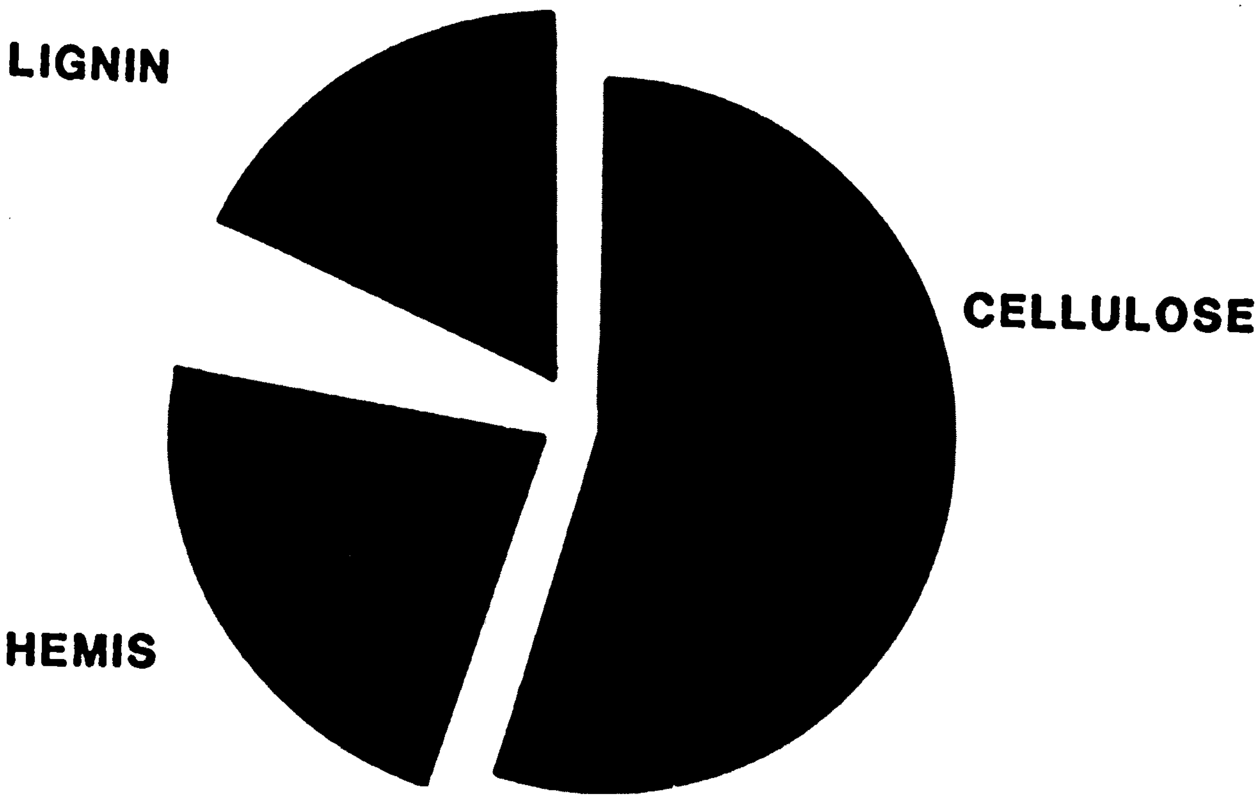


FIGURE 3. Aspen wood is unusually high in polysaccharides and low in lignin.

TABLE 1. Extractives-free chemical compositions of several common hardwoods and softwoods, % [4].

	-Cellulose	Lignin	Hemicelluloses
Trembling Aspen	53	16	31
Red Maple	44	24	32
Balsam Fir	45	29	26
Jack Pine	42	29	29
White Spruce	45	27	28

Two simple things stem from aspen's chemical composition. First, the low lignin content means that aspen wood can be softened or delignified more easily than any of the other wood species in Table 1. Thus, chemical pulping can be fast and efficient, and mechanical pulping can be done at unusually low applied power. Second, high polysaccharide content in the wood leads to comparatively high pulp yields from chemical processes. These things go hand-in-hand.

It is also true that sound, fresh aspen wood is an exceptionally "white" wood; as a consequence, pulps made from it are relatively light in colour even before any chemical bleaching or brightening is done. Note, however, that biological stain and decay can greatly reduce the brightness of the wood.

A minor chemical component of the wood, not shown in Figure 3, is the group of compounds called extractives. These low-molecular-weight organic compounds can be dealt with effectively in most chemical pulping processes. In sound aspen wood, the extractives comprise about 2%-4% of the wood mass [5], a level not very different from that in many other important Canadian wood species. What is unusual in aspen is the extractives content of the inner bark--it is typically 4 to 5 times that in the wood. Add to this the fact that aspen is a relatively difficult species to debark [6], and you have the potential for serious pitch problems in pulping and afterwards. In addition, some aspen extractives, if they reach the chlorination stage of a bleach plant, can form very sticky pitch deposits; these may later come loose and cause pulp contamination. To avoid some of these problems, aspen logs are often aged for a year before they are debarked and chipped. A range of practical solutions to extractives-related problems in kraft mills has been provided by Allen [7].

The Achilles heel of aspen trees is biological decay. When the trees decay, it is usually from the inside out, and is often due to a white rot fungus named Fomes igniarius [3]. The fungus tends to get into the trees via wounds where old branches decayed and fell off; it goes to work in the centre of the tree, metabolizing both carbohydrates and lignin. Figure 4 shows a typical result: heart rot has extended through much of the wood. Lignin content can increase to about 30% of the mass of this area, and the specific gravity of the wood can drop from 0.35 - 0.40 in the sound wood to 0.15 in the heart-rot.

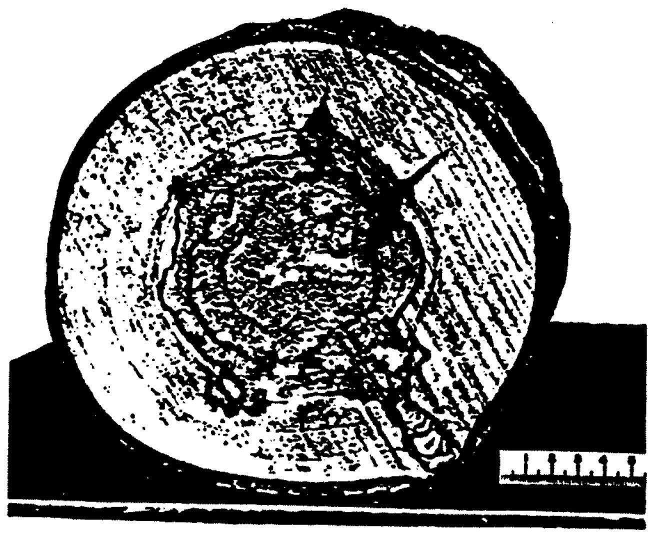


FIGURE 4. As aspen trees age, they often become susceptible to heart rot. In this case, the area of advanced decay has 50% more lignin and less than half the density of the sound wood which surrounds it. Scale in centimeters.

This heart rot often begins by the time an aspen tree has reached 50 - 60 years of age, and is usually extensive by age 80 or more. Unfortunately-- from a harvesting perspective-- you cannot always tell the soundness of these trees simply by looking at them.

The more extensive the decay, the more severe the pulping problems: retarded delignification rates, lower pulp yields, darker pulp, more difficulty in bleaching, pulp strength loss [8-10]. Obviously, the economic picture deteriorates as well, including the negative impact of transporting low-density wood from harvesting areas to mill sites.

If the decay is not particularly severe, it may cause only minor problems in pulping and bleaching. Some of it may even be removed in normal chipping and screening, but probably not enough to avoid the problems cited above [9]. When it represents more than a modest proporation of the chip mass, the decayed wood should be separated from the sound wood chips before they enter the pulping system. The Paprifer process can do this; it is a patented chip upgrading process, shown schematically in Figure 5, which can remove the decayed wood efficiently [10].

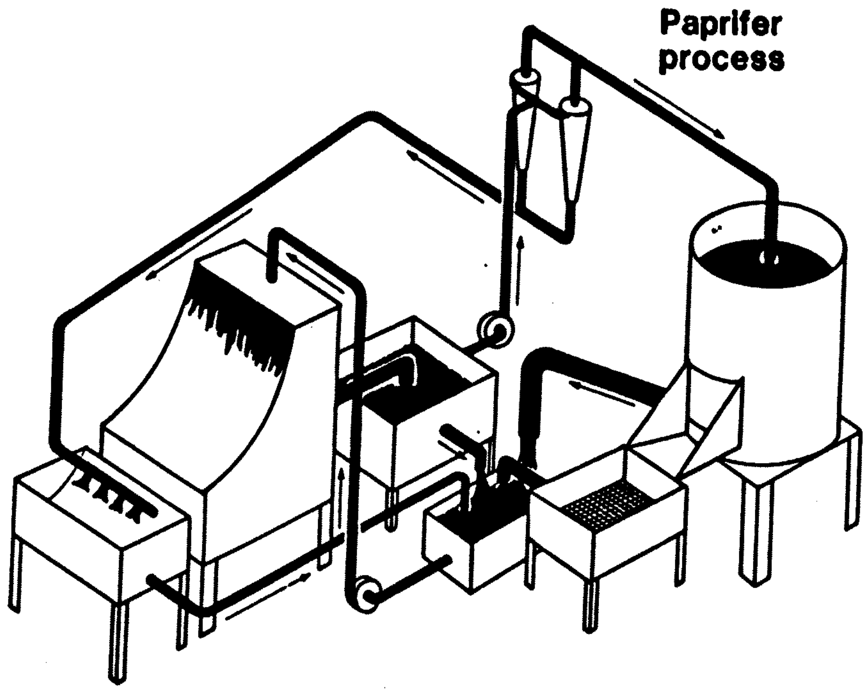


FIGURE 5. The Paprifer chip upgrading system, originally designed to process whole-tree chips, can also upgrade aspen chips contaminated with low-density decayed wood [10].

PULPING PROCESSES

Many chemical pulping processes can deal effectively with aspen; Table II lists several broad categories. Of these, some are etablished realities in both the technical and commerical senses; kraft pulping is foremost among them. Other processes have reached different levels of technical feasibility, but are not within the realm of commercial reality.

TABLE II. A general subdivision of chemical pulping processes which work with aspen.

Inorganic, alkaline:
Kraft, Soda, Soda-Anthraquinone,
Alkaline Sulphite-Anthraquinone, Semi-Chemical Processes

Inorganic, acidic:
Acid Sulphite, Bisulphite

Organic:
Alcohol + Catalyst, Phenol + Catalyst
Ethyl Acetate + Acetic Acid + Catalyst ("Ester")

The main reality: Kraft

Kraft pulping of aspen illustrates many of the factors which result in commercial reality. Kraft liquor reacts rapidly with aspen wood, and the yield of unbleached pulp is high for a chemical pulping process. This is the quite logical outcome of beginning with a wood species of comparatively low lignin content and high polysaccharide content. Bleaching is also easy, and the final pulp brightness can be well into the low 90s (% ISO). The job can be done readily in conventional kraft mills originally designed to pulp softwoods, and aspen operations have a comparative advantage on the chemical recovery sides of such mills.

The extent of kraft aspen pulp production in Canada is partly disguised by how it is manufactured. As set out in Table III, four types of mills do this job. Most prominent in a capacity are the first two: 100% species-pure aspen mills, and @90%/10% aspen/softwood mills. The latter are single-line mills, and usually have to pulp a small amount of softwood along with aspen so as to be able to run the bleached pulp successfully across their pulp drying machines. A pure aspen pulping and bleaching line must have a secondary source of bleached softwood pulp which can be blended into the aspen pulp just before it reaches the pulp dryer.

TABLE III. How aspen is used in kraft mills.

* 100% Species-pure
* 90%/10% Aspen/Softwood
* 25%-50% in Mixed Hardwoods
* < 5% in Softwood

Many of the traditional hardwood kraft mills in central and eastern Canada pulp aspen routinely, but as one component of a mixture of species usually including maples, birches, beech, and minor proportions of other hardwoods. The aspen content of these mixed hardwood pulps is typically in the range 20% - 50%. These mills cook some softwood chips too, again to reinforce the hardwood pulp in wet web strength for runability on pulp drying machines.

Finally, a few <u>softwood</u> kraft mills consume small amounts of aspen-- usually <u>5% or less</u>-- within what is otherwise a softwood chip furnish. Cooking aspen under process conditions designed for softwoods probably negates its advantage in rapid delignification, but there may remain some benefit in yield from wood relative to softwoods.

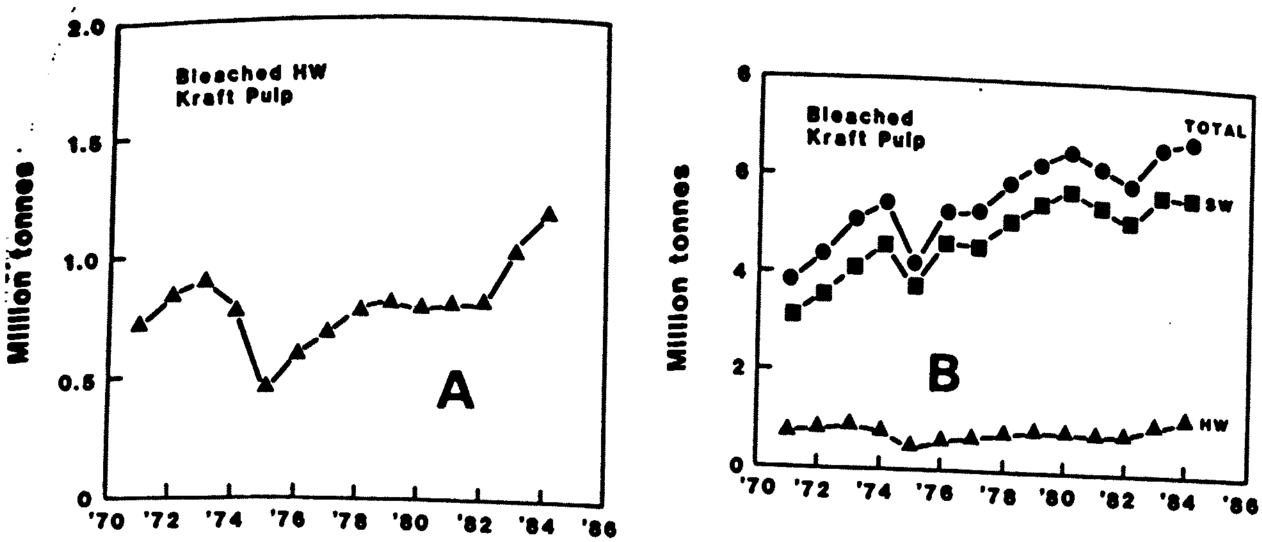


FIGURE 6. (A) Hardwood kraft pulp production has doubled since the mid-1970s; aspen now comprises about half the tonnage. (B) Bleached softwood kraft pulp production far exceeds hardwood kraft production [2].

If you add up the production of fully bleached aspen kraft pulp in all of the forms listed in Table III, the Canadian output by the mid-1980s was at least 500 000 tonnes/year, or approximately half the hardwood kraft pulp production (Figure 6A). In a broader perspective, however, hardwood kraft production accounts for only @15% of the bleached kraft pulp currently made in Canada-- the other 85% is softwood pulp (Figure 6B). In the United States, by contrast, about 45% of the kraft pulp production is from hardwoods.

Table IV provides some typical pulping and bleaching results when making fully bleached kraft pulp from sound aspen wood. Pulping can be done with alkali-to-wood charges well below those required for softwoods, and the unbleached pulp yields usually fall in the range 54% - 58% [8-10]. Not only is this considerably above the yields of bleachable-grade softwood pulps (@40% - 48% from wood), but substantially lower amounts of organic and inorganic materials end up in the black liquor, thereby off-loading a mill's chemical recovery system at a given pulp production rate. To exploit these advantages, such a mill is often operated at a production rate some 15% - 25% above its production capacity on softwood.

Aspen pulp is considerably easier to bleach than softwood pulp, usually at a saving of 30% - 40% in total equivalent chlorine demand across a conventional C/DEDED sequence. This difference may be reduced if extra amounts of bleaching chemicals are used to bring the hardwood pulp to super-high brightnesses of 92% - 93% ISO.

TABLE IV. Typical results when sound aspen wood is pulped in kraft liquor, and the pulp is bleached to high brightness. Results with spruce are given for comparison.

	ASPEN [8, 14]	SPRUCE
PULPING:		
	a	b
Total pulp yield, %	54-58	47-49
Rejects, %	< 1	< 0.5
Kappa number	17	30
C/DEDED BLEACHING:		
C/D + D1 + D2, equivalent chlorine consumed, %	6	10-11
Toatl NaOH applied, %	2.5	4.0-4.5
Final brightness, % ISO	90	90
Bleached yield from wood, %	50-54	44-46

(a) Cooking conditions: 14% active alkali, 25% sulphidity, 170°C maximum temperature, 4:1 liquor:wood.
(b) Cooking conditions: 18% active alkali, 30% sulphidity, 170°C maximum temperature, 4:1 liquor:wood.

When added together, the kraft pulping, bleaching, and chemical recovery benefits of aspen operations result in manufacturing costs per tonne of pulp which are significantly lower than those of making softwood pulps. In the currently buoyant state of the international kraft pulp market, aspen pulp is being quoted at prices quite close to those of softwood pulps [11]; on balance, therefore, it is more profitable to produce. Furthermore, its market acceptance is good in North America and abroad, and aspen kraft pulp finds many applications in the manufacture of printing papers, tissue, and towelling. In such products, the aspen pulp contributes to uniformity of sheet formation, softness, and surface smoothness.

Note that the overall mechanical strength of kraft pulp from sound aspen wood is not outstanding (Figure 7) [12] -- in tear-tensile strength, for example, it is equivalent to mixed hardwood pulp, and weaker than 100% birch pulp.

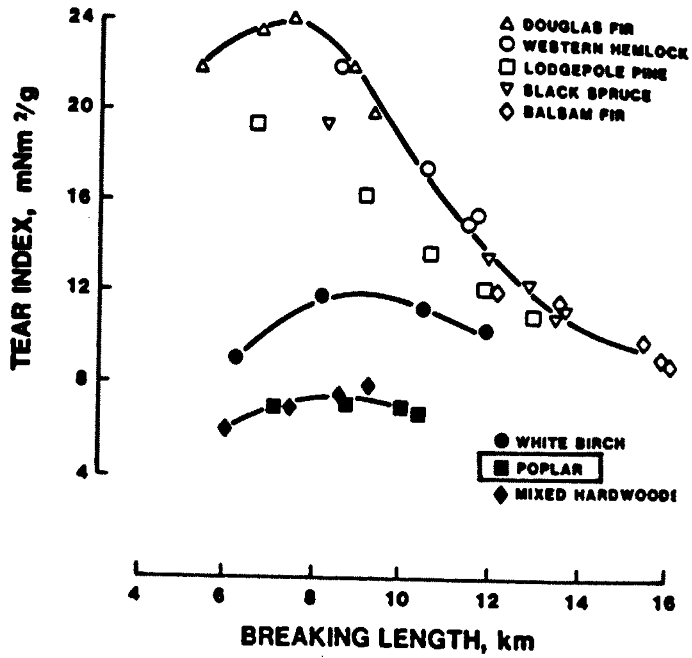


FIGURE 7. In tear-tensile strength, kraft aspen pulp is on a par with that from mixed E. Canadian hardwoods, but is much weaker than typical softwood pulps [12].

A minor reality: Semi-chemical

There are six semi-chemical mills in Canada. They use a variety of mildly alkaline pulping processes to convert hardwoods into corrugating medium. Their average production rate is @250 tpd. The total production of semi-chemical pulp comprises less than 3% of all the chemical pulp made in Canada.

Nevertheless, aspen is a species of note in these mills too; it is readily available, and performs well in both pulp making and in the corrugating medium. These semi-chemical mills use mixed hardwoods; in at least one of them, as much as 60% of the chip furnish is aspen.

The merits of aspen versus other Canadian hardwoods in semi-chemical pulping processes are not well documented in the literature. It is probable that any comparative advantages of aspen are of a lesser degree in semi-chemical pulping than in kraft pulping, first because much less chemistry takes place in semi-chemical cooking, and also because the refining of the semi-cooked chips further reduces any advantages originating in pulping.

Possibility: Soda-AQ

Soda-anthraquinone (AQ) pulping, a modern successor to soda pulping of hardwoods, is practised on a commercial scale at one mill in the United States and one mill in Australia; neither runs on aspen. The anthraquinone performs two functions in the cooking liquor: it accelerates the delignification, and it helps to preserve polysaccharides from dissolution in the aqueous NaOH cooking liquor [13].

The attraction of this process is that it avoids the deliberate use of sulphur-containing chemicals, thereby eliminating most of the noxious odours of kraft pulping and reducing some of the problems of corrosivity. On the negative side, neither soda nor soda-AQ pulping is a realistic process for delignifying softwoods, mainly due to problems with pulping rates and pulp strength.

Soda-AQ pulping of aspen has been investigated, and the process was found to be viable in a technical sense [14]. Relative to the kraft process, the rate of soda-AQ pulping was satisfactory (although not quite as fast), and the pulp yield, bleachability, and pulp strength were all equivalent (Table V).

TABLE V. Results from soda-anthraquinone pulping of sound aspen wood, followed by C/DEDED bleaching [14].

	SODA-AQ	KRAFT
PULPING:		
Total pulp yield, %	58	57
Rejects, %	1	1
Kappa number	17	18
C/DEDED BLEACHING:		
C/D + D1 + D2, equivalent chlorine consumed,%	6.0	6.1
Total NaOH applied, %	2.5	2.6
Final brightness, % ISO	89	90
Bleached yield from wood, %	56	55

The economic reality of a soda-AQ hardwood mill is much like that of a kraft mill-- a scale of 500 tpd or higher would probably be required to provide an adequate return on investment, because almost all the same unit processes are used. An interesting development which holds the promise of simplifying the chemical recovery cycle of soda-based mills is the direct alkali recovery system (DARS) [15]; it is now being tried on an industrial scale at the soda-AQ hardwood mill of Associated Pulp & Paper Mills, Burnie, Tasmania, Australia.

Possibility: Alkaline sulphite-AQ

This case is similar to that of soda-AQ: alkaline sulphite-AQ pulping is already practised commercially, but in comparatively few mills, none of them in Canada and none pulping aspen. The process employs an aqueous cooking liquor containing sodium sulphite, sodium carbonate, and anthraquinone. Delignification is much slower than in kraft liquor, but this is partly offset by higher pulp yields and brighter unbleached pulps [16].

Alkaline sulphite-AQ (AS-AQ) pulping of aspen has been reported [17]. Although the delignification rate was considerably faster than that of softwoods [18], it was still much slower than kraft pulping of aspen (Figure 8).

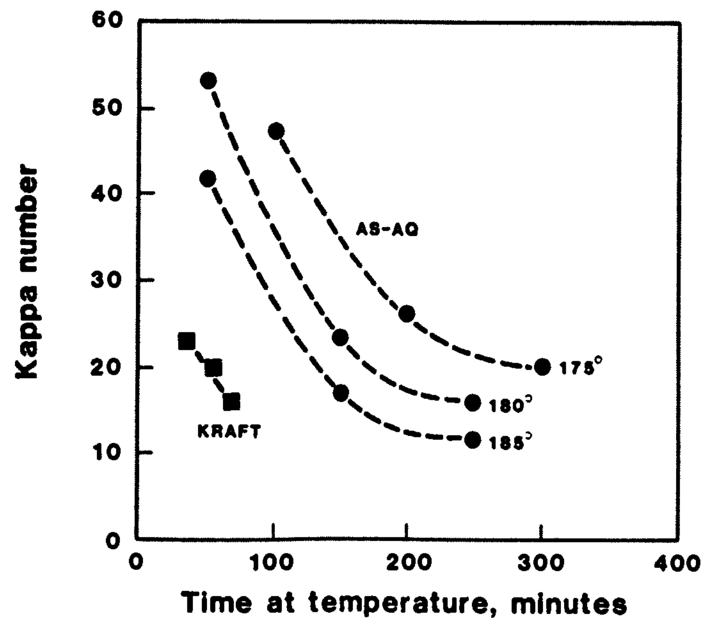


FIGURE 8. Alkaline sulphite-AQ pulping was much slower than kraft pulping, despite a higher alkali charge and higher temperature; the kraft pulping was conducted at 175°C [17].

The yields of bleachable-grade AS-AQ pulp form sound aspen were as high as 66%, and rejects levels were reasonable. The pulp had an unbleached brightness (at 25 kappa number) of @70% ISO, twice the brightness level of unbleached aspen kraft pulp!

Table VI shows that bleaching in a C/DEDED sequence brought the AS-AQ pulp to 92%+ brightness; C/DED bleaching alone reached @91% brightness. With higher amounts of chlorine and chlorine dioxide, or with the use of oxygen and/or hydrogen peroxide in caustic extraction, brightnesses of 93-94% could probably be attained.

The final yield of bleached pulp was about 60%, some six percentage points above kraft level. this ranks among the highest bleached pulp yields on record for purely chemical delignification in a commercially feasible process.

TABLE VI. Results of alkaline sulphite-AQ pulping and C/DEDED bleaching of sound aspen wood *vs* a kraft control [17].

	ALKALINE SULPHITE-AQ	KRAFT
PULPING:		
Total pulp yield, %	66	57
Rejects, %	1	1
Kappa number	25	18
C/DEDED BLEACHING:		
C/D + D1 + D2, equivalent chlorine consumed, %	6.7	6.1
Total NaOH applied, %	2.8	2.6
Final brightness, % ISO	92+	90
Bleached yield from wood, %	60	55

Possibility: Organosolv

Organosolv processes use aqueous solutions of organic solvents to delignify wood; catalysts are often added. Table VII lists some recent examples of this type of approach [19-23]. The usual aim is to separate, as cleanly as possible, the lignin from the polysaccharides, and it is not unusual to try to split the polysaccharides into cellulose and hemicellulose fractions at the same time [24].

As Table VII demonstrates, organosolv pulping of sound aspen wood usually provides unbleached pulp yields which are similar to those from kraft pulping. The conditions of pulping are often rigorous; for example, aqueous alcohol pulping is conducted at 190-200°C, ad the pressure inside the pulping vessel is substantial. Efficient washing of the unbleached pulp is crucial for economic recovery of the organic solvent.

TABLE VII. Some cooking liquor ingredients and results of organosolv pulping of sound aspen wood.

PROCESS	ACTIVE INGREDIENTS [a]	PULPING TEMP., °C	PULP YIELD, %	KAPPA NUMBER	PULP STRENGTH [b]	REF.
Alcohol	Ethanol	190-200	53-58	27-36	Lower	19
Alcohol	Methanol	190	65-70	?	Lower	22
Ester	Ethyl acetate Acetate acid	@170	50-52	@10	Lower	21
Kraft	NaOH, Na2S	@170	54-58	@17	--	8,14

(a) The organosolv processes use aqueous solutions of these active ingredients; they also use catalysts, often mineral acids such as HCI.

(b) In terms of tear, tensile, and burst strength relative to kraft pulp from sound aspen wood [Ref. 8,12,14].

Because aspen is comparatively easy to delignify in almost <u>any</u> chemistry (alkaline or acid, organic or inorganic), it is a favourite starting point for studies of organosolv processes. Strictly in the sense of pulping rate and yield, the results are usually quite good. Unfortunately, the story often stops there, with insufficient attention paid to pulp washing, bleachability, and the intricacies of complete and economical solvent recovery. No organosolv pulping process has yet become commercially viable. In addition, some of these processes are severly limited because they cannot pulp softwoods effectively [25,26], and many cannot produce pulps which are able to compete in strength with kraft pulps. In fact, even with sound aspen, organosolv processes generally provide pulps with strength properties only on a par with those of kraft pulps from <u>100% decayed</u> aspen wood [8,12].

Perhaps a more realistic path would be to take the chemical approach to its limit-- organosolv pulping to very high levels of lignin removal, followed by selective stripping of the residual lignin and the hemicelluloses. This could be a way to produce very pure chemical cellulose for conversion to cellulose derivatives, an approach which may hold more promise for organosolv processes than the traditional one of producing fibres for papermaking.

SUMMARY

Aspen trees provide a huge natural forest resource in Canada, but their use in wood products and in pulp and paper is only a tiny fraction of the potential. By far the most common fibre product is fully bleached kraft pulp, and in all its forms, this currently generates several hundred millions of dollars in annual sales. The only other recognizable use of aspen in chemical pulp mills in Canada is within the mixed hardwood furnishes used to make semi-chemical corrugating medium.

The possible use of aspen in many other chemical pulping processes has been investigated; its unusual wood chemistry makes it the species of choice for such studies. Some processes (e.g., soda-anthraquinone, alkaline sulphite-anthraquinone) are completely feasible in a technical sense, but technical factors alone do not guarantee commercial implementation Other processes, particularly the organosolv ones, remain unproven in a mill-wide sense, and thus are even farther removed from possible application.

It is possible to grow hybrid aspen trees to a harvesting age of 10-15 years in Canada, but that does not represent the reality of our extensive natural forests. Until the means are found to deal economically with the current aspen timber resource, and particularly with its high incidence of decayed wood, it will remain something of an orphan among the major wood species of Canada. In advancing the status of aspen utilization in the Canadian pulp and paper industry, products and marketing will be at least as important as the means to produce the pulp and paper materials themselves.

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OVERVIEW OF HIGH-YIELD PULPING OF ASPEN

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ABSTRACT

This paper gives an account of our experiences in chemimechanical and chemithermomechanical pulping of trembling aspen (Populus tremuloides Michx.). In chemimechanical pulping, the pH of fresh cooking liquor appeared to be one of the most important parameters affecting the pulp quality. Alkaline cooking liquor was preferred over the acid liquor. The optimum pulp yield for good sheet strength was about 85%. In the case of chemithermomechanical pulping, the usage of sodium hydroxide was essential for producing a good quality pulp from aspen. The chemithermomechanical pulp of aspen could be used to partially replace the chemical pulps in newsprint furnish without adversely affecting the sheet properties.

PART I - CMP AND CTMP OF TREMBLING ASPEN

In view of increasing shortages of long-fibered softwood resource in certain regions [1], the use of short-fibered hardwood species has become the subject of increasing interest in pulp and paper manufacture throughout the world [2-6]. During the past years, we have been committing ourselves in valorizing hardwoods for the production of pulp and paper [7-12].

In this report, an account is given of the pulping behavior of trembling aspen in chemimechanical and chemithermomechanical pulpings, and of the papermaking properties of the resulting pulps.

EXPERIMENTAL

CHEMIMECHANICAL PULPING

Chips were prepared from freshly cut aspen trees aged from 28 to 38 years. The principal experimental parameters were: total SO_2/o.d. wood, 8-13%; pH of fresh liquor, 4-10; liquor-to-wood ratio, 5; cooking temperature, 140°-170°C; cooking time, 15-70 min. The cooked chips were first defiberized, at atmospheric pressure, in a Sprout-Waldron laboratory refiner. The resulting coarse pulps were further refined to a Canadian standard freeness of 300 mL by means of a PFI mill. Pulp properties were evaluated by following the TAPPI standard methods.

CHEMITHERMOMECHANICAL PULPING

Chemithermomechanical pulping was carried out in a Sunds Defibrator pilot plant. The main experimental conditions were: sodium hydroxide, 2-5%; sodium sulfite, 2-20%; heating temperature, 126°-140°C; heating time, 5-15 min. The refining consistence was approximately 25%. The pulp freeness was targeted at about 100 mL.

CHEMIMECHANICAL PULP

Among the cooking parameters studied, the pH of fresh cooking liquor appeared to be the most important factor influencing the pulp properties. As shown in Figure 1, for a given tensile strength, the pulps produced in an acid milieu required more refining energy in comparison with the pulps made in alkaline conditions; alkaline liquor was more effective in softening the wood components.

It was also noted that the pulps prepared in alkaline milieu could be developed to yield handsheets with better mechanical properties, as demonstrated in Figure 1. These fibers showed better fibrillation and formed denser sheets when compared with those produced in acid liquor.

The handsheet properties of aspen chemimechanical pulp varied as a function of pulp yield. For example, the tensile breaking length augmented almost linearly with decreasing pulp yield, as illustrated in Figure 2. The tensile breaking length tended, however, to level off in the neighbourhood of 85% yield which seemed to be optimum for the chemimechanical pulps of aspen. Further decrease in pulp yield gave little effect on tensile strength.

A plot of tear index versus breaking length shows that these two parameters had linear relationship, as revealed in Figure 3.

Brightness of the aspen chemimechanical pulp was relatively low, that was about 45%, regardless of pulp yield. However, these pulps responded quite well to either hydrosulfite or hydrogen peroxide bleaching [13].

CHEMITHERMOMECHANICAL PULP

The pulp yield of aspen chemithermomechanical pulp was in the range of 92-94%, depending upon the degree of chemical pretreatment of chips.

The results obtained from the chemithermomechanical pulping of aspen indicated that the use of sodium hydroxide in the pretreatment of chips was essential to produce a good quality pulp. Figures 4 and 5 reveal that both tensile and tear strengths of handsheets were considerably improved as the level of sodium hydroxide was increased. It was, however, noted that only marginal gain in mechanical properties was obtained when the amount of sodium hydroxide was above 5%. And, since the optical properties of handsheets degraded gradually with increasing quantity of sodium hydroxide, the 5% level was considered as optimum in this study.

In contrast, the sodium sulfite had little influence on the mechanical properties of the handsheet, except it helped improve the brightness of pulp.

It was also observed that the chemithermomechanical pulp responded very well to peroxide and hydrosulfite bleaching; the former agent was, however, preferable over the latter [14).

Laboratory newsprints were made by blending the chemithermomechanical pulp of aspen with the industrial pulps, such as stone groundwood (SGW), semi-bleached kraft (SBK) and high yield sulfite (HYS). As an example, some properties of the laboratory newsprints containing CTMP/SGW/SBK are presented in Figure 6.

Figure 6A shows that it was possible to produce a newsprint containing little or no SBK but with acceptable tensile breaking length. This reveals that the CTMP fibers had excellent bonding capacity. These hardwood fibers, being relatively short, did not yield satisfactory tearing resistance to the sheets when compared with the standard newsprint containing 15% SBK and 85% SGW (Figure 6B). This implies that a certain amount of chemical pulp was necessary in the furnish. But if tear index of 6-7 mN.m2/g was an acceptable value, then the SBK content could be reduced from 15% to 5-10%. This would, however, depend on the runnability of the mixed furnish on a commercial paper machine.

As seen in Figure 6C, the CTMP content had somewhat negative effect on opacity of the handsheet. The drop in opacity was, however, relatively small, about two and one-half points.

In a semi-industrial machine trial, it was demonstrated that the chemical pulp component in newsprint could be partially replaced by the CTMP of aspen [15].

CONCLUSION

Very-high-yield (85%) chemimechanical pulp of good quality could be produced from aspen. Concerning the pulp quality, it was observed that alkaline cooking liquor was more effective than the acid liquor.

Ultra-high-yield (90% or higher) pulp of good quality could also be made by means of a mild chemical pretreatment of chips prior to pressurized refining. This pulp could be used as a potential replacement component for the chemical pulp in newsprint furnish.

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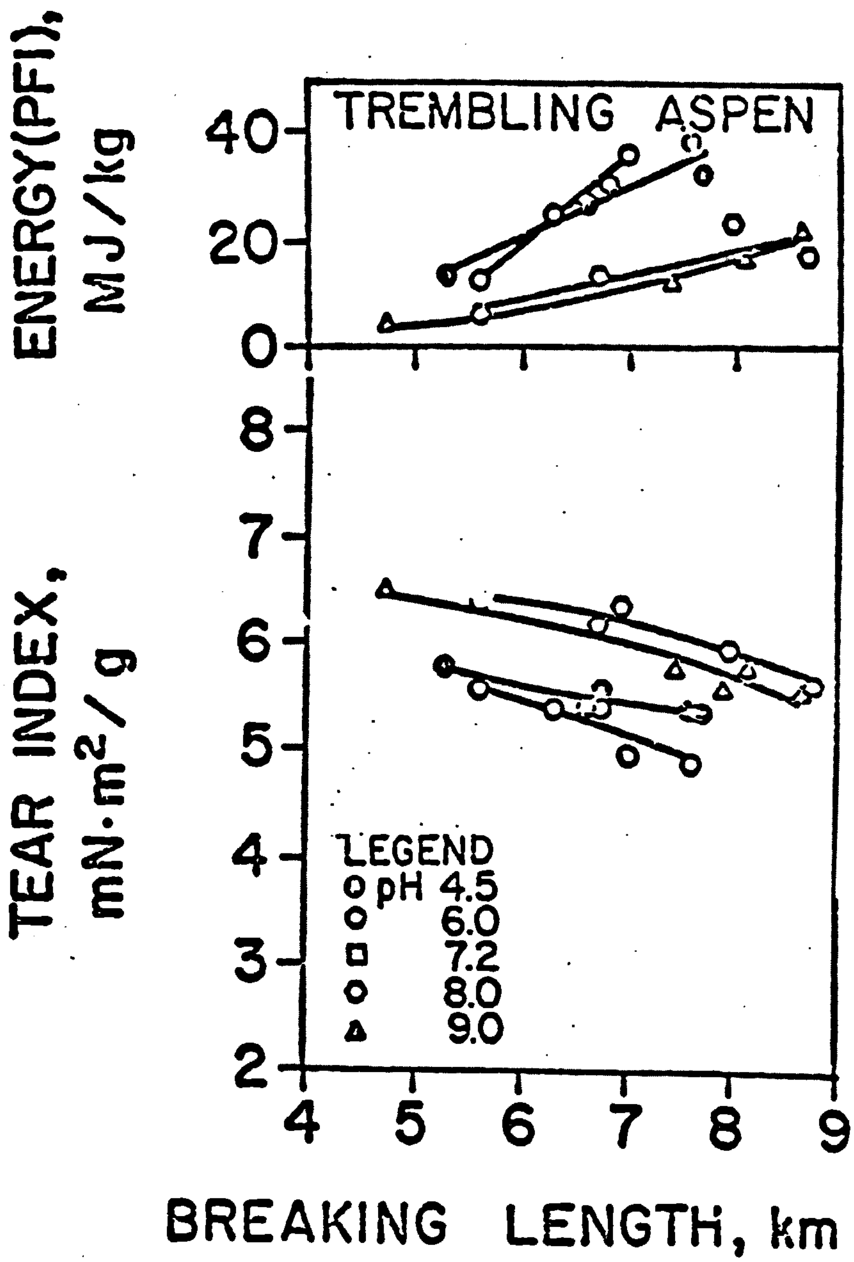

FIGURE 1. Influence of fresh cooking liquor pH on chip refining energy, and tear index and breaking length of handsheets.

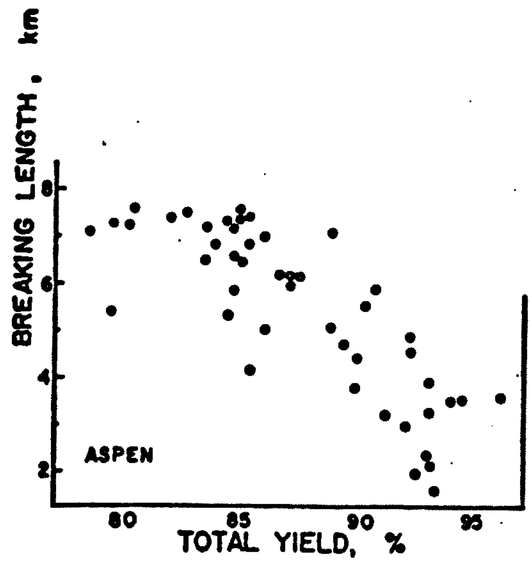

FIGURE 2. Variation of breaking length with total yield, for pulps of 300 ml CSF.

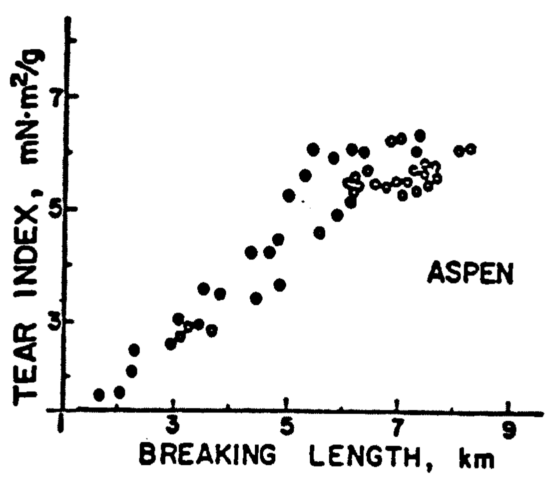

FIGURE 3. Variation of tear index with breaking length, for pulps of 300 ml CSF.

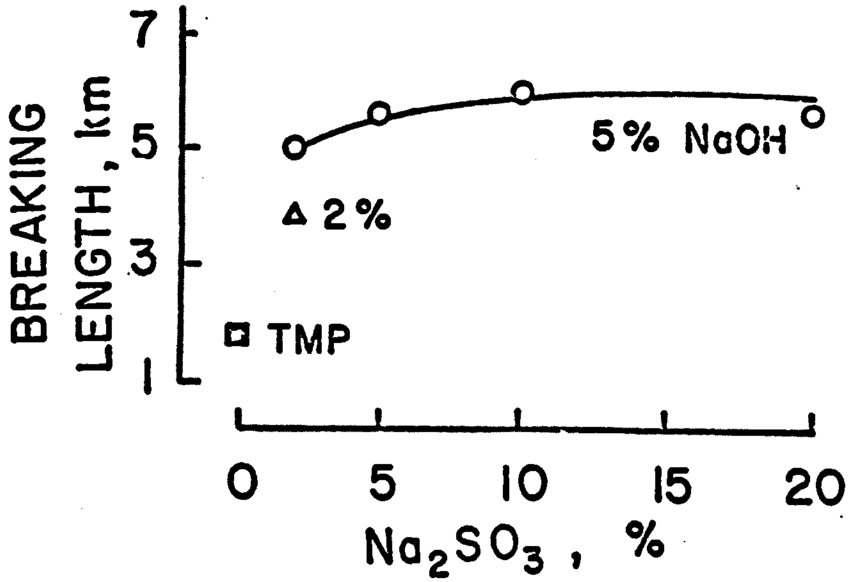

FIGURE 4. Effect of sodium hydroxide and sodium sulfite on breaking length of aspen chemithermomechanical pulps.

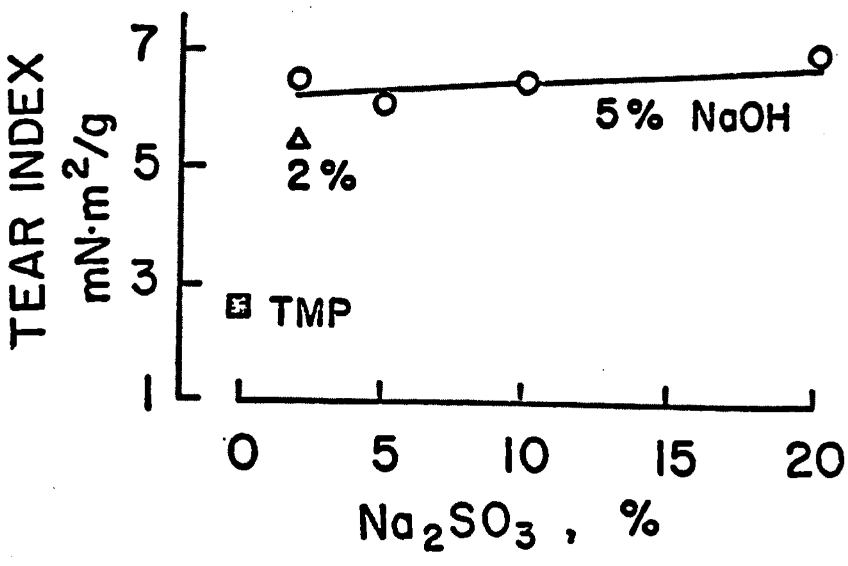

FIGURE 5. Effect of sodium hydroxide and sodium sulfite on tear index of aspen chemithermomechanical pulps.

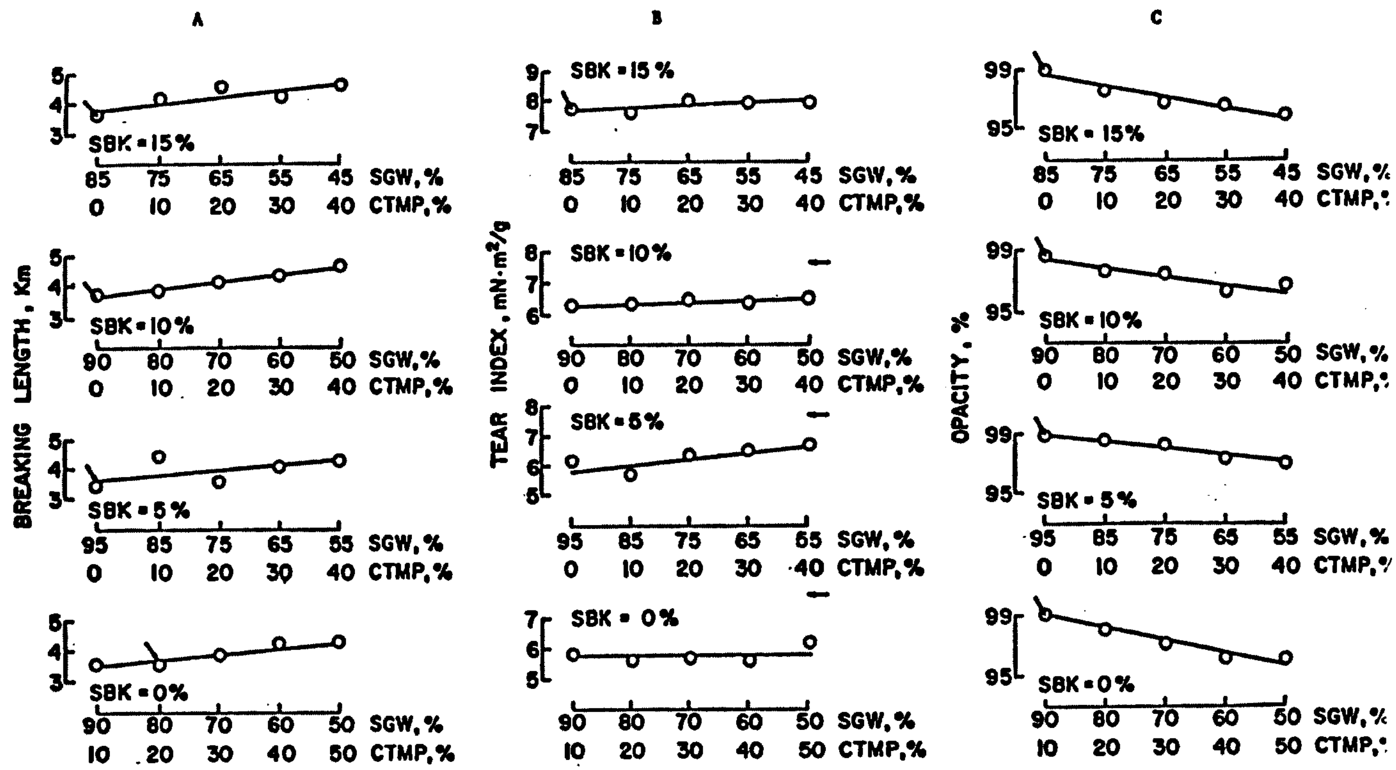

FIGURE 6. Properties of newsprint blends containing 4 levels of semibleached Kraft (SBK) and various proportions of stone groundwood (SGW) and aspen chemithermomechanical pulp (CTMP): A) breaking length; B) tear index; C) opacity. The arrows indicate the value of a standard newsprint blend containing 15% SBK and 85% SGW.

PART II - SEMI-INDUSTRIAL TRIAL ON NEWSPRINT CONTAINING ASPEN CTMP

INTRODUCTION

In view of the interesting results obtained from laboratory newsprint, attempts were made to pursue our study at semi-industrial scale by using a semi-industrial paper machine which was made available to us by the Departement de Technologie du Papier du Cegep de Trois-Rivieres. This Fourdrinier paper machine with a wire of 0.7 m wide, runs at 45 m/min.

A paper containing 20% low-yield sulphite (LYS) and 80% stone groundwood (SGW) was manufactured to serve as a reference for the comparison of sheet properties. These two industrial pulps were both produced from softwood.

The formulation of newsprint was made according to Table 1. As shown in the Table, three series of newsprint were manufactured. The LYS was used in the first two with a rate of 20% and 10%. The third series contained only CTMP and SGW. A paper containing 100% CTMP was also made. The quantity of SGW in the compositions varied depending on the amounts of LYS and CTMP used.

Characteristics for the mixtures of pulps and the machine-made paper are presented in Tables 2 to 5. The standard formulation of 20% LYS and 80% SGW is also shown in each table for comparison.

The results were analysed by means of multiple regression. The paper properties were discussed in relation to those of standard newsprint (reference).

RESULTS AND DISCUSSION

OPTICAL PROPERTIES

As shown in Figure 1, the sheet opacity decreases as the amount of CTMP in the paper increases. This is due to the improved fiber flexibility and conformability of CTMP as a result of chemical pretreatment of chips. However, at 30% CTMP, the difference in opacity between the aspen newsprint and the standard newsprint is not substantial, that is 93.7% vs. 95.4%. In fact, an opacity of 90% would be sufficient for a commercial newsprint.

On the other hand, the newsprint containing 30% CTMP has a brightness similar to that of the reference newsprint, as indicated in Figure 2.

PHYSICAL PROPERTIES

The observed decrease in sheet opacity is in fact related to the reduction in bulk of sheet with increasing amount of CTMP in the paper (Figure 3). It is noted, however, that the drop in bulk occurred significantly only when the CTMP content is more than 30%.

The increase in CTMP content affects also the sheet porosity. The combination of LYS with aspen CTMP seems, however, to improve the porosity when compared with the reference sheet (Figure 4).

The strength properties, such as burst, tensile and tear, are illustrated in Figures 5-7. Generally speaking, the addition of CTMP help improve the mechanical characteristics of paper. As seen in the Figures, it is possible to obtain a newsprint having strength properties comparable and even superior to those of the reference newsprint when the aspen CTMP content reaches about 50% of the newsprint composition. In terms of bonding strength, it seems possible to completely replace the chemical pulp by CTMP and yet one could maintain good strength properties.

Surface properties of the newsprint produced were also evaluated and are shown in Figures 8-9. The Parker Print Surf roughness test showed that a newsprint having 30% CTMP yielded similar roughness property as the reference sheet (Figure 8).

IGT printability test indicated that the newsprint containing aspen CTMP had better pick resistance than the reference newsprint (Figure 9). This shows that the aspen CTMP improves interfiber bonding.

CONCLUSION

This semi-industrial trial on making newsprint containing aspen CTMP indicates the potential use of the ultra-high-yield pulp from aspen as a replacement pulp for the high cost chemical pulp. This means signifcant savings in terms of energy, chemicals, raw material, as well as pollution abatement for the pulp and paper industry.

TABLE 1. Formulations of newsprint stock

X_1 : LYS , %							
X_2 : CTMP , %							
X_3 : SGW , %							
X_1 :	20	20	20	20	20	20	%
X_2 :	50	40	30	20	10	0	%
X_3 :	30	40	50	60	70	80	%
X_1 :	10	10	10	10	10	%	
X_2 :	50	40	30	20	10	%	
X_3 :	40	50	60	70	80	%	
X_1 :	0	0	0	0	0	0	0 %
X_2 :	100	50	40	30	25	20	10 %
X_3 :	0	50	60	70	75	80	90 %

TABLE 2. Characteristics of the pulps used in laboratory newsprint making.

PROPERTIES / PULP	SGW[1]	LYS[2]	HYS[3]	SBK[4]	CTMP[5]
Can. Std. freeness, ml	40	560	636	670	94
Brightness (Elrepho), %	60	49	40	-	57
Porosity, mL/min	135	424	2850	1440	68
Opacity, %	98	94	94	94	87
Burst index, kPa.m2/g	1.75	5.37	5.79	5.67	3.75
Tear index, mN.m2/g	5.0	8.00	10.2	11.6	7.80
Breaking length, km	3.34	8.38	8.50	7.17	6.30
Stretch, %	1.55	1.91	2.54	3.08	2.55
Bulk, cm3/g	2.52	2.06	2.17	1.68	1.61

1: Stone groundwood; 2: Low-yield sulfite; 3: High-yield sulfite; 4: Semi-bleached Kraft; 5: Aspen CTMP from Trial G.

TABLE 3. Properties of newsprint containing only aspen CTMP and SGW.

LYS, %	20	0	0	0	0	0	0	0
CTMP, %	0	10	20	25	30	40	50	100
SGW, %	80	90	80	75	70	60	50	0
CSF, ml	81	51	57	58	59	54	---	89
Bauer–McNett Classification % R14	2,3	1,1	0,8	1,0	1,0	0,9	---	0,2
R28	14,2	8,9	7,4	7,1	6,7	6,7	---	3,4
R48	18,9	20,5	17,7	18,7	19,1	19,6	---	29,1
R100	16,9	24,7	23,1	25,9	27,4	28,0	---	36,9
R200	14,1	16,3	14,6	14,5	13,8	13,4	---	12,2
P200	33,6	28,5	36,4	32,8	32,0	31,4	---	18,2
Bulk, cc/g	2,46	2,39	2,61	2,47	2,43	2,51	2,30	1,88
Porosity, ml/min	237	214	313	268	244	247	125	115
Roughness F	7,2	6,6	7,1	6,7	7,0	7,2	7,5	7,5
(Parker Print Surf), T	5,9	5,6	6,1	5,7	6,1	6,4	6,3	6,6
Brightness(Elrepho), %	57,3	58,4	58,4	57,9	58,0	57,8	52,0	44,8
Opacity, %	95,4	95,8	92,9	94,2	93,7	93,9	93,0	85,7
Burst, (kPa•m²/g)	1,91	1,47	1,46	1,50	1,61	1,67	2,14	3.26
Tear, (mN•m²/g) MD	3,99	3,25	3,33	3,51	3,68	3,71	3,54	4,02
CD	4,54	3,04	3,67	3,90	4,11	4,17	3,74	4,67
MD/CD	0,96	1,07	0,91	0,90	0,90	0,89	0,95	0,96
Tensile, km MD	5,34	4,53	4,71	4,64	4,98	5,21	5,55	8,13
CD	3,15	2,92	2,98	3,05	3,15	3,22	3,65	4,18
MD/CD	1,70	1,55	1,58	1,52	1,58	1,62	1,52	1,94
Stretch, % MD	1,32	1,37	1,32	1,38	1,33	1,35	1,50	1,95
CD	2,07	2,03	1,96	2,12	2,07	2,12	2,17	2,79

TABLE 4. Properties of newsprint containing 10% LYS and various proportions of CTMP and SGW.

LYS, %	20	10	10	10	10	10
CTMP, %	0	10	20	30	40	50
SGW, %	80	80	70	60	50	40
CSF, ml	81	70	72	75	72	131
Bauer–McNett Classification % R14	2,3	1,0	0,8	0,9	1,1	2,0
R28	14,2	9,6	8,8	9,2	9,5	14,2
R48	18,9	18,6	18,1	19,5	17,8	24,8
R100	16,9	21,0	24,0	26,0	22,1	25,7
R200	14,1	15,9	14,2	14,2	15,4	10,1
P200	33,6	35,9	34,1	30,2	34,1	23,2
Bulk, cc/g	2,46	2,44	2,18	2,41	2,36	2,20
Porosity, ml/min	237	274	230	303	297	324
Roughness F	7,2	6,6	6,1	6,7	6,5	6,6
(Parker Print Surf), T	5,9	5,3	4,8	5,5	5,4	5,7
Brightness(Elrepho), %	57,3	58,5	58,1	58,0	56,2	56,8
Opacity, %	95,4	95,4	95,6	93,6	94,6	91,8
Burst, (kPa•m²/g)	1,91	1,35	1,57	1,58	1,59	2,16
Tear, (mN•m²/g) MD	3,89	3,67	4,06	4,21	4,13	4,95
CD	4,54	4,10	4,67	4,75	4,43	5,66
MD/CD	0,86	0,90	0,87	0,89	0,93	0,87
Tensile, km MD	5,34	4,15	4,51	4,61	4,48	6,95
CD	3,15	2,77	2,88	3,00	2,94	3,79
MD/CD	1,70	1,50	1,57	1,54	1,52	1,83
Stretch, % MD	1,32	1,51	1,61	1,43	1,45	1,14
CD	2,07	2,16	2,29	2,18	2,26	2,35

TABLE 5. Properties of newsprint containing 20% LYS and various amounts of CTMP and SGW.

LYS, %	20	20	20	20	20	20
CTMP, %	0	10	20	30	40	50
SGW, %	80	70	60	50	40	30
CSF, ml	81	81	82	106	---	143
Bauer-McNett Classification % R14	2,3	1,9	2,4	2,4	---	2,6
R28	14,2	13,3	12,4	13,9	---	14,3
R48	18,9	19,9	20,0	22,2	---	24,3
R100	16,9	19,4	23,2	22,1	---	22,8
R200	14,1	12,9	12,4	11,1	---	9,4
P200	33,6	32,6	29,7	28,3	---	26,6
Bulk, cc/g	2,46	2,26	2,50	2,22	2,54	2,22
Porosity, ml/min	237	240	311	309	329	352
Roughness F	7,2	6,5	7,3	6,6	7,2	6,8
(Parker Print Surf), T	5,9	5,4	6,3	5,7	6,5	6,0
Brightness(Elrepho), %	57,3	56,4	56,8	56,5	57,7	56,8
Opacity, %	95,4	95,9	92,7	93,3	91,1	91,9
Burst, (kPa·m²/g)	1,91	1,79	1,97	1,96	1,70	2,26
Tear, (mN·m²/g) MD	3,89	4,15	4,10	4,63	3,89	4,85
CD	4,54	4,72	4,82	5,19	4,48	5,73
MD/CD	0,86	0,88	0,85	0,89	0,87	0,85
Tensile, km MD	5,34	5,94	6,13	6,50	5,60	7,34
CD	3,15	3,29	3,34	3,68	3,29	3,29
MD/CD	1,70	1,81	1,84	1,70	1,70	2,23
Stretch, % MD	1,32	1,26	1,28	1,30	1,30	1,14
CD	2,07	2,24	1,96	2,01	2,01	2,18

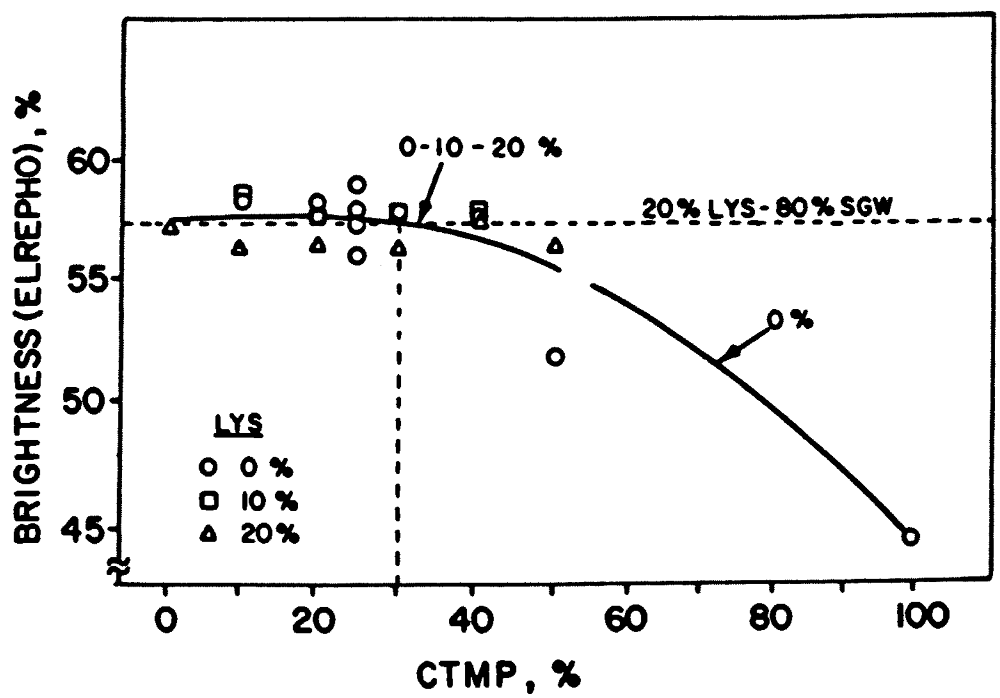

FIGURE 1. Variation of sheet brightness as a function of CTMP addition.

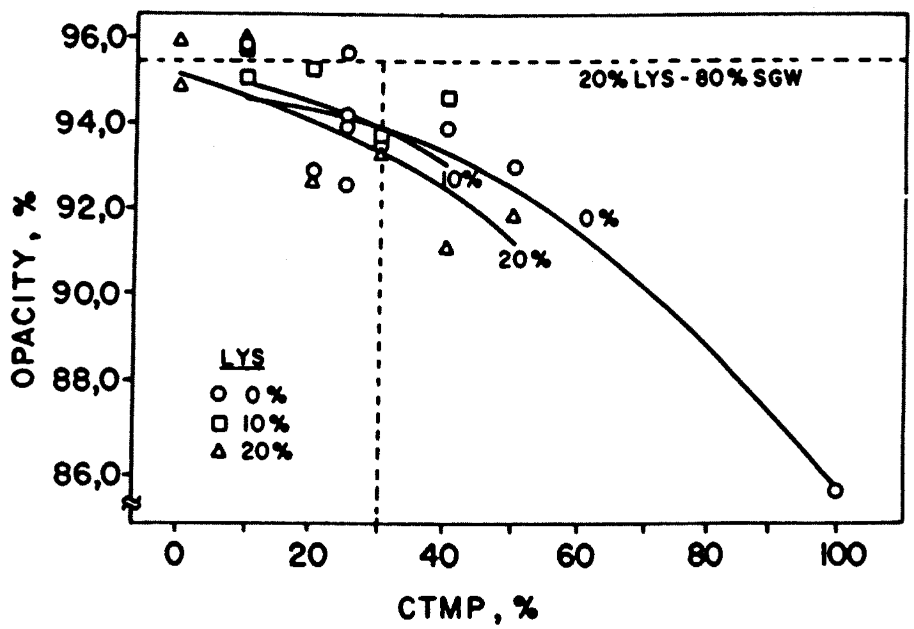

FIGURE 2. Variation of sheet opacity as a function of CTMP addition.

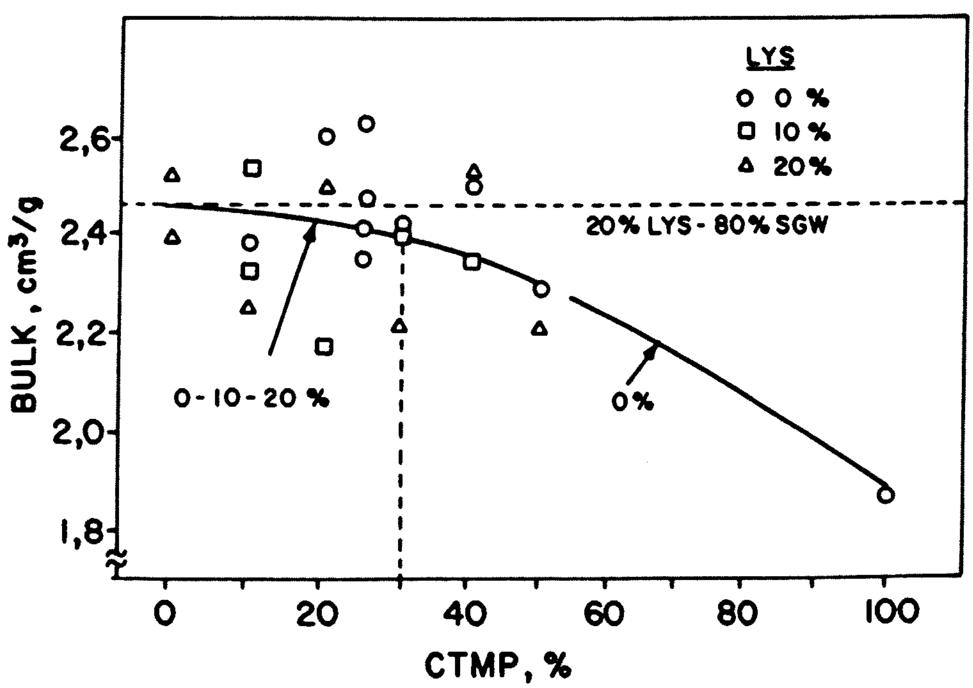

FIGURE 3. Variation of bulk of newsprint as a function of CTMP addition.

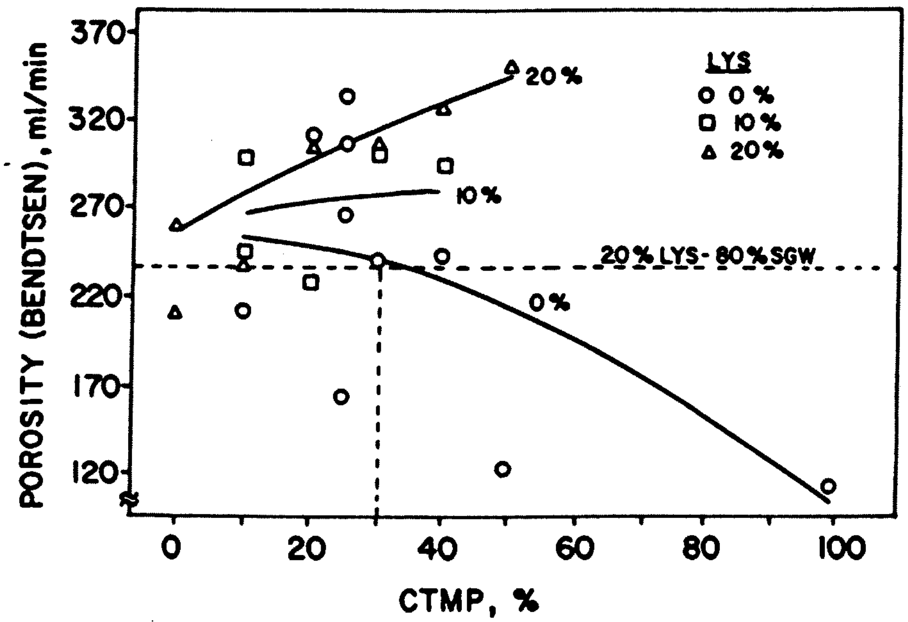

FIGURE 4. Effect of the addition of CTMP on newsprint porosity.

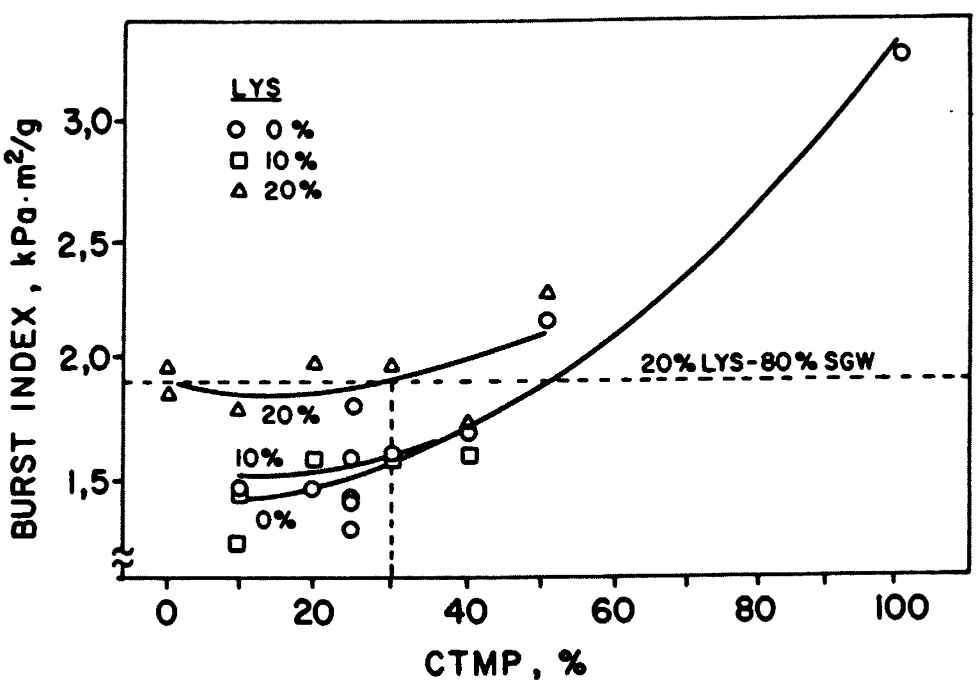

FIGURE 5. Effect of the addition of CTMP on burst strength of newsprint.

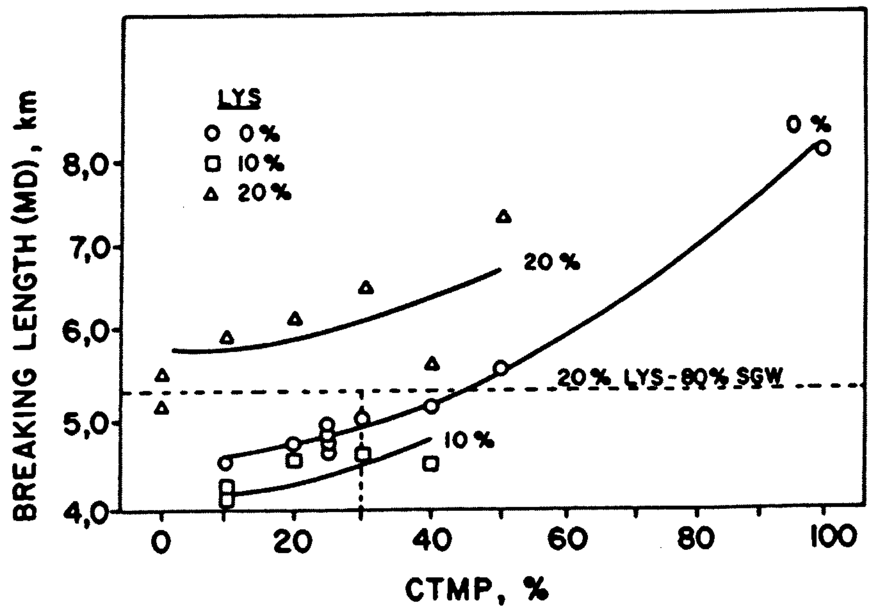

FIGURE 6. Influence of the addition of CTMP on tensile strength of newsprint.

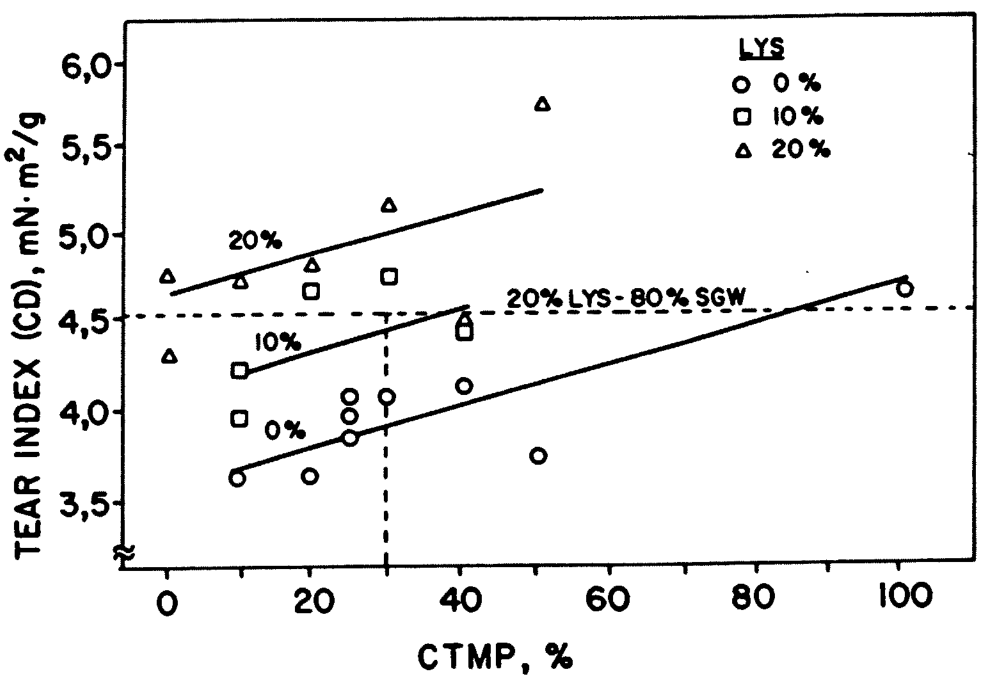

FIGURE 7. Influence of the addition of CTMP on tear strength of newsprint.

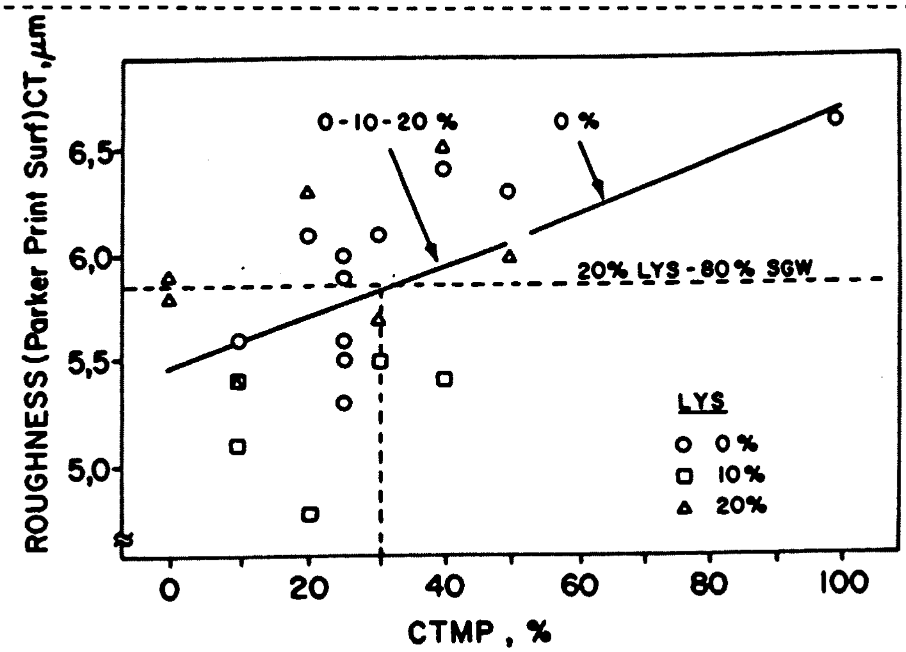

FIGURE 8. Variation of sheet surface roughness as a function of CTMP addition.

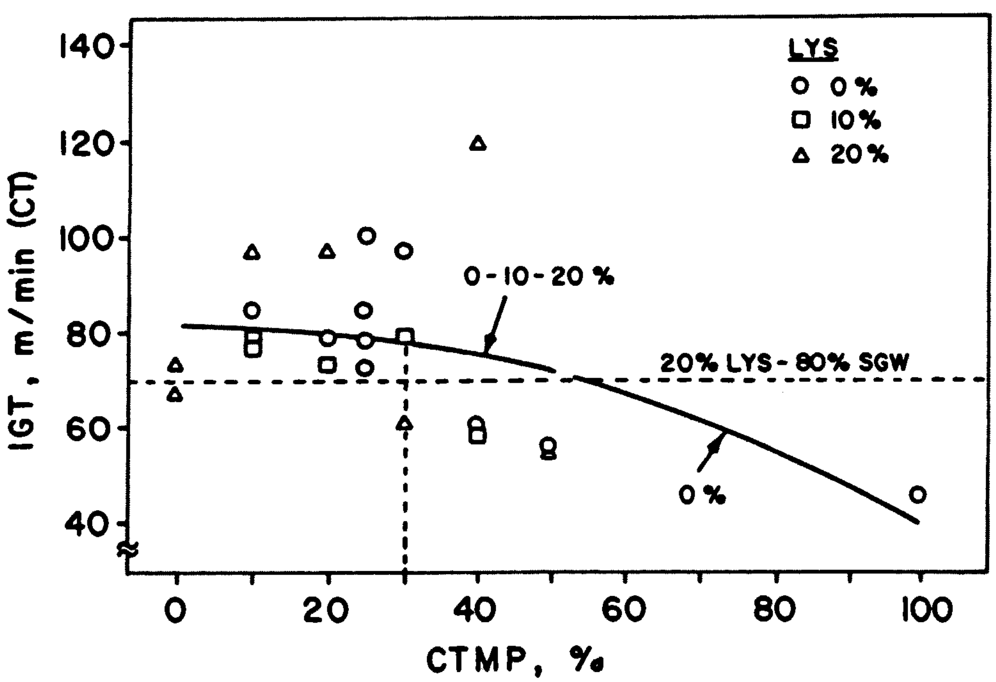

FIGURE 9. Effect of the addition of CTMP on pick resistance of newsprint.

INNOVATIONS FOR HARDWOOD UTILIZATION: CATALYSED ORGANOSOLV PULP AND SACCHARIFICATION

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I. NAEM PULPING

Primarily underutilized, pure and mixed aspen, poplar, birch and softwood raw materials can be effectively converted to fully bleached chemical pulps at high yield (> 54%) by the neutral alkali earth metal (NAEM) salt catalysed organosolv pulping process with ethyl alcohol and lignin as by-products. Besides the high pulp yield and viable by-products, the process advantages include: small economies of scale, low capital investment, extremely low overall process-water requirement, low pulp manufacturing costs, lack of environmental pollution and a high rate of return on investment. Small-scale plants under 100 tpd are also possible.

II. ACOS HYDROLYSIS TO WOOD CHEMICALS

By slight modifications to the organosolv chemistry, the pulping process is converted into a highly efficient wood hydrolysis process which quantitatively decomposes wood into its chemical components of sugars and lignins. These can serve as basic feedstocks for biological and chemical technologies leading to any or a combination of ethyl alcohol, acetone, butyl alcohol, propyl alcohol, phenols and aromatic hydrocarbon products to supply oxygenates and other liquid fuel chemicals into the growing liquid fuel markets. This industry would depend solely on forest and wood processing residues as its source of raw material and thus would not compete in any way, but complement the traditional wood uses of lumber and pulp production. Process advantages include quantitative chemical (sugar and lignin) recoveries, small economies of scale, low environmental stress and high rates of return on investment.

Integration of organosolv pulping with organosolv wood hydrolysis would more than double the potential output of Alberta's forests. Due to the currently high interest in oxygenates (alcohol) as octane enhancers in gasoline in the USA, the additional revenue would have a substantial effect on the profitability of aspen processing to pulp and chemicals in Alberta as well as significantly stabilize forestry operations in the future.

INTRODUCTION

Aspen, balsam poplar and birch represent some 13.5 million m^3 or 40% of Alberta's potential annual yield of forest resource. Currently, only about 1% of this resource is used for the manufacture of products and natural decay of overmature timber (over 40 years of age) devours 10% to 20% of this wood volume per year. Assuming that the above annual cut represents only 30% of the total growing associate biomass (it is perhaps less), an additional 31.5 million m^3 cellulosic biomass could be salvaged if commercial uses would be found to make use of such low value wood.

Constraints to aspen/poplar utilization have been extensively studied in the recent past. Utilization potentials of aspen have centered on reconstituted glued wood products such as waferboard, oriented strandboard (OSB) and plywood and to a minor degree on manufacture of dimension lumber. These uses are severely limited by the substantial variability of aspen stands, the large distance from viable markets and the currently limited size of the panel product and dimension lumber markets accessible to Canada.

Somewhat better and more open potentials seem to exist for pulp and paper products. With new demands created by information explosion technologies (computer and telecommunication) writing and specialty papers showed 4% to 6% annual growth, whereas the overall growth for pulp products continues at the rate of 1.8% to 2% per annum. Of the current 50 million tonnes total pulp and paper production, 25% (13 million T) originates from Canada. World pulp and paper demand is expected to grow to 100 million T/year by the year 2000 and if Canada is to maintain its share of the market, substantial new pulping capacity will be required by that time. Increasing amounts of this new demand are currently supplied by thermomechanical and particularly short fibered (Eucalyptus and Gmelina) pulps from South America. Aspen pulps are expected to be fully competitive with these hardwood pulps in the future.

Constraints to expand the pulping industry in Alberta seem to be set by a number of factors such as: the excessive capital cost of economically viable pulp mills (> $400 million), environmental problems associated with water/wastewater usage/disposal, high transportation costs and distance from markets. Such constraints can be overcome only if new, more efficient pulping processes are developed and introduced. To date, the high capital cost and environmental (water use) problems were responsible for the reluctance of close to half a dozen wood processing companies to build new grassroots pulping facilities in Alberta (and across Canada, for that matter) during the past 15 years. The urgency for changing this situation cannot be overemphasized considering that short fiber hardwood pulps are gaining significant acceptance in the marketplace.

The forest and waste residue volume (31.5 M M^3) associated with the annual allowable hardwood harvest in Alberta is sizable indeed. Its utilization for wood chemical products is facilitated and encouraged by the fact that such use has no wood quality criteria and both decayed and sound wood residues have equal utility in the conversion process. Of the two major chemical product streams of sugars and lignin, sugars can be fermented into ethyl alcohol (a liquid fuel and important industrial chemical) and the lignin can be processed to phenols suitable for manufacture of phenol formaldehyde resins, high capacity absorbents, aromatic hydrocarbons.

Development of these technologies and markets would significantly improve the otherwise very low wood utilization standard of hardwood forests, reduce the effective harvesting costs for hardwood logs and, in general, improve the profitability of forestry operations in Alberta.

I. ORGANOSOLV PULPING

Organosolv processing of wood to pulp and dissolved wood chemical employs a water-miscible organic solvent, such as an alcohol or ketone and a suitable catalyst. Table 1 provides a broad summary of the various organosolv systems proposed in the past. Of these systems, only a few are currently researched intensively with an aim toward commercialization. Published results on aspen, poplars and other comparable species, are summarized in Table 2.

It is suggested that the combined parameters of pulp yield, chemical and physical/mechanical properties of the respective pulps are reflections of the capabilities of the processes listed in Table 2. These values are indicative of the utility and economics of the process in question. Thus, a high pulp yield at low Kappa number (residual lignin content) and a high viscosity is desirable for best pulping results. For aspen pulps, Kappa numbers above 30 are considered high especially if the viscosity is below 20 cP. The level of strength properties (especially breaking length or tensile and tear) on the other hand are a reflection of the pulp's papermaking potentials.

A further important consideration of a new pulping process is its versatility with respect to production of various grades of papers and pulps and its flexibility with respect to adaptability to different wood species. Papermaking properties of pulp fibers have been effectively controlled by manipulating the pulping process by which the fibers were produced. However, for one reason or another, not all wood species can be pulped by the conventional pulping methods in use today, economics (high chemical consumption) or unacceptable pulp quality being such reasons.

Thus, the capability of mixed species (hardwoods and softwoods) processing is a desired characteristic of new pulping process especially if one considers that most northern hardwood forests contain various proportions of aspen, poplar and birch and occasionally softwoods (spruce, pine and fir). The best organosolv pulping method is expected to treat all these species with nearly equal efficiency without the necessity of separating the chips of the various species.

No organosolv pulping process has reached commercial scale to this date. On the basis of published results, the NAEM catalysed organosolv pulping process fulfills most, if not all, the requirements of short cooking time, high pulp yield at low lignin content, high pulp (cellulose) viscosity and high pulp strength. Other advantages of this process will become evident from the discussion which follows. Thus, the NAEM catalysed organosolv process is capable to produce a bleachable grade aspen pulp in 30 minutes at a 63% yield having a Kappa number of 25 and a TAPPI 0.5% CuEn viscosity of 50 cP. This pulp also has the highest sheet strength among all the pulps produced by the processes in Table 2 listed. Similar strength values were also reported by Professor Sarkanen and recently closely approached with poplar pulps from 30L cooks by Michie [1].

With respect to first pilot plant facilities, the MD Papier process in West Germany is considered to be the furthest advanced as it operates a 100 kg/day capacity continuous pulping pilot plant near Munich, West Germany. A 2 T/day capacity pilot plant of similar construction is currently underway. This pilot plant is a miniature replica of a real organosolv pulp mill, complete with solvent and lignin recovery. Another organosolv reactor with continuous chip feeding against high pressure (34-50 bar) is now operating in Brazil. Other high-pressure feeders are now also available in Canada.

PULPING BY THE NAEM PROCESS

Pulping of aspen by the NAEM process [2] involves digestion of the chips in a closed pressure vessel at 190°C with a solvent system composed of 80% methyl alcohol and 20% water in the presence of small amounts of alkali earth metals as catalyst. The cooking times are under one hour and typically around 30 to 40 min. At the end of the cook, the liquor is withdrawn and the chips disintegrated in the presence of excess solvent. The pulp fibers are washed with the solvent and sent to the bleach plant where they can be bleached by simple two- (D-P) or three-stage (C/D-E-H) sequences to up to 90% GE brightness. The cooking liquor withdrawn is allowed to expand and cool by flashing. On total removal of the methyl alcohol, the dissolved lignin precipitates out as a fine powder, leaving the dissolved sugars behind in the aqueous phase. Solvent removal and liquor re-circulation concentrate the sugars in the aqueous phase and these following simple polishing can be fermented to ethyl alcohol. The residual methyl alcohol left behind in the aqueous phase is recovered along with the fuel grade ethanol.

Both softwood and hardwood pulps bleach with relative ease. The bleaching chemical requirements are commensurate with the residual lignin content (Kappa No.) of the pulps. The Kappa number of high yield pulps is readily reduced by pre-bleaching such as prenox to quite manageable levels.

In comparative tests, strength properties of both bleached and unbleached hardwood and softwood pulps were found to be equal to those obtainable by the kraft process from the same species. Unbleached pulps required lixiviation, a process adapted by Paszner and Behera [3] involving ion exchange of divalent ions (Ca^{++} and Mg^{++}) for sodium with a weak acid wash followed by a soaking in a mild alkali solution. Bleached pulps do not require lixiviation if the initial bleach step is carried out under acidic conditions. Alkali soaking of the chips before disintegration can be beneficial and prevents excessive fiber damage due to the brittle nature of the fibers emerging from the 80% alcohol solutions.

The bleached fiber pulp is flash dried to produce a fluff pulp at 15% to 20% moisture content.

ADVANTAGES OF THE NAEM CATALYSED ORGANOSOLV PULPING PROCESS

I. YIELD

Perhaps one of the first and most obvious advantages of the NAEM catalysed pulping process is its capability to produce bleachable grade pulps at a wide range of yields (52% to 72%). The high pulp yields become possible because of the preferential topochemical effect and high initial delignification selectivity of the cooking solvent used [4]. Detailed studies of the delignification process on NAEM catalysis revealed that initially, lignin removal is restricted almost exclusively to the middle lamella holding the fibers together in the wood matrix. Thus, even high yield pulps do not require refining because they contain less than 0.2% rejects.

Conservatively calculated, in a 150 T/day capacity bleached pulp mill, every percentage point increase in the pulp yield between 43% (bleached kraft pulp yield) and 58% (NAEM catalysed aspen organosolv pulp, ie., 15 percentage point increase in pulp yield between kraft and organosolv processing) represents $0.52 M/percentage, or a total of $7.8 M in increased revenue to the mill per year. Therefore, a high bleachable pulp yield is economically most important. Recently, such high pulp yields (68%) were confirmed from $CaCl_2/H_2SO_4$ catalysed organosolv cooks on poplar by Michie [1]. The relatively low bleached pulp yield of the kraft process (38% to 43%) has long been criticized as inadequate in the past. The higher pulp yields (as compared to the other organosolv processes) of the NAEM catalysed process are believed to be due to the substantial hemicellulose retention afforded by the high delignification specificity of the neutral catalysts (pH 4.2) used at the high (80%) alcohol concentration in the cooking liquor. It was found earlier that the selectivity of alcohol solvents for lignin decreases with increasing water content in the cooking liquor.

It is thus obvious that the NAEM catalysed process yields some 20% to 35% more salable pulp than the kraft process.

II. CAPITAL COST

Due to process simplicity, lack of complicated chemical recovery and pollution abatement equipment requirements, organosolv pulp mills are expectd to cost only one-third as much to construct as kraft mills for comparative pulping capacities. Detailed calculations show that while the legendary minimum capacity kraft pulp mill (700 T/day) will cost around $400 M to construct, the same capacity NAEM catalysed organosolv mill will cost only $126 M to build. Sensitivity analysis also shows that the minimum economical capacity organosolv pulp mill is around 80 to 100 T/day (Figure 1) costing about $35 M. The advantages of such a small pulp mill are multifold, one of which is that smaller sustained yield units can readily supply the wood requirements in perpetuity without facing long hauling distances for wood collection. At the same time, the option also exists to base such small mills entirely on chip supplies produced by saw mills within a reasonable proximity and thus eliminating the costly woodroom expenditures (log booming, sorting, and chipping).

The small economies of scale pulping (as low as 50-80 T/day) therefore significantly affect the capital cost necessary for establishing a pulp mill, whereas at the same time assure increased profitability and competitiveness of the industry on international markets. Similarly, such small capacity mills would be ideally suited for providing small incremental capacities to existing mills without the dangers of overloading the recovery furnace of such mills having independent recoveries (distillation) of their own.

III. ENVIRONMENTAL CONSIDERATIONS

Both sulphite and kraft chemical pulping processes suffer from extensive air and water pollution due to the presence of and necessity to recover the sulphur compounds from the spent cooking liquors. Up to 45% to 50% of the capital cost for erection of kraft mills is dictated by chemical recovery and pollution abatement. About half of this expenditure (or $200 M in the case of a minimum economical capacity kraft mill) must be considered as nonproductive and laid out to secure compliance with current environmental laws.

Further, the effluent load from bleached kraft mills is between 5,000 to 15,000 T per tonne of bleached pulp. This amount of effluent requires treatment prior to discharge into the waterways to eliminate its BOD and toxicity.

Regarding both of these considerations, the organosolv process shows considerable advantages. Since organosolv cooking liquors do not contain sulphur and the NAEM salts are environmentally harmless (the oceans and fresh water supplies contain substantial quantities of calcium choloride, magnesium chloride and magnesium sulphate), effluents for the NAEM catalysed organosolv process will not require extensive treatment before discharge. It is anticipated that the organic loads will be largely recovered in the form of by-products the pulping liquor.

Both the water supply criteria and effluent disposal problems are grossly minimized from organosolv pulp mills due to the fact that 80% of the process liquor is made up of alcohol which is recovered and extensively recycled. The absence of sulphur from all stages of pulping makes solvent and by-products recoveries (lignin precipitation, sugar fermentation and organic acid recovery) very simple and inexpensive indeed.

IV. BY-PRODUCT RECOVERIES

Theoretically, sugars and lignin are the major by-products of pulping with small amounts of acetic acid and methanol forming. Bleach plant effluents contain mono- and dicarboxylic acids as oxidation products of lignin.

Sugar and lignin utilization as by-products of the pulping process has long been practiced by the sulphite pulp industry. However, less than 10% of the total world pulp production is made by this process today.

In the kraft process, the sugars are degraded to isosaccharinic acid in the alkali liquor, their reconversion to fermentable sugars is difficult and the recovery from the spent liquor seriously disrupts both the energy and cooking chemical recoveries of the process. Similarly, lignin recovery from the kraft black liquor requires acidification, a process both costly and disruptive of the energy and cooking chemical recoveries from the spent liquor. For the kraft process, energy self-sufficiency is largely predicated on the burning of the black liquor organic solids (sugars and lignin) and, although it can be shown that the cost of this form of energy is the most expensive energy money can buy, due to the requirements for chemical recovery, the law of economics is completely ignored by the industry.

In organosolv pulping, by-product (lignin) recovery is an incidental benefit of the solvent (alcohol) recovery. On flashing the cooking liquor, the lignin is automatically precipitated out in a granular powderous form. The sugars remain dissolved in the aqueous phase and can be readily transferred into a fermentable state with a minimum of effort. Due to the extensive solvent recirculation between the organosolv pulping stages and removal of the organic phase (distillation of the alcohol) sugar concentrations as high as 30% can be reached. Such high sugar content mash allows for use of the most energy efficient fermentation/distilla- tion process known today.

In a 150 T/day capacity NAEM catalysed organosolv pulp mill, the by-product credits from lignin and ethanol marketing exceed the total value of the raw materials (wood, catalyst, solvent and bleaching chemical) and thus contribute significantly to the excellent economics of the process (Table 3).

Lignin utilization is expected to reach commerical levels as a result of organosolv process developments. Lignin constitutes up to one-third of the mass of wood and thus substantial quantities will become available on commercialization of the organosolv process. Organoslv lignins are known to be free of contaminants (sugars and metal ions), have high solubility in organic solvents because of their non-condensed form and low molecular ($\underline{M}_w$ = 1200-2800) and high reactivity in various chemical applications. Through appropriate arrangements, better than 50% and up to 70% of the phenol can be replaced with organosolv lignins in phenol-formaldehyde resins. Large quantities of lignin could be marketed as industrial (metal) absorbents, aromatic liquid fuels, phenols and solvents. The question of lignin utilization, though currently studied very intensively, is largely unsettled. The value of lignin ranges between $60/T to as high as $950/T depending on the end use. Marketing of the lignin by-product, therefore, is expected to contribute substantially to the economics of organosolv pulping.

V. SHEET (PAPER) PROPERTIES

Recent studies by Paszner and Behera [3] have shown that organosolv pulps following the alkali treatment had equivalent strength to similar kraft pulps.

With aspen pulps a breaking length (tensile) of 11.3 km and a tear factor of 70 to 80 can be achieved. There are indications that in admixtures with birch even these values could be exceeded and that such pulps would be fully competitive with European beech and South American (Brazilian) Eucalyptus pulps. The production costs of aspen organosolv pulps would be substantially lower, especially if manufactured in optimum (ca. 400 T/day) rather than minimum capacity (100 T/day) mills.

In summary, based on the currently available knowledge on organosolv pulping, this new technology excels in both technological and economic terms, and is expected to open up vast opportunities in processing and marketing the unused aspen resources in Canada. The expressed interests of equipment manufacturers recently [5,6] is an indication and confirms the above statements.

II. WOOD WASTE PROCESSING BY THE ACID CATALYSED ORGANOSOLV SACCHARIFICATION (ACOS) PROCESS

Up to 70% of the primary wood biomass ends up in one form or another in waste. Its chemical utilization could greatly contribute (double or triple) to the degree of resource exploitation, and also increase the profitability of primary wood (lumber, pulp and paper) conversion. The lack of wood quality criteria of raw material destined for chemical conversion eliminates competition for prime wood.

Traditional technologies, weak and strong acid hydrolysis and gasification, as well as the newer technologies of enzymatic hydrolysis and steam explosion, failed to provide economically viable alternatives for converting wood waste into ethanol. The problems with these technologies are well documented in the literature [7].

Organosolv saccharification represents basically the same technology as described earlier for pulping by Kleinert and others, however, we have refined the technique by judicious selection of the conditions under which rapid hydrolysis of cellulose and dissolution of the lignin, and indeed that of wood, occurs. The Kleinert process was optimized for maximum fiber production, whereas the ACOS process is optimized for maximum hydrolysis.

During the process of investigations, it was found that, in the presence of an acid catalyst, acetone rapidly complexes at high temperature with the carbohydrates in the wood matrix even in the presence of water, causing its rapid and quantitative disproportionation into monomeric sugar derivatives (isopropylidenes) and a largely depolymerized natural lignin product [8]. The sugar derivatives can be quantitatively decomposed to recover the reducing sugars and the solvent (acetone).

Technologically, the ACOS process shows many similarities to the NAEM catalysed pulping process, the difference being that in the ACOS process, the reagents and process conditions are selected in such a way that total decomposition (hydrolysis and dissolution) of wood is obtained within the digester proper within the given hydrolysis time. Recovery of cellulose (microcrystalline cellulose) is only an option and can be obtained by interrupting the hydrolysis process at around 70% weight loss of the feedstock. In pulping, on the other hand, the conditions are so selected as to minimize the hydrolytic attack on the carbohydrates (hemicelluloses and cellulose) to assure maximum pulp yield and strength.

Recoveries of solvent, lignin and sugar for ACOS process largely duplicate those described for recovery of the by-products from the pulping spent liquor. Characteristically, however, due to the more rapid hydrolysis rate in the ACOS process, the concentration of sugars in the aqueous phase after evaporation of the solvent (acetone) reaches between 30% to 50% depending on the solvent-to-substrate ratio used. In spite of the high hydrolysis temperature (180° to 220°C) no furfurals were detected in the hydrolysis liquors due to the protective effect of the complexes, and the low acid concentration (0.005 M) used.

As indicated above, the sugar yield exceeds 95% of the theoretical yield. Thus the ethanol yield from aspen wood calculates to about 480 L/T if simultaneous xylose/hexose fermentation is practiced, as became possible recently by the new BIOSTIL process [9]. The process also yields about 170 kg of powdered lignin, some methanol and mixed phosphates if phosphoric acid is used as acidification catalyst for the secondary hydrolysis phase where the sugar/ acetone complexes are destroyed.

Feasibility and economic calculations indicate that the required non-credit rated ethanol selling price will vary between \$0.503/L for a 100 T/day (16,000,000 L/Year) capacity plant to \$0.260/L for a 1,000 T/day (158,400,000 L/Year) plant. Credit-rated ethanol selling prices for the same capacities calculate to \$0.378/L and as low as \$0.135/L, respectively. Medium capacity plants at 300 T/day should be able to produce ethanol at \$0.20/L when the lignin selling price is fixed at \$150/T. A sample calculation of the ethanol production costs for 300 T/day capacity plant using a mixed sawdust feed is provided in Table 4. Capital costs calculate to \$13.5 M at 100 T/day to \$53.5 M at a 1,000 T/day capacity. At the current \$0.63/L rice for ethanol, plants as small as 110T/day (16,000,000 L/Year) feedstock consumption seem to be economically viable.

To confirm the technical and economical predictions for the ACOS process, a pilot plant of 100 L/day capacity is currently under active testing in Brazil. Plans for an ACOS (5,000 L/day) pre-commercial plant is in an advanced planning stage.

SUMMARY

Under the prevailing economic and industrial conditions, both paper products and liquid fuels are expected to represent good potentials in large volume marketing of aspen in the future. The long-term viability of such a scheme is largely predicated on the fact that pulp and paper, and liquid fuel production from aspen and other associated species will present new directions of hardwood utilitzation of Alberta's forest resources. Integrated production of pulp and paper and fuel ethanol is considered to be a highly compatible means of aspen utilization since it provides the means for 100% utilization of the growing biomass without restrictions as to the quality of the raw material supply. Therefore, integrated production of pulp and wood chemical (ethanol and lignin) by organosolv means suggests itself as an attractive means to maximize the value of the unused Alberta hardwood resource.

In terms of these products, the current 13.5 million m^3 (3.375 million MT) allowable prime timber volume is worth $1.2 billion when converted to bleached pulp. It is anticipated that about three times this volume or 40.5 million m^3 (10.1 million MT) woodwaste is associated with the above allowable prime wood production. At 420 L alcohol/T this biomass represents $2.15 billion when converted to ethyl alcohol with an associated $367 million in lignin sales. Thus the total revenue from the converted aspen resource could be $3.717 billion annually. No doubt, both injection of such revenues and creation of jobs required to bring about such conversion would have a very significant effect on the provincial economy in the future.

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Table 1.
MAJOR ORGANOSOLV PULPING SYSTEMS

SOLVENT	CATALYST
ETHYL ALCOHOL	HCl, NaOH, NH_3, $Al_2(SO_4)$, $AlCl_3$, $(NH_4)_2S$, $NaHCO_3$+ MAQ, HCOOH
METHAYL ALCOHOL	$CaCl_2$, $MgSO_4$, NaOH, SO_2, Oxalic acid, Salicilic acid, Kcl/HCl
i-PROPYL ALCOHOL	$NaHSO_3$, Na_2SO_3
BUTYL ALCOHOL	HNO_3, AQ
ETHYLENE GLYCOL	$Al(SO_4)_3$, $AlCl_3$,
PHENOL	HCl
CRESOL	-
FORMIC ACID	-
ACETIC ACID	-
ACETIC ACID/ETHYL ACETATE	-
ACETONE	HCl, NH_3
M.E. KETONE	-
CYCLO HEXANONE	NH_3
DIOXANE	HCl, H_2SO_4
SULFOLANE	Na_2S, H_2SO_4
DMSO	SO_2, NO_2, H_2SO_4
1,6 HEXANEDIAMINE	-

Table 2.

COMPARATIVE RESULTS ON ORGANOSOLV PULPING OF ASPEN

Proponent	Kl	MD I	MD II	B/K	P/C	Bt	Jap	Yg
Wood Species	Aspen	Poplar		Aspen	Aspen	Birch	Beech	Aspen
Temp(C)	190	195		190	190	100	185	170
Time(min)	120	45		180	30	240	300	180
Solvent(%)	EtOH(50)	EtOH(60)	EtOH(50)	EtOH(60)	MeOH(80)	Phenol(40)	Cresol(80)	HOAc(33) EtOAc(33)
Catalyst	-	-	NaOH	-	$CaCl_2$	HCl	-	-
Yield(%)	52	55	46	53	62	42	53	48
Kappa No.	18	57	35	27	19	14	25	10
Viscosity(cP)	22	26		32	55	30	19	NA
Breaking(km)[@]	7100	7800		7200	11000	7800	5300	NA
Burst[@]	39	NA		50	60	42	33	NA
Tear[@]	78	66		65	71	68	60	NA

[@]300 mL CSF

KI:Kleinert
MD:MD Papier(W.Germany)
B/K:Bec/Katzen(Alcohol Pulp Recovery)
P/C:Paszner/Chang(Catalysed Organosolv)
Bt:Battelle(Phenol Pulping)
Jap:Papan PPRII(Cresol Pulping)
Yg:Young(Ester Pulping)

Table 3. ORGANOSOLV PULP PRODUCTION ECONOMICS

PLANT DESCRIPTION

PRODUCTION: PULP: 150 TPD* (49 500 TPY) Bleached Pulp.
Pulp Yield 63%, Kappa No. 25, Bl.Y.: 58.3%

LIGNIN: 13 700 TPY
SUGARS: 13 218 TPY
(ETHANOL: 6 084 TPY; 7 665 450 L/Y)

CAPITAL COST: $ 50 000 000

Item	Quantity	Unit cost	TOTAL
RAW MATERIALS			
Wood Chips, T	84 905	45	3 820 755
Catalyst, T	400	300	120 000
Solvent Make-up, T	743	260	193 180
Bleaching Chemicals, T	1 485	650	965 250
ENERGY			
Steam, T	490 000	9	4 410 000
LABOR			
Operating	15	25 000	375 000
Supervisory	3	40 000	120 000
Overhead @ 30%			148 500
MAINTENANCE (3% of TCI)			1 500 000
CAPITAL CHARGES (0. 2153 of TCI)			10 756 000
TAXES & INSURANCE (2% of TCI)			1 000 000
TOTAL OPERATING COST			$ 23 408 685

PRODUCTION COST $ 23 408 685 : 49 500 = $ 472/T

BY-PRODUCT CREDITS (18 612x150)+(6 084x620) = $ 5 827 080

CREDIT-RATED PRODUCTION COST: $ 17 581 161:49 500= $ 355/T

PROFITS 49 500 x $ 625 = $ 30 937 500

Less Production Costs: $ 17 581 161

NET PROFIT: $ 13 356 339 (CDN)

TABLE 4.

ACOS ETHANOL PRODUCTION ECONOMICS

PLANT DESCIPTION:

FEEDSTOCK: 300 tonnes/ day (99 000 T/Yr) sawdust

PRODUCTION: 480 L of 95% ethanol per tonne sawdust. Annual production of 47 421 000 L/Yr at 330 days per year.

CAPITAL COST: $ 26 000 000

ITEM	QUANTITY	COST	TOTAL
SAWDUST, T	99 000	$ 7.00	693 000
ACID CATALYST, T	683	55.00	37 565
H_3PO_4, T	4 455	300.00	1 336 500
(H_2SO_4, T)	(4 455)	55.00	(245 025)
NEUTRALIZING AGENT, T	5 000	45.00	225 000
SOLVENT MAKE-UP, T	875	700.00	612 500
NUTRIENTS,			990 000
ENERGY, STEAM, T	484 110	9.00	4 365 990
LABOR:			
Operating	15	25 000.00	375 000
Supervisory	3	40 000.00	120 000
Overhead @ 30%			148 500
MAINTENANCE (3% of TCI)			780 000
CAPITAL CHARGES (0.2153 of TCI)			5 597 800
TAXES AND INSURANCE (2% of TCI)			520 000
TOTAL OPERATING COST:			$15 241 605 ($14 701 380)

PRODUCTION COST: $ 15 241 605 : 47 421 000 = $ 0.321/L

$ 14 701 380 : 47 421 000 = $ 0.310/L

Credit-rated ethanol cost: $ 8 302 155 : 47 421 000 = $ 0.196/L

REVNUE CONSIDERATIONS: At a current selling price of $ 0.398/L the annual operating profit is $ 3 651 417 or 14% on the investment. Accordingly, the by-product rated return is 36.9%.

PITCH CONTROL DURING THE PRODUCTION OF ASPEN DRAFT PULP

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When the wood supplied to a fully bleached kraft pulp mill is changed from softwoods to aspen (Populus tremuloides Michx.), the mill will tend to produce greater amounts of pitch-dirt contaminated pulp and may suffer production losses unless a number of precautions are taken. The reasons for this and the precautions are reviewed in this paper.

At the source of the problem is a substance, found both in softwoods and aspen, called pitch, or wood resin, which can be defined as the material in wood or wood pulps which is insoluble in water, but soluble in neutral organic solvents [1]. To determine the amount of wood resin in a sample of wood or pulp, a solvent extraction is carried out on the powdered wood or pulp in a Soxhlet extractor [2]; the amount of material dissolved in the solvent (the "extractives") provides a measure of the quantity of wood resin present.

Over the years, a number of different solvents have been used, ranging from ether and ethyl alcohol through to acetone, dichloromethane and the combinations of solvents, alcohol/benzene and ethanol/toluene. Unfortunately, each solvent dissolves a slightly different amount of material from the wood. Ether and alcohol probably do not remove all of the extractives, whereas the more powerful solvents such as acetone, dichloromethane and alcohol/benzene tend to dissolve all of the extractives and, in addition, take up certain small amounts of lignin and hemicellulose [3,4]. As will be seen later, this poses a problem when one compares work in the literature by different authors who have used different solvents.

NATURE OF PITCH PROBLEMS, SOFTWOOD AND ASPEN

There are a number of different kinds of pitch problems in kraft mills. Usually the worst deposition is in the unbleached screenroom on:

- the walls of pipes
- the surfaces of vats
- the screen plates
- the brownstock decker apron, and
- the repulper screw.

Although the deposits sometimes plug screen slots and cleaners, which necessitates cleaning them, the worst problems occur when the deposits break away from their surfaces of attachment. They get chopped up by pump impellers, agitators, etc., and culminate as finely dispersed dirt in the final product. In softwood mills, deposition in the unbleached part of the mill, followed by dirt problems, constitutes the major kind of pitch problem. In mills using aspen as a wood source, deposition in this area is usually greater than for softwoods; consequently, the use of aspen usually leads to greater amounts of dirt in the finished pulp unless more stringent measures are taken to control pitch.

In aspen mills, considerable deposition can sometimes be experienced in the E_2 and D_2 washers, bleached screens, cleaners and pulp machine. When this happens, runnability problems can be experienced and detached deposits can cause dirt and streaks in the pulp sheet. This kind of deposition is less prevalent in softwood mills.

The increased tendency for foaming caused by aspen use in some mills is sometimes countered by mill personnel with higher feed rates of brownstock defoamer. This can lead to problems with defoamer deposition, which often manifests itself with a rapid buildup of co-deposited defoamer and pitch, and subsequent dirt problems.

COST

The cost of pitch problems to the Canadian pulp and paper industry is considerable. It is difficult to estimate precisely; indeed, the amount varies from one mill to another and, within a mill, from year to year. From the author's experience, it is not uncommon for an 800 t/d fully bleached kraft pulp mill using softwoods, to spend, or lose, up to a million dollars per year. If the same mill uses aspen, this figure probably can be doubled.

The main components of this cost are additives and sales of off-grade pulp. When a mill is making dirt-contaminated pulp, the selling priced depends to a large extent on the market, but it is not uncommon to have to discount it by up to 40%.

The pitch problems are often sporadic and when they do occur they can be very expensive, especially if aspen is used. For example, a recent pitch problem in a western Canadian mill pulping aspen was estimated to cost 100 tons of production per day over a period of several months. This, in itself, would translate into about $50,000 of sales per day. Moreover, the substandard pulp was causing a loss in customer confidence. Under some conditions, this can be the most troublesome aspect of this kind of problem; valued customers begin to look elsewhere for good pulp.

WHY ASPEN GIVES MORE PROBLEMS

What are some of the reasons that aspen causes more serious pitch problems during kraft pulp manufacture? There are several.

The first is that aspen is one of the most resinous of Canadian tree species. Shown in Table I are the ether extractives contents of the woods from a number of softwood and hardwood species. The amount of extractives in aspen varies from 1.0% to 2.7% of the weight of wood. All of the softwood species except jack pine have less ether extractives. Jack pine itself is notorious for the large amounts of resin it contains and the pitch problems that it can cause during certain kinds of pulp manufacture, especially sulfite. Of the hardwood species in Table I, only birch equals or exceeds aspen in extractives content. Some of the values in this table may well be for seasoned wood; it was not clear in many of the papers from which they were taken whether or not the wood had been seasoned. In work from the author's laboratory, in which acetone was used for a solvent, the extractives content of aspen wood from a freshly cut tree was found to be 4.5%. This is a result which has since been repeated with wood from several different trees from several different locations in Ontario and Quebec. Thus, the extractives content of aspen, especially fresh aspen, is very high.

TABLE I. DIETHYL ETHER EXTRACTIVES IN VARIOUS WOODS [1]

SPECIES	EXTRACTIVES CONTENT (% of O.D. Wood)
Aspen	1.0-2.7
Spruce	0.4-2.1
Balsam fir	1.0-1.8
Douglas fir	0.4-2
Eastern hemlock	0.2-1.2
Western hemlock	0.3-1.3
Jack pine	1.3-4.3
Sugar maple	0.2-0.9
Beech	0.3-0.9
White birch	1.5-3.5

A second reason for the increased propensity for pitch problems when aspen is used is that the wood sometimes contains substantial amounts of bark and wood rot [5]. Especially in the winter months, when the wood is frozen, it is difficult to remove all of the bark from aspen logs. As is evident from Table II, the amount of alcohol/benzene extractives in aspen bark is greater than that found in the wood. Using the values 4.5% for the wood and 18% for the bark, it is evident that the amount of extractives in the bark is four times that of the wood. Furthermore, overly mature aspen wood often contains large amounts of wood rot. In the Russian literature, where the species Populus tremula has been examined, it was shown that the decayed wood contains a somewhat larger amount of extractives than the sound wood [6]. Preliminary work at PAPRICAN has shown that the acetone extractives content of decayed aspen can be several times that of sound wood [7].

TABLE II. PERCENT EXTRACTIVES IN ASPEN WOOD, BARK AND WOOD ROT

WOOD [8,9]	BARK [8,10]	WOOD ROT [6]
1.1[a] - 4.5[b]	11[a] - 18[c]	Shown to be higher than wood for *Populus tremula*[d]

---

a) Alcohol/benzene extractives.
b) Acetone extractives, which are usually comparable in magnitude with those of alcohol/benzene.
c) Sum of alcohol and benzene extractives.
d) Ether extractives.

Another important reason why aspen causes greater amounts of pitch deposition in kraft pulp mills is that its resin does not contain much saponifiable material. The latter becomes soap under the alkaline conditions that prevail in a kraft digester. The soaps actually aid in removing the remainder of the resin, the unsaponifiable or non-soap portion, from the pulp. In Figure 1a is a schematic representation of a soap molecule, in solution, with its hydrocarbon tail and carboxylate anion head group. Above a certain concentraion, the critical micelle concentration (CMC), these soap anions cluster together with their hydrocarbon tails on the inside and the head groups on the outside to form micelles (Figure 1b). The importance of this phenomenon, which always occurs in kraft digesters, is that these micelles are capable of solubilizing some of the unsaponifiable material [11,12]. The latter actually dissolves in the centres of the micelles (Figure 1c), where the hydrocarbon tails are concentrated. This phenomenon is the basis of detergency and is an important aspect of resin removal during kraft cooking. If there is not much soap generated in the wood during a kraft cook, then, clearly, there will be less removal of resin in the digester.

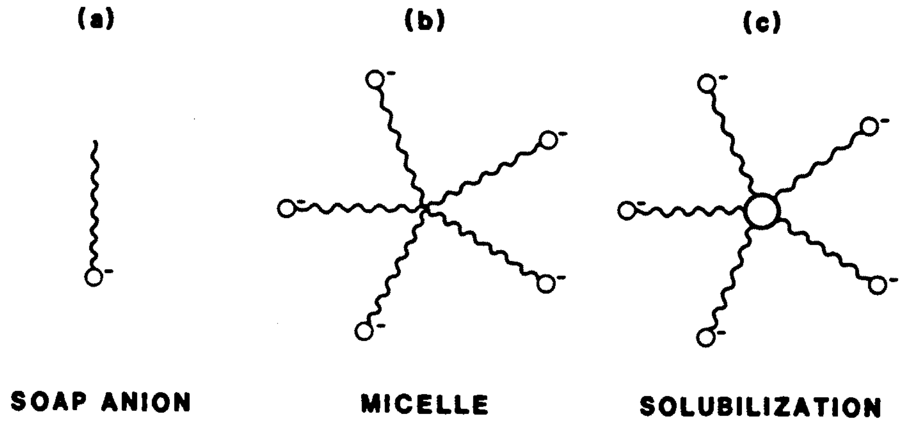

FIGURE 1: Schematic diagrams of: (a) a soap anion; (b) a micelle; and (c) a micelle solubilizing unsaponifiable material in its interior. Above the CMC soap anions in aqueous solution cluster together to form micelles which can solubilize unsaponifiable material. As the soap and micelles can be washed from the pulp in the brownstock washers, this constitutes an important mechanism of resin removal.

It is therefore appropriate to consider the ratio of saponifiables to unsaponifiables in the extractives of the wood. This, it turns out, is a good way to compare the deresination qualities of various different kinds of wood [13]. Shown in Table III are the saponifiables to unsaponifiables ratios for three species of wood: aspen, spruce and pine (calculated from the data of Nugent et al [9]). It has been estimated that for hardwoods a ratio of less than 3 will lead to poor deresination [13]. It is evident that, of the fresh woods, aspen has the lowest ratio of saponifiables to unsaponifiables. Spruce, on the other hand, has a ratio almost twice as high as aspen, and pine has a very high ratio indeed. Pine is, of course, well known for its very high soap content and the incidence of pitch problems with this species in kraft mills is relatively low.

TABLE III. SAPONIFIABLES/UNSAPONIFIABLES RATIOS OF FRESH AND SEASONED WOOD FROM THREE SPECIES

	FRESH	SEASONED 2 MONTHS
Aspen	1.2	0.3
Spruce	2.2	2.2
Pine	6.8	5.7

In the right hand column of this table, we have the saponifiables to unsaponifiables ratios for the three species after the wood has been seasoned for two months. It is interesting that the ratio decreases for aspen, which is a bit misleading, because seasoning generally leads to fewer resin problems. However, the concept probably holds for comparing the deresination tendencies of different species at a given time of seasoning.

Storage time of wood before pulping is a very important factor in determining whether or not pitch problems are encountered with aspen wood. Shown in Figure 2, for various amounts of seasoning, are the dichloromethane (DCM) extractives contents of wood pulps produced from birch and pine, taken from the work of Assarsson [13]. From the similar chemical compositions of the extractives in birch and aspen, and the close parallelism in the changes that occur in the resin of these two species during seasoning [14,15], it can very likely be inferred that similar results to those shown for birch in Figure 2 can be obtained with aspen. For unbleached pine, it is evident that, as the wood is stored as chips from 0 to 4.5 months, the amount of extractives in the pulp increases. Thus, pine is best used when it is absolutely fresh. Moreover, the benefits of pulping fresh pine are carried through to the fully bleached pulp. The situation for birch and aspen is apparently just the opposite. With chip storage, the amount of extractives in the pulp decreases with time. This is due to a number of reasons: the enzymatic hydrolysis of fats, the oxidation of fatty acids (eventually to water and CO_2), the consumption of fatty material by microorganisms, and, possibly, the evaporation of some of the more volatile resin components from the wood [9]. All of these lead to a decreased amount of extractives with time. However, even more importantly, the chemical composition of the resin changes with these processes. It appears that some of the unsaponifiables which are the most difficult to remove are hydrolyzed during storage [13].

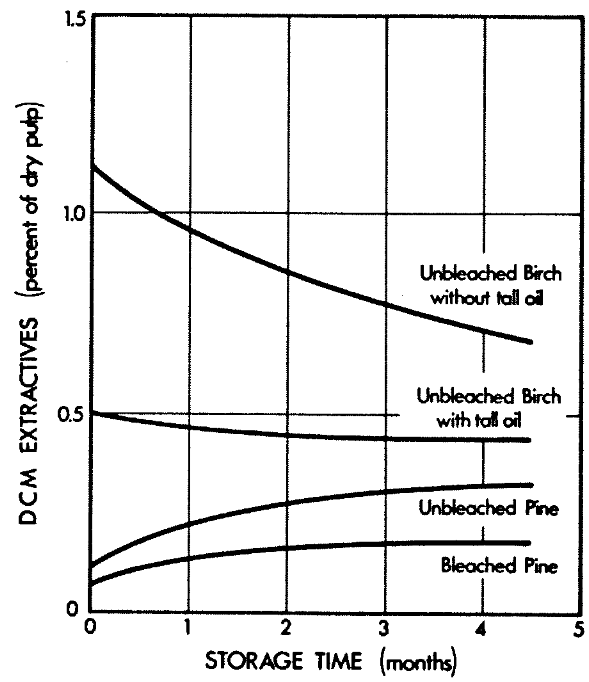

FIGURE 2. Effect of chip storage on the dichloromethane extractives contents of birch and pine kraft pulps [13].

It is interesting that, if tall oil is added to the digester during a cook of fresh birch (Figure 2), the amount of extractives in the unbleached pulp is almost halved [13]. This is a way of increasing the deresination of the pulp and, of course, is based on the introduction into the digester of soaps which solubilize the unsaponifiable portion of the resin.

METHODS OF PITCH CONTROL

Pitch control methods can be broken into two classes, those requiring changes in the wood or process and those requiring additives.

TABLE IV. PITCH CONTROL METHODS REQUIRING CHANGES IN THE WOOD OR PROCESS.

1. Season aspen wood before pulping [13].
2. Ensure good debarking [13].
3. Use a sufficiently large alkali charge to avoid zero residual effective alkali [16].
4. Improve white liquor clarification [17].
5. Improve efficiency of brownstock washing [18,19].
6. Control pH of unbleached screenroom water to 6.0-6.5 [20,21].
7. Avoid high feed rates of defoamer [22].
8. Avoid use of silica-in-oil or was-in-oil defoamers in the bleach plant.
9. Improve screening and cleaning.
10. Maintain pH below 6 on pulp machine [20].

The methods requiring changes in the wood or process are given in Table IV. These consist of seasoning the aspen wood before pulping, ensuring good debarking, and using a sufficiently large alkali charge to avoid zero residual effective alkali. The latter is somewhat more important when using aspen because the wood rot is often acidic in nature and tends to neutralize some of the alkali in the digester [5]. Other methods include improving the white liquor clarification (to remove calcium carbonate which tends to co-deposit in the unbleached area), improving the efficiency of brownstock washing (so that more soaps, micelles and solubilized resin are removed), and controlling the pH of the unbleached screenroom white water to 6.0-6.5. This last procedure can almost eliminate all deposition in the screen room because it stops the formation of calcium soaps which are one of the major glues in the deposits in this are of the mill [21]. In addition, calcium carbonate begins to dissolve at this lower pH [23]. High feed rates of defoamers should be avoided in the pulp mill and the use of silica-in-oil or wax-in-oil defoamers should be entirely eliminated in the bleach plant, as this kind of defoamer is designed for hot brownstock conditions and deposits heavily when used in the bleach plant. Other methods requiring changes in the wood or process involve improved screening and cleaning (to remove the dirt particles in the fully bleached pulp), and maintaining a pH below 6 on the pulp machine (to avoid the formation of sticky calcium soaps).

TABLE V. PITCH CONTROL METHODS REQUIRING ADDITIVES.

1. Add tall oil at the digester (1.5-2.5% of O.D. wood) [13,24].
2. Add surfactants at the digester [24].
3. Use talc [25].
4. Use dispersants (brownstock screenroom, E stages of bleaching, pulp machine) [24].

Methods of pitch control requiring additives (Table V) include the addition of tall oil at the digester. Scandinavian work with birch suggests that 1.5% to 2.5% is a good dosage [13]. It is interesting that many Canadian mills used this technique when they first started to pulp aspen, but have discontinued it because they found it was not sufficiently effective to warrant the cost and effort.

Synthetic surfactants are another class of additives sometimes used for deresination in the digester. These work by the same mechanism as shown earlier for soaps. The jury is out on whether or not this is an effective means of pitch control; certainly it can be expensive.

The use of talc is widespread in kraft pulp mills for combatting hardwood pitch problems. Talc is effective in the unbleached area because it is a detackifying agent and tends to reduce the stickiness of deposits and thereby inhibit their growth. It also has resin sorptive properties which become appreciable further along in the bleachery.

Finally, dispersants have been used in some kraft mills. In the unbleached screenroom their effectiveness has been shown to depend on the lignin concentration [26]. In some mills they are ineffective if the lignin concentration in the brownstock screenroom is high enough [27]. For deresinating the pulp, the introduction of dispersants in the E stages of bleaching is a classical method of removing resin [24]. Dispersants are also sometimes used in the pulp machine area if deposits are encountered.

AREAS FOR FURTHER RESEARCH

During the preparation of this review of the literature and technology of pitch control during the kraft pulping of aspen, a number of areas for further research surfaced. A list of some of these is given in Table VI.

TABLE VI. AREAS FOR FURTHER RESEARCH.

1. Determine the effectiveness of Canadian tall oils, which contain less soap than those from the U.S.A., for pitch control.

2. Investigate, under controlled laboratory conditions, whether nor not surfactants are cost effective for pitch control when added in a kraft digester.

3. Determine whether or not rosin size added in the digester is an effective way to control aspen pitch problems. Usually resin acids are not found in the deposits in unbleached kraft pulp mills.

4. Develop better ways to remove the resin in the kraft digester.

CONCLUSION

In conclusion, the technology exists for using aspen wood with relatively few pitch problems in a bleached kraft pulp mill. There are costs associated with this (some of them site-specific), but the choice of whether or not to use aspen often boils down to balancing these costs against the often cheaper wood and the higher yield of pulp from this species. In addition, a company faced with this choice will also have to consider its markets.

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HIGH-YIELD PULP FROM NORTH AMERICAN ASPEN (*Populus tremuloides*)

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ABSTRACT

Systems suitable for the manufacture of high yield pulps from North American Aspen (Populus tremuloids) are outlined. Physical property profiles of Aspen CTMP for a range of chemical treatments are discussed for end use applications in newsprint and magazine grades, in writing grades and in tissue products. The effects of treatment conditions on the properties of Aspen CMP, suitable for the partial replacement of bleached hardwood chemical pulp, are also discussed.

The implications of stain and decay on the quality of Aspen CTMP are outlined. It is shown that the main deleterious effects of increased rot content are related to yield loss and brightness degradation, particularly after peroxide bleaching, strength properties only being seriously affected for chips exhibiting an advanced state of decay.

The paper concludes with a comparison between the effects of separate and combined refining of Aspen and Spruce.

INTRODUCTION

The genus Populus with some thirty sub-species, together with the many different forms of Eucalyptus, represents the most common wood species in the world. In Europe, North Africa and temperate Asia a number of poplar sub-species (yellow poplar, black poplar, white poplar, pyramid poplar) are found in plantations, as garden trees and commonly as a 2-20% component in natural coniferous or hardwood forests. The most widespread sub-species in Europe is European aspen (Populus tremula) and this wood grows extensively over an area which extends from Norway and over the larger part of Europe, southward as far as North Africa and eastward across Northern Asia to Japan.

In North America, the situation is similar. Various sub-species of populus including trembling aspen (Populus tremuloides), cottonwood (Populus deltoides), bigtooth aspen (Populus grandidentata) and balsam poplar (Populus balsamifera) are found extensively in many of the forests of Canada and the United States. Despite this widespread availability and the fact that the poplars are by far the best hardwood species for high yield pulping, their usefulness as a raw material for the pulp and paper industry is not yet fully recognized.

For obvious reasons, this situation will change in the future. This paper discusses some ways of producing different pulp qualities from trembling aspen (Populus tremuloides). Pulp qualities are discussed in detail, the bleaching response of the pulp is considered and the influence of rot and wood decay on yield and pulp quality is highlighted as this aspect is of major importance.

MORPHOLOGY AND COMPOSITION OF HARDWOODS

Relative to softwoods, hardwoods in general exhibit a more complex physical structure. While softwoods essentially consist of one type of fibre (the tracheid) hardwoods, in addition to containing normal libriform cells, contain a larger proportion of parenchyma cells plus a rather high weight proportion of short but large diameter vessel elements. The main purpose of these vessel elements relates to the greater requirement of hardwoods to rapidly transport water through the wood structure to the crown of the tree during the relatively short growing season.

Hardwoods and softwoods differ considerably not only in terms of morphology but also in terms of chemical composition, hardwoods in general containing significantly lower amounts of lignin and correspondingly higher levels of cellulose and hemicellulose than softwoods. Furthermore, the manner in which the lignin is distributed within the middle lamella and into the cell wall also differs between hardwoods and softwoods. In softwoods the concentration of lignin in the middle lamella is about 73% while that in the cell wall is 13%. In hardwoods, the lignin concentration is higher in the middle lamella and lower in the cell wall with a more clearly defined transition zone. With softwoods, the more pronounced lignification of the cell wall restricts swelling in the presence of alkali to a greater extent than in the case of hardwoods, implying that different approaches may be necessary for the optimization of quality in the high yield pulping of softwoods and hardwoods.

CHEMITHERMOMECHANICAL PULP FROM NORTH AMERICAN ASPEN (POPULUS TREMULOIDES)

Conventional thermomechanical pulp from softwoods at freeness levels in the range 75-150 ml CSF exhibits a satisfactory combination of mechanical and optical properties. Such pulp can be used directly as the major furnish component of newsprint and other high volume printing grades. Refiner mechanical pulp from Aspen, while exhibiting good light scattering coefficient and thus high opacity, has poor bonding properties which do not even match the strength characteristics of stone groundwood. Thus, in order to achieve a suitable compromise between strength and optical properties, chemical pretreatment of hardwoods with sodium sulphite and sodium hydroxide is a prerequisite if furnish costs are to be maintained within reasonable limits.

Chemithermomechanical pulp (CTMP) from Aspen can be produced by impregnating the chips with a combination of sodium sulphite and sodium hydroxide and subsequently allowing them to undergo alkaline swelling in a reaction bin prior to refining. Aspen CTMP produced by such a process can be used for a wide range of end products. Resulting pulp quality will be dependent to a large extent on the amount of chemical treatment and on the amount of energy transferred during the refining process.

Quality data for Aspen TMP and CTMP covering the freeness range 100-200 ml CSF, produced by the impregnation of chips with 2% sodium sulphite and 1.0-5.0% sodium hydroxide are given in Table 1. Without chemical impregnation, Aspen TMP, despite its high specific energy requirement, exhibits physical properties which are inferior in most respects to those exhibited by stone groundwood produced from softwoods. The optical properties of Aspen TMP on the other hand are impressive, the pulp exhibiting scattering coefficients and opacities which are well in line with those exhibited by typical stone groundwood at equivalent levels of drainage.

A mild chemical impregnation of Aspen chips using 2% sodium sulphite and 1.2-2.0% sodium hydroxide prior to preheating and refining improves pulp quality to the point where it is comparable in optical properties and in most strength properties to TMP produced from softwood chips to an equivalent level of drainage. The lower fibre length of the Aspen however, while it improves formation and density characteristics, results in low tear strength equivalent to that of stone groundwood.

Further increases in the chemical impregnation levels result in additional quality changes as indicated in Table 1. These manifest themselves in terms of decreased shive content with corresponding improvements in density and bonding properties but at the expense of reduced scattering coefficient and opacity. As is evident from Table 1, impregnation with 2% sodium sulphite and 5% sodium hydroxide reduced the scattering coefficient to a level equivalent to that of hardwood chemical pulp. In addition, and as anticipated, this high level of sodium hydroxide resulted in a severe decrease in brightness.

At lower freeness levels, Aspen CTMP produced by mild chemical impregnation can be used as a major furnish component of printing grade papers, in some cases without additional bleaching. For other specialty grades, some form of brightening would be required. If the pulp is to be used at higher freeness levels for use in tissue manufacture, where it is known to impart the important characteristic of softness, peroxide brightening to the brightness range 75-80% ISO brightness would be essential.

TABLE 1. QUALITY CHARACTERISTICS OF UNBLEACHED ASPEN TMP AND CTMP.

Pulp Type		TMP		CTMP		CTMP		CTMP		CTMP	
Chemical Charge											
Na_2SO_3	kg/t	0		18		20		20		20	
NaOH	kg/t	0		12		20		40		50	
Yield	%	96.2		92.5		92.1		89.2		86.5	
Freeness, CSF	ml	100	200	100	200	100	200	100	200	100	200
Shive Content	%	0.50	1.50	0.20	0.60	0.15	0.50	0.14	0.48	0.06	0.35
Long Fibre Content	%	2.9	3.6	8.2	7.9	7.3	10.8	7.5	11.2	8.5	12.0
Density	kg/m^3	365	330	409	322	440	400	545	490	604	560
Burst Index	$kPa \cdot m^2/g$	0.90	0.50	1.60	1.21	2.00	1.48	2.60	2.00	3.10	2.43
Tensile Index	Nm/g	23	18	39	31	43	38	51	44	60	49
Tear Index	$mN \cdot m^2/g$	3.10	2.65	4.8	3.8	5.3	5.1	6.2	5.8	6.7	6.5
Brightness, ISO	%	58.0	58.0	61.0	61.6	58.0	58.0	49.5	49.5	44.5	45.5
Light Scattering Coefficient	m^2/kg	68.0	60.0	52.0	51.0	47.0	45.5	41.0	40.0	34.5	34.0

CHEMIMECHANICAL PULP FROM NORTH AMERICAN ASPEN (POPULUS TREMULOIDES)

For some end use applications, the upper quality limits of Aspen CTMP may prove to be inadequate. Thus, for the partial or complete replacement of bleached hardwood kraft pulp in certain paper grades, Aspen chips must be treated in such a manner that improved bonding properties over those attainable by a CTMP type process are achieved at higher levels of drainage. In order to achieve such physical property profiles, higher chemical impregnation levels are required and the impregnated chips must be sulphonated to a greater extent than is the case with CTMP. This is achieved by digestion at higher temperature and for longer retention times than those employed in the manufacture of Aspen CTMP.

Impregnation of Aspen chips with 16-20% sodium sulphite followed by digestion for 30 minutes at temperatures in the range 130°C-160°C and two stage refining to a final drainage level of 350 ml CSF resulted in the unbleached pulp quality characteristics given in Table 2. Digestion temperature clearly has a strong influence on the yield, brightness and physical property profiles of the resulting CMP. While the higher yield pulp produced by vapour phase digestion at 130°C exhibits strength characteristics which are only marginally better than those of a typical Aspen CTMP, increasing the digestion temperature improves the density and bonding properties and adversely affects the opacity by decreasing the light scattering coefficient. The resulting properties of the pulp appear to be more in line with those of an unbleached low yield chemical pulp. High temperature digestion also has a serious effect on the unbleached pulp brightness.

TABLE 2. PHYSICAL PROPERTIES OF NORTH AMERICAN ASPEN CMP (UNBLEACHED PULP QUALITY AT 350 ml CSF)

Cooking Temperature	°C	130	140	150	160
Cooking Time	min	30	30	30	30
Sodium Sulphite Application	%	15.7	20.6	18.0	17.8
Approximate Yield	%	88.0	87.5	86.5	83.5
Specific Energy Consumption	kWh/t	1800	940	850	730
Density	kg/m^3	450	535	570	610
Burst Index	kPa m^2/g	1.70	2.80	3.10	3.60
Tensile Index	Nm/g	40.0	50.0	55.0	64.0
Tear Index	mN m^2/g	5.5	6.4	6.6	6.8
Opacity	%	89.2	86.5	84.2	81.0
Unbleached Brightness	%	59.6	62.2	61.7	58.4
Bleached Brightness*	%	80.2	79.1	76.0	75.2

** 4% peroxide application*

RESPONSE OF ASPEN TMP AND CTMP TO PEROXIDE BLEACHING

The response of Aspen TMP at an unbleached yield level of 96.2% and of two Aspen CTMP qualities at unbleached yield levels of 92.5% and 89.2% to peroxide bleaching was evaluated in the laboratory. The two CTMP pulps were produced by impregnating chips with 2.0% sodium sulphite and 1.2% and 4.0% sodium hydroxide respectively. In each case, laboratory bleaching was carried out at 10.0% consistency and at peroxide application levels of 1.0, 2.0 and 4.0%. Further details of these peroxide bleaching studies are given in Table 3. The effect of bleaching on the optical and strength properties of the three pulps is given in Table 4. At unbleached yield levels in excess of 90%, Aspen pulp can be readily bleached to a brightness level of 80%. At unbleached yield levels below 90%, the relatively severe sodium hydroxide treatment involved in the impregnation stage lowers the unbleached brightness level to 50% or below and this clearly has a strong influence on the ultimate bleached brightness attainable. It is also evident from Table 4 that the peroxide bleaching had the anticipated positive effect on the strength properties of the pulp, resulting in significant improvements in density and bonding properties.

These trials were carried out on pulps produced in a series of pilot plant trials and in order to substantiate these data, laboratory bleaching tests were also carried out on Aspen CTMP produced in a commercial operation. Aspen CTMP, produced by impregnating chips with 2% sodium sulphite and 1.5% sodium hydroxide prior to preheating and refining, was bleached in the laboratory to 75%, 80% and 85% ISO brightness in a single stage bleaching operation using 12, 20 and 45 kg peroxide per BD tonne respectively, the bleaching involving a 2 hour retention time at 10% consistency. By modifying the system to a two stage operation with recycling of residual peroxide to the primary bleaching stage, the peroxide requirements to achieve the same levels of brightness were reduced to 10, 13 and 32 kg peroxide per BD tonne respectively.

As noted above in the case of Aspen CTMP, Aspen CMP will also respond reasonably well to peroxide bleaching. Table 2 includes data showing the response of Aspen CMP to bleaching involving a 4% peroxide application. At higher digestion temperatures and thus correspondingly lower starting brightness levels, a 4% peroxide application improved the pulp brightness to the range 75.0-76.0%. While this level of peroxide may appear high, the consumption, and thus the overall economics of the bleaching process, can be reduced significantly by the use of a more sophisticated bleaching system permitting high consistency bleaching and the recycle of residual peroxide present in the pulp after the bleach tower. Such systems are already in operation in Europe and North America and require no further description in this paper.

TABLE 3. CONDITIONS USED FOR THE BLEACHING OF ASPEN TMP AND CTMP.

Pulp Type		Aspen TMP			Aspen CTMP			Aspen CTMP		
Pulping Conditions:										
Preheating Temperature	°C		125			100			100	
Preheating Time	min		5			5			5	
Sodium Hydroxide	%		0			1.2			4.0	
Sodium Sulphite	%		0			1.8			3.0	
Bleaching Conditions:										
H_2O_2	kg/t	10	20	40	10	20	40	10	25	40
NaOH	kg/t	10	20	25	10	20	25	15	20	25
Na_2SiO_3	kg/t	40	40	40	40	40	40	40	40	40
DTPA	kg/t	5	5	5	5	5	5	5	5	5
Final pH		8.2	8.3	8.1	8.2	8.4	8.5	10.8	10.8	10.7
Residual H_2O_2	kg/t	2.1	3.2	11.6	2.7	5.0	10.0	2.0	3.0	8.9
Pulp Consistency	%	10	10	10	10	10	10	10	10	10
Temperature	°C	60	60	60	60	60	60	60	60	60
Time	h	3	3	3	3	3	3	3	3	3
Unbleached Yield	%	96.2	96.2	96.2	92.5	92.5	92.5	88.2	88.2	88.2
Bleached Yield*	%	96.6	95.7	95.1	97.7	96.7	96.5	97.1	96.5	96.2
Total Pulp Yield	%	93.0	92.2	91.7	90.5	89.7	89.5	86.5	86.5	86.2

** Based on unbleached pulp*

TABLE 4. RESPONSE OF ASPEN TMP AND CTMP TO PEROXIDE BLEACHING.

Raw Material		Aspen TMP (96.2% Yield)				Aspen CTMP (92.5% Yield)				Aspen CTMP (89.2% Yield)			
Peroxide Application	kg/t	0	10	20	40	0	10	20	40	0	10	20	40
Freeness, CSF	ml	115	115	110	112	92	76	74	68	165	160	158	160
Density	kg/m³	348	369	385	391	421	437	463	485	510	532	546	562
Burst Index	kPa.m²/g	0.71	0.75	0.90	0.96	1.76	1.81	2.17	2.33	2.12	2.31	2.48	2.73
Tensile Index	Nm/g	26.0	28.0	28.2	29.2	40.7	43.7	47.2	51.2	47.9	49.3	51.0	55.3
Tear Index	mN.m²/g	2.8	2.7	3.3	3.1	4.7	5.0	5.6	5.5	5.9	6.8	6.2	6.2
Brightness	%	59.5	70.0	73.5	75.7	60.5	72.5	75.0	77.5	51.0	61.0	63.5	67.5
Opacity	%	96.5	92.0	90.1	90.0	92.0	86.0	84.5	82.5	90.0	83.5	81.0	78.5
Light Scattering Coefficient	m²/kg	68.5	65.5	64.5	64.5	53.0	50.5	49.0	45.5	40.0	37.5	36.0	34.5
Light Absorption Coefficient	m²/kg	9.2	4.4	3.2	2.8	6.8	2.7	2.1	1.5	9.7	4.7	3.9	2.8
Brightness ISO (cold disintegrated)	%	60.0	73.0	76.9	79.7	65.2	75.5	78.2	80.6	49.0	57.7	62.3	66.6

EFFECT OF ASPEN WOOD QUALITY ON PULP QUALITY

The trials discussed so far in this paper were carried out on good quality Aspen chips exhibiting little or no visible sign of decay. It is well-known, however, that most Aspen stands contain trees covering a wide quality range with clear, undamaged specimens at one end of the spectrum and specimens showing signs of advanced decay at the other end. Quantitative data on the effect of level of decay on pulp quality however are in very limited supply and a series of trials was carried out to evaluate the effect of wood quality on resulting pulp quality.

Aspen logs from a particular Aspen stand in Canada were thus sampled and segregated into four different wood quality classes. This segregation was done based on the visual appearance of the butt ends with respect to stain and decay. The four classes contained clear logs, stained logs, logs showing visible signs of incipient decay and logs showing obvious signs of advanced decay respectively.

After chipping and screening, CTMP was produced from each quality class by impregnating chips with 2.5% sodium sulphite and 2.5% sodium hydroxide prior to preheating (103°C for 5 minutes) and two stage refining. Resulting pulp quality data for pulps covering the freeness range 60-200 ml CSF are given in Table 5. It is evident that the most obvious effect of increased level of decay in the chips is a decrease in the brightness level of the CTMP, the clear Aspen exhibiting a brightness level of 57.0% and that showing advanced decay having a brightness level as low as 40.0%. The two intermediate qualities of stained wood and wood showing signs of incipient decay had brightness levels of 49.0% and 45.0% respectively.

With regard to mechanical properties, CTMP produced from clear and stained Aspen exhibited better consolidation and bonding properties at a given level of drainage relative to the wood showing signs of incipient and advanced levels of decay, the latter quality resulting in the lowest CTMP quality as anticipated. This quality of pulp also exhibited poor tear strength due to its lower long fibre content relative to the pulps produced from the better quality chips. It is also evident from Table 5 that pulp yield was related directly to the level of decay. The yield levels shown in parenthesis in this table include the combined effects of fines loss on chip screening and yield loss across the CTMP pulping operation.

TABLE 5. THE EFFECT OF ROT ON ASPEN QUALITY

Type of Wood		Clear Aspen			Stained Aspen			Incipient Decay			Advanced Decay		
NaOH	%	2.8			2.8			2.8			2.8		
Na_2SO_3	%	2.8			2.8			2.8			2.7		
Yield	%	88.7 (86.5)*			88.0 (85.2)			89.2 (85.4)			89.2 (83.4)		
Freeness, CSF	ml	170	120	67	162	123	78	192	132	72	144	108	88
Specific Energy	kWh/t	1620	1840	2300	1505	1670	1815	1535	1825	2160	1775	1935	2000
Long Fibre	%	16.3	13.0	11.7	22.6	18.9	13.6	28.1	19.2	14.6	15.4	9.7	11.5
Fines	%	15.7	19.3	19.4	16.5	16.4	18.3	16.5	16.0	18.5	20.0	21.9	21.5
Density	kg/m^3	389	404	444	361	388	450	328	358	410	358	385	376
Burst Index	$kPa.m^2/g$	1.42	1.81	2.19	1.12	1.49	2.12	1,07	1.27	1.85	1.15	1.29	1.33
Tensile Index	Nm/g	37.3	41.7	48.5	36.5	42.2	48.2	29.6	32.5	45.1	32.6	36.7	36.7
Tear Index	$mN.m^2/g$	4.9	4.9	5.1	5.8	5.6	5.5	5.7	5.0	4.9	3.9	3.7	3.9
Brightness	%	57.0	56.5	56.5	48.5	49.0	48.0	45.0	46.5	45.0	40.0	40.5	40.0
Light Scattering Coefficient	m^2/kg	46.0	48.5	48.0	41.5	41.0	44.5	40.0	44.0	44.5	44.0	47.0	45.5
Light Absorption Coefficient	m^2/kg	7.4	8.1	7.4	10.9	10.3	11.6	11.4	11.9	14.6	16.6	17.4	14.5

** Adjusted yield for fines loss on chip screening*

Laboratory bleaching studies were carried out on the various CTMP qualities referred to above with reference to Table 5 and the bleaching response of the various pulps is shown in Table 6. It is evident that the unbleached brightness differences noted between the various wood qualities persist, as anticipated, through the bleaching process. Thus, while the CTMP produced from clear Aspen showed a brightness increase from 61.0% to 75.6% at 2% peroxide application, the CTMP produced from chips displaying signs of advanced decay exhibited a brightness improvement from 42.7% to 63.8%. For any given plant, starting wood quality will have an extremely strong influence on final brightness. Thus, for a multi-product mill, high grading of chips may represent an essential feature of the front end design.

TABLE 6. PEROXIDE BLEACHING OF ASPEN CTMP PRODUCED FROM CHIPS EXHIBITING INCREASING ROT CONTENT.

Raw Material	Unbleached Pulp yield*	H_2O_2 kg/t	NaOH kg/t	Na_2SiO_3 kg/t	DTPA kg/t	Residual H_2O_2 kg/t	Final pH	Brightness %	COD kg/t
Clear Aspen	86.5%	Unbleached						61.0	166
		10	10	40	5	3.1	8.9	72.2	192
		20	15	40	5	7.7	9.2	75.6	198
		40	20	40	5	21.5	9.4	78.2	215
Stained Aspen	85.2%	Unbleached						52.9	177
		10	10	40	5	1.2	9.1	59.7	198
		20	15	40	5	5.9	9.2	67.2	212
		40	20	40	5	17.7	9.4	70.3	217
Incipient Decayed	85.4%	Unbleached						50.2	158
Aspen		10	10	40	5	0.8	8.9	59.5	182
		20	15	40	5	3.2	8.9	65.2	189
		40	20	40	5	9.7	9.0	71.1	197
Advanced Decayed	83.4%	Unbleached						42.7	157
Aspen		10	10	40	5	1.1	9.1	51.1	183
		20	15	40	5	5.0	8.6	63.8	190
		40	20	40	5	10.7	8.9	66.4	199

* *Pulp yield includes fines loss on chip screening*

REFINING OF HARDWOOD AND SOFTWOOD CHIP MIXTURES

In some cases, CTMP mills are predicated on the basis of raw material based on a mixture of softwoods and hardwoods. An important question arising from this situation is whether the two wood species should be treated separately or whether the chips should be mixed prior to impregnation and refining. In some cases, the answer to this question is resolved directly on the basis of available line capacities but in some cases the possibilities exists to treat the two species separately.

The data shown in Table 7 shed some light on this question. This table contains CTMP quality for the separate refining of Aspen and Spruce chips, and also provides physical property data related to mixtures of Spruce and Aspen CTMP in the admixture ratios 70:30, 50:50 and 30:70. For comparison, the final column provides data for a 50:50 Spruce:Aspen CTMP produced by impregnating a Spruce: Aspen chip mixture with 1.6% sodium sulphite and 0.4% sodium hydroxide. It is evident from these data that at least at the level of drainage evaluated, the difference in pulp quality between separate and combined treatment is small. One advantage of separate refining appears in terms of improved density and surface smoothness profile, with little or no significant differences being evident in terms of mechanical and optical properties. It should be indicated, however, that separate treatment of softwood and hardwood species offers the possibility of producing a pure mechanical pulp on the softwood line and this clearly offers improvements in light scattering coefficient and opacity to the final pulp blend after mixing.

TABLE 7. CTMP FROM SEPARATE AND COMBINED TREATMENT OF SPRUCE AND ASPEN CHIPS.

Wood Species:		Separate Refining					Refining of Mixed Chips
Spruce	%	100	70	50	30	0	50
Aspen	%	0	30	50	70	100	50
Chemical Application:							
Sodium sulphite	kg/t	15.0	16.8	18.0	19.2	21.0	16.0
Sodium hydroxide	kg/t	0	2.4	4.0	5.8	6.0	4.0
Freeness, CSF	ml	96	101	99	100	100	100
Density	kg/m³	440	441	441	442	462	420
Burst Index	kPa m²/g	3.60	2.60	2.40	2.10	1.50	2.40
Tensile Index	Nm/g	60.9	48.7	45.1	45.0	39.6	47.0
Tear Index	mN m²/g	7.7	7.6	7.2	6.4	3.7	7.3
Surface Roughness	ml/min	220	236	214	236	154	260
Light Scattering Coefficient	m²/kg	49.5	50.5	51.5	55.0	54.0	53.5
Opacity	%	92.0	92.5	93.5	94.5	95.5	94.0
Brightness	%	61.0	60.0	58.0	57.0	56.5	58.0

CONCLUDING REMARKS

Future trends in the pulp and paper industry must include serious attempts to extend existing raw material resources. In North America and Europe, Aspen in its various forms currently represents an under-utilized species. The process technology required for the production of high yield pulp from Aspen is available. Its application results in pulps exhibiting a combination of mechanical and optical properties which are comparable with those of softwood mechanical pulps and even hardwood chemical pulps. Raw material quality, however, has been identified as an important factor, excessively decayed wood resulting in pulps of inferior strength and poor brightness. These deficiencies cannot be compensated for in a subsequent bleaching process.

ASPEN PRESSURE GROUNDWOOD PULP

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1. INTRODUCTION

Tampella is a fully integrated forest products manufacturing company with a product range from building materials to paper, principally groundwood printing papers, to boxboard. The principal location of its engineered metal products group and foundry is in Tampere, Finland. Tampella delivered its first grinders in 1868 and now some 800 units have been manufactured. The majority of the deliveries have been to Scandinavia, but there are Tampella grinders in operation around the world. These grinders produce pulp with freeness varying from very fine; for example, lightweight coated freenesses as low as 30 CSF to as coarse as possible, for example, board freenesses in the 400 CSF range. Several wood species are used for grinding in addition to the customary northern Spruce, which is the prime species for the manufacture of groundwood pulp both in North America, Scandinavia, and now in a recent development in Scotland. Other species would include Southern Pine, Poplar and Eucalypt as suitable sources of quality groundwood pulp.

2. HISTORICAL DEVELOPMENT OF PGW

Tampella has been delivering conventional grinders for almost 120 years, but Pressure Groundwood systems have been a recent development with pre-trial work beginning in 1978 and the first commercial trials in 1979-80. In less than a decade, over 50 pressurized units have been manufactured and the Pressure Groundwood process has developed very quickly into a sophisticated and highly automated technology. Most of that development has taken place in Europe with only one plant in operation to-date in North America, Madison Paper in Maine, with the second plant, Lake Superior Paper Industries, about to start up in December of this year. Oji Paper Company, Tomakamai Mill started up a PGW Line in 1986, as did Albbruck in Germany.

3. THE PROCESS - BASIC PULPING MECHANISM

Pressure grinding is based on the conventional stone grinding technology that has developed continuously since first commercialized in 1857, and the same principle of fiber separation mechanism applies. That is, when the pulpstone rotates, its grits cause rapid compression-release cycles at a frequency in the range of 50 kilohertz, which causes elastic deformation in the fiber matrix of the wood. These compression-release cycles and the internal friction of the wood lead to rapid heating of the wood to a depth of .5 to 1.5 millimeters from the grinding interface between the stone and the wood. The weaker the lignin-rich middle lamella of the wood matrix and the primary cell wall, the easier it is to free the fibers undamaged from the wood through the softening of the matrix components. Thus, it is advantageous for the pulp quality if fiber separation takes place at a temperature higher than plasticization or the softening temperature of lignin.

The Tampella Pressure Groundwood Process differs from conventional grinding in two respects;

1. The grinding occurs under overpressure. (Figure 1)

2. The shower water temperature is high; ie., in excess of 90°C.

Due to overpressure, the boiling point of water is suppressed; and this has a positive effect on the grinding process. The evaporation of the bound water in the wood as well as from the stone surface is diminished. The overpressure in the grinder allows the use of hot shower water; and thus, temperature within the whole grinding zone and overall in the grinder is higher. The synergistic effect of overpressure and high temperature provides more favorable conditions for fiber separation than in atmospheric grinding. The fibers are now released from the wood matrix more readily and less damaged in the presence of a lubricating water film on the stone surface. The long fiber content of PGW is therefore high and the fiber-to-fiber bonding potential is superior to conventional stone groundwood.

4. THE PROCESS - PGW SYSTEM

The overpressure in the grinder is initially induced by compressed air. The steam generated by grinding partially causes overpressure; and, therefore, compressed air is needed in continuous operation primarily for pressurization of the logfeed chambers. The pulp is blown from the grinder by means of grinder overpressure, and at low consistency (1.5-2.0%), through a large diameter pipe into a pressure shredder. The shredder disintegrates any slivers coming from the grinder, to avoid plugging the blow valve ahead of the blow cyclone (Figure 2).

The pressure relief occurs at the blow valve which controls the level in the pipeline ahead of the shredder. The flash steam escaping from the pulp is separated in the cyclone and is utilized in a heat recovery system.

The pulp from the cyclone is under atmospheric pressure and it is led from the cyclone to thickening where the outgoing consistency will reach 10 to 15 percent. Most of the hot water is recovered and recirculated back to the grinder as shower water. Because the temperature is around the boiling point of water, the thickener, whether it is a drum-type thickener or a disc thickener, works with an overpressure. This hot shower water circulation is a very closed system and is described as the "hot loop" where shower water temperatures are maintained over 90°C without any external heat makeup.

The thickener discharge will be re-diluted to screening consistency with mill white water and the same water will also be used as makeup water for the hot loop.

5. PRINCIPAL COMPONENTS

5.1 The Pressure Grinder

Tampella Pressure Grinders are designed and manufactured to withstand pressures up to three-bar overpressure (42 psi) and temperatures up to 130°C (265°F). The operating principle is that of a two-pocket grinder and some of the parts used are identical to those used in conventional Tampella Grinders. The grinder is manufactured with the change from cast iron to welded carbon steel construction lined with stainless steel so that all the wetted parts as well as the sealing surfaces are of stainless steel construction, AISI 316 or equivalent.

The log charge is made to the grinder through two equalizing chambers which work as a pressure lock. The chamber is sealed with two gates operated by water hydraulic cylinders which are activated by sequence valves. When logs from the equalizing chamber are dropped into the pocket the lower gate will be closed and the pressure from the chamber is released to the exhaust system. The upper gate is now opened providing that there is a new log charge waiting. When the log charge has dropped from the gate into the pocket, the logs are pressed against the pulpstone by a solid stainless steel pressure shoe loaded by the hydraulic cylinder. The high pressure showers ahead and after each pocket clean the stone surface efficiently. Solid and labyrinth type fingerbars as well as the doctoring plow are adjusted to close tolerance to the pulpstone to maintain uniform pulp quality with low shive and sliver content. Pitless grinding is now the norm so the grinder is delivered without a dam. The pulp from the grinder is exhausted through an outlet at the side of the vat, discharging down to the shredder.

All movements of the gates and the pressure shoes are actuated by a dedicated computer TAMSEC control system to minimize the pocket charging time and the manpower requirement. Control for the pulpmill is centralizd in one panel room, usually located on the mezzanine floor overlooking the grinders. Wood supply to the grinders is supervised by one panel operator and pulpmill supervision by a second panel operator.

For pressurized operation, the grinder is completely sealed and for the shaft sealing, mechanical seals are used. The gates have a double O ring seal.

5.2 Pressure Shredder

The Tampella Pressure Shredder is equipped with rotating and stationary hammers which crush the slivers down to matchstick size. Size control is maintained by a screen plate which prevents material from discharging before being reduced to size.

5.3 The Cyclone

This may be either an atmospheric or a pressurized cyclone. The latter cyclone is a more recent development to facilitate the manufacture of PGW-S or Super PGW. As you would anticipate, this is the unit that separates the pulp from the flash steam. The steam is utilized in an atmospheric-type system by direct or indirect heat recovery, principally for process water heating and it is used for area heating as well. If it is a pressure unit the steam would be captured and conveyed to a reboiler where, with mechanical recompression, it would be used for dryer steam in papermaking.

5.4 The Pressure Thickener

The pressure washer thickener is a modification of a conventional pressure washer and uses overpressure above the pulp mat for creating the pressure differential needed for dewatering. The overpressure is created by a high pressure blower which is mounted separately from the thickener. At normal running conditions, the overpressure inside the hood is approximately one meter water column, which is adequate to give the desired outlet consistency in the PGW process. Because the dewatering area over which the overpressure is constant is approximately 180 degrees, higher drum speeds can be used than in conventional types of thickeners. As an alternative to the pressure washer thickener, a more recent development has been the pressure disc filter. This is designed for the higher pressures which would be anticipated with Super PGW. A prototype unit of the pressure disc filter is in service at the Tampella Pilot Plant in Finland.

6. COMPETITIVE POSITION OF PGW IN MECHANICAL PULP MANUFACTURE

PGW has a similar low-energy requirement of conventional stone groundwood pulp. PGW has excellent papermaking properties in that the long fibers are more fibrillated and have a higher bonding potential than those of conventional groundwood and, for example, TMP. The strength of the short fiber fraction of PGW is also very high and because it is a well-developed fiber PGW pulp has very low linting propensity. In addition to these good papermaking properties, the optical properties of PGW are excellent with good brightness, opacity, which combined with smoothness, make this a premium pulp for groundwood printing papers. Competitively it is most economical as a process in a high energy cost harvesting area where the principal wood form is delivered as roundwood. The process is highly automated and has a low manpower requirement. For example, in a standard mill producing 400 to 600 tons per day of PGW, the pulpmill manpower requirement would be two to three per shift, including woodhandling.

7. PROCESS ALTERNATIVES WITH ASPEN

Alternate 1: Standard PGW process with screening and cleaning followed by post refining and peroxide bleaching.

Alternate 2: CPGW with in-situ alkaline peroxide treatment in the grinder with the options of post-bleaching and/or post refining.

CPGW features initial alkaline peroxide addition to the hot loop followed by screening and cleaning as previously. Post refining and post bleaching can be included in this alternative as well. The standard PGW process has a pressure thickener after the grinder/shredder/cyclone to recover hot shower water to be returned to the grinder. The "hot loop" would return the residual chemical plus low, fresh chemical makeup to provide a high chemical concentration within the hot loop. This would have the benefit of in-situ treatment of the pulp in the grinding zone. While it is a short dwell time between the grinder and the thickener, there is the driving force in relatively high peroxide concentration, high temperature, and pressure to provide efficient bleaching. The hot loop bleaching would be accomplished with a minimum additional capital cost to the process machinery, just for the chemical makeup, storage, and handling. In CPGW pilot trials performed, we discovered additional reduction of specific energy consumption and lower chemical consumption compared to standard PGW.

8. CHEMICALLY ENHANCED ASPEN PRESSURE GROUNDWOOD PULP

Aspen is a wood pulp furnish readily available in pure and mixed stands in Alberta and in other areas of Canada and the United States. Aspen has a lower density than the other hardwoods utilized in mixed hardwood pulping but its use has been limited primarily because it has a lower average fiber length than those, for example, of Birch. Conventional groundwood pulps (GW) have been found low in strength and so have been used more as a filler pulp in papermaking. Aspen pulp has high opacity and, due to the relatively short fiber length, good formation characteristics, which are valuable factors in the manufacture of high quality printing papers.

Recent publications have reported that by conventional thermomechanical pulping, no significant improvements in strength were achieved despite high specific energy consumption [1]. In order to get improved pulp from Aspen by refining, chemical pretreatment by sulphonation of the wood chips was recommended. This pretreatment increased the production costs, tended to have a negative impact on the yield and on the effluent load, as well as on the optical properties, like scattering coefficient.

A research team headed by Anssi Karna reported to the 1986 CPPA Annual meeting the results of applying PGW technology to an Aspen furnish [5]. The investigation reported was carried out, partly in pilot scale at Tampella's Research Center (see Figure 3), partly in the laboratory. The average data on an Aspen TMP and softwood groundwood from an operating mill in the U.S. was used as a reference base. Normal quality Aspen from a U.S. mill, containing two to three percent by volume of heartwood decay, was ground under conditions described in the following table:

TABLE I. EFFECT OF GRINDING CONDITIONS

Pulp	Grinder pressure kPa	Shower water temperature, °C
GW 0/75	0	75
PGW 300/75	300	75
PGW 300/95	300	95
PGW 450/95	450	95

The improvement in pulp properties was significant but, except for shive content, less beneficial than those normally realized on softwoods comparing conventional groundwood with PGW, especially in view of the increase in specific energy consumption, which was about 20% (Figure 4). The properties of the Aspen groundwood pulps were clearly superior to those of TMP using the refernce pulps as a basis of comparison. The brightness of all Aspen PGW pulps was close to that of groundwood at 62% ISO brightness, though varying degrees of wood decay caused some scatter in the data. These results are summarized in Table II and compared against Freeness in Figures 5A to 5H.

TABLE II. RELATIVE CHANGES AT 140 ml CSF BETWEEN PULPS GW 0/75 vs PGW 300/95.

SEC	+ 20%
Shive content	- 23%
Long fibre content	+ 13%
Tear strength	+ 14%
Apparent density	+ 4%
Tensile strength	+ 20%
Initial wet strength	+ 33%
Internal bond	0%
Scattering coefficient	0%

9. POST REFINING AND BLEACHING

The second area of investigation by Karna, et al, was on the effect of normal peroxide bleaching on Aspen PGW pulp and in combination with post refining. The post refining of mechanical pulp at low consistency is common practice in the production of high quality mechanical printing grades like SC and LWC. This technology, in which the specific energy consumption is in the order of 0.1 megawatt hours per ton (5 Horsepower Days Per Ton), followed by peroxide bleaching (2.6 percent H_2O_2, 3% NaOH), was applied in laboratory scale with some of the Aspen experimental pulps. The results of these trials are summarized in Table III. For comparison, Table III also contains some average mill data on Aspen TMP and mill groundwood pulps from a softwood mixture of Black Spruce and Balsam Fir 60:40.

The final Aspen pulps had a denser sheet formation than the softwood groundwood probably due to the differencs in fiber dimension and fiber flexibility (Figure 6A to 6C). The fines content in the post refined and bleached Aspen PGW pulp was significantly lower than that of the other final pulps. The tensile and tear strength of the PGW pulp was equal to softwood groundwood with even higher burst strength, indicating good bonding characteristics of the PGW fibers. Note that the porosity of the Aspen PGW sheet was very low, especially when compared with the TMP sheet. Based on these results, very favorable printing properties can be predicted on papers made from post refined and bleached Aspen PGW pulps.

TABLE III. THE EFFECT OF POSTREFINING AND PEROXIDE BLEACHING ON THE CHARACTERISTICS OF EXPERIMENTAL AND MILL PULPS.

		ASPEN						SOFTWOOD MIX. Bl.Spruce+Balsam fir	
		$GW_{0/75}$ Experimental		$PGW_{300/95}$ Experimental		TMP	Mill	GW	Mill
		Pit stock	Postref. + bleached	Pit stock	Postref. + bleached	Decker stock	Postref. + bleached	Post-refined	Bleached
CSF	ml	92	45	106	38	140	38	50	39
Brightness, ISO	%	64	71	65	73	55	76	64	71.
Apparent density	kg/m^3	343	425	350	430	345	425	390	400
BMc.N. fractions									
+ 28	%	12.5	4.2	14.4	5.6	6.2	2.0	11.5	8.0
+200	%	57.6	59.8	59.5	63.5	65.0	61.4	54.0	54.5
-200	%	29.9	36.0	26.1	30.9	28.8	36.6	34.5	37.5
Stretch	%	2.3	3.1	2.5	3.0	2.0	2.6	3.2	3.4
Tensile index	Nm/g	17.9	27.7	18.4	33.7	13.6	27.2	28.2	33.5
Tear index	mNm^2/g	2.7	2.4	2.8	2.7	1.6	2.4	2.8	2.7
Burst index	$kPam^2/g$	0.83	1.62	0.90	1.87	0.58	1.30	1.69	1.77
Bond, Scott	J/m^2	120	340	120	330	70	295	310	350
Porosity, Sheffield	ml/min	112	31	74	22	250	52	43	33

10. IMPACT OF CHEMICAL ADDITION TO SHOWER WATER

The third area of investigation was in the effect of adding chelating agent and alkaline peroxide into the shower water "hot loop". The Tampella research team of Tuominen and Pietarila reported to the 1986 TAPPI Pulping Conference in Toronto the results of trials at the Tampella Research Center pilot plant which corroborated the results obtained by Karna earlier on North American Aspen [6]. These trials were conducted on Finnish Spruce (Picea abies) and Aspen (Populas tremula), at shower water temperature of 105°C and overpressure of 250 kPa. The bleach liquor consisting of hydrogen peroxide, DTPA, and sodium silicate was added to the shower water "hot loop" so that the peroxide concentration was in the range of 0.1 to 0.4 gpl, pH 8.5. Sodium hydroxide additions were made to the bleach liquor to adjust the pH from a base of 8.5

to 9.3. The conventional groundwood grinding was completed without chemicals and with a shower water pH of 5.5

The peroxide grinding at pH 8.5 resulted in a reduction in specific energy consumption (SEC) of approximately 30%. Figure 7 illustrates the effect of peroxide bleaching chemical on the relationship between freeness and specific energy consumption.

Very strong positive change occurred in the strength properties of the pit pulp with improvements in the order of 15-50%. This is tabulated in Table III. Raising the shower water pH to 9.3 achieved further improvements in strength properties, except for tear. High pH also gave a further reduction in specific energy consumption.

Despite the increase in density and in the bonding ability of the fibers, the light scattering coefficients of the pulps produced with alkaline peroxide grinding conditions remained at a very high level, typical of conventional Aspen PGW.

Pit pulps were then bleached on a laboratory scale with standard conditions; 15% consistency, 60°C, one-hour reaction time, with a peroxide charge of 1.5% on OD pulp at an initial pH of 11.

TABLE IV. EFFECT OF ADDING DTPA AND PEROXIDE INTO SHOWER WATER AND SUBSEQUENT PEROXIDE BLEACHING AT MEDIUM CONSISTENCY ON $PGW_{250/105}$ FROM FINNISH ASPEN.

		Pressure grinding		Laboratory bleaching	
		Reference w/o	With chemicals →		
DTPA dose	%	-	0.45	0.20	0.20
H_2O_2 dose	%	-	2.1	1.5	1.5
Initial pH				11.0	12.5
SEC in grinding	MWh/t	2.04	1.36	-	-
CSF	ml	105	103	74	70
Wet strength (25%)	N/m	98	105	123	133
Wet stretch (25%)	%	6.0	6.2	7.8	8.9
Brightness ISO	%	63.3	74.8	83.7	82.1
Apparent density	kg/m^3	300	353	498	553
Stretch	%	2.0	2.5	3.1	3.3
Tensile index	Nm/g	20.4	25.9	43.6	47.4
Tear index	mNm^2/g	2.9	3.2	4.1	4.5
Burst index	$kPam^2/g$	0.79	1.33	2.25	2.52
Bond, Scott	J/m^2	98	176	465	503
Scatt. coeff.	m^2/kg	74.4	73.1	57.3	50.9
Porosity, Bendts.	ml/min	>500	468	123	95

When comparing the light scattering coefficients of both pit pulps which are tabulated in Table III and the post bleached pulps tabulated in Table IV, it can be noted that at constant density, constant tensile index or constant pulp brightness, the peroxide grinding followed by medium consistency peroxide bleaching, produced pulp with a higher light scattering coefficient than was produced by reference grinding.

Pit pulp brightness of the reference pulp was 63% ISO. Peroxide grinding at pH 8.5 produced a pit pulp brightness of 74% ISO with a peroxide consumption of 0.2% on OD pulp. This is illustrated in Figure 8 where the impact of alkaline peroxide grinding is seen in the final bleached pulp brightness achieved. Medium consistency bleaching of the pit pulps showed the advantage of grinder bleaching. For a final brightness of 82% ISO, the total peroxide consumption was reduced by about 40%. At lower brightness targets, the advantage was even greater.

In the alkaline peroxide grinding when the pH of the bleach liquor was raised to 9.5, the pit pulp brightness of 73% ISO was achieved with a peroxide consumption of 0.6% on OD pulp. That is compared with a consumption of 0.2% at pH 8.5. Despite the increased consumption in grinding, the maximum brightness of 84.5% ISO was achieved with a total peroxide consumption of 2.6% on OD pulp, which equals the total amount consumed by the pulp ground in the presence of peroxide at the lower pH.

TABLE V. PRESSURIZED GRINDING OF ASPEN; EFFECT OF PEROXIDE AND pH ON PIT PULP PROPERTIES.

shower water: H_2O_2	g/l	-	0.35	0.35
pH		5.5	8.5	9.3
SEC	kWh/t	2040	1410	1360
CSF	ml	105	107	103
wet strength	N/m	98.1	86.7	105.3
wet stretch	%	6.03	6.97	6.24
density	kg/m^3	301	328	353
tensile index	Nm/g	20.4	23.2	25.8
tear index	mNm^2/g	2.9	3.4	3.2
burst index	$kPam^2/g$	0.79	1.06	1.33
Scott Bond	J/m^2	98	149	176
light scattering coeff.	m^2/kg	74.4	76.4	73.1
brightness	% ISO	63.3	73.7	74.8

TABLE VI. PRESSURIZED GRINDING OF ASPEN; EFFECT OF PEROXIDE AND pH IN GRINDING ON BLEACHED PULP PROPERTIES.

shower water: H_2O_2	g/l	-	0.35	0.35
pH		5.5	8.5	9.3
CSF	ml	80	79	74
wet strength	N/m	105.0	122.1	132.5
wet stretch	%	6.72	7.07	8.91
density	kg/m^3	400	459	498
tensile index	Nm/g	35.2	41.1	43.6
tear index	mNm^2/g	4.5	4.0	4.1
burst index	$kPam^2/g$	1.58	1.96	2.25
Scott Bond	J/m^2	231	460	465
light scattering coeff.	m^2/kg	61.0	59.3	57.3
brightness	% ISO	74.7	81.2	83.7

DISCUSSION AND CONCLUSIONS

Northern softwood mechanical pulp manufactured principally from Spruce has been the accepted standard for comparison in the development of pulps for the manufacture of high quality printing papers such as LWC and SC. This is primarily because of the excellent optical and printing properties of Spruce mechanical pulp. There is a well established trend throughout our industry toward higher brightness and lower basis weight printing papers. An economical option to improve printing properties would be to reduce the amount of chemical pulp in the paper furnish. This could be implemented by improving the strength of PGW with chemical modification without causing a deterioration of its high light scattering capacity.

Because of the high specific energy consumption and low strength of the pulp produced, hardwoods are not commonly acceptable for refiner mechanical pulping. In order to reduce these disadvantages, various chemical pretreatments and treatments have been used on the furnish. Chemical treatment performed in the PGW grinder by adding alkaline peroxide bleach chemicals to the grinder shower water has been successfully demonstrated in these trials.

The results obtained also demonstrated that grinder pre-bleaching followed by medium consistency post bleaching produced a bright, strong Aspen pulp with a high light scattering capacity. In addition, both the grinder specific energy consumption and the bleach chemical consumption were reduced. Further improvement in the efficiency of this chemical treatment was obtained by raising the grinder pH.

The results reported for Aspen at shower water temperatures of 105°C, grinder overpressure levels of 250 kPa was for pit pulps only. Further benefits may be found by optimizing the grinding temperature and pressure and by post refining the pulp.

In conclusion, we see a very bright future for Aspen PGW pulping. The pilot scale experience which we just reviewed will be exploited on a commercial scale by Lake Superior Industries at Duluth, Minnesota, when this new 200,000 metric ton per year SC mill comes into production in December, 1987.

Tampella will present a paper at the International Mechanical Pulping Conference in June which will disclose the next phase in this technological development. Studies have been completed at the Tampella Research Center where the shower water temperature was raised to 140°C and grinder overpressure to 450 kPa to produce a Super Pressure Groundwood Pulp with strength properties 10-30% higher than conventional PGW. Tampella is prepared today to deliver a commercial system for Super PGW that will exploit this technology.

SUMMARY

1. Pressurized grinding of Aspen at 105°C, 250 kPa overpressure, in the presence of alkaline bleach liquor at pH 8.5, compared to grinding without chemicals, the following benefit was realized:

    1.1 The specific energy consumption was reduced by 30%.

    1.2 The pit pulp strength was improved by 15-50%.

    1.3 The post bleached pulp strength, except for tear, was improved by 15-100%.

    1.4 The light scattering improved at certain strength levels.

    1.5 The pit pulp brightness improved so that total peroxide consumption for a given bleached pulp brightness was reduced by 40-80%.

2. Raising the pH in alkaline peroxide grinding from pH 8.5 to pH 9.3 resulted in:

2.1 A further reduction in specific energy consumption of approximately 5%.

2.2 Further improvement in pit pulp and bleached pulp strength of 5-20%.

2.3 No increase in total peroxide consumption while bleaching to a higher final brightness.

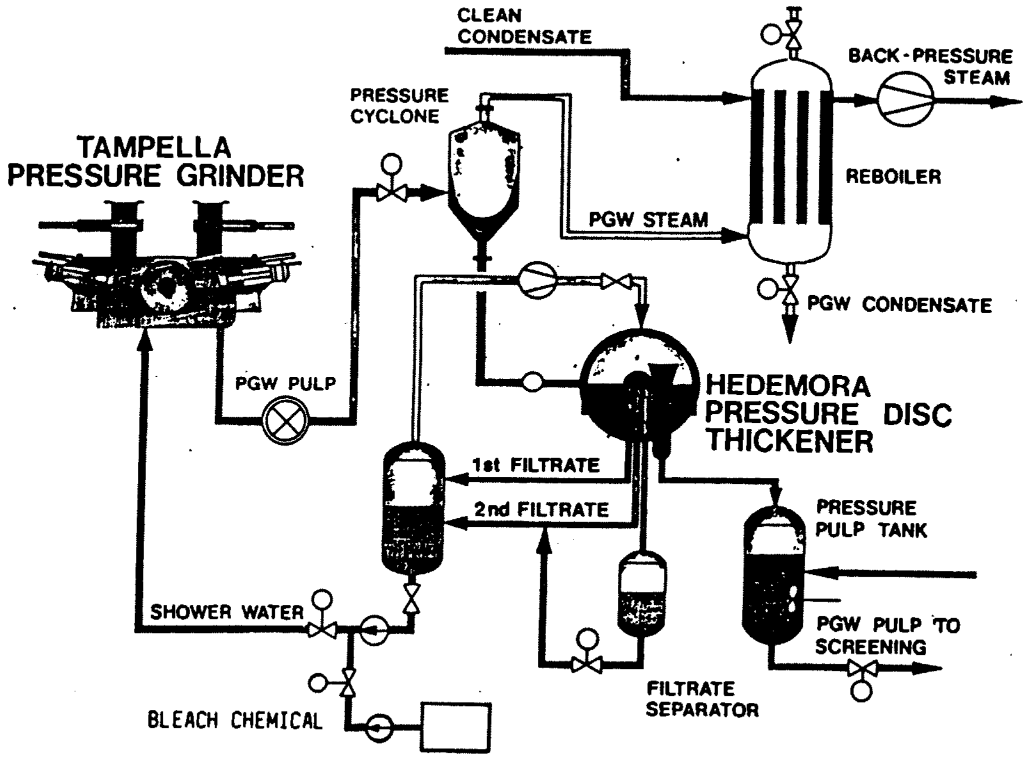


FIGURE 1. GPGW Process with Heat Recovery

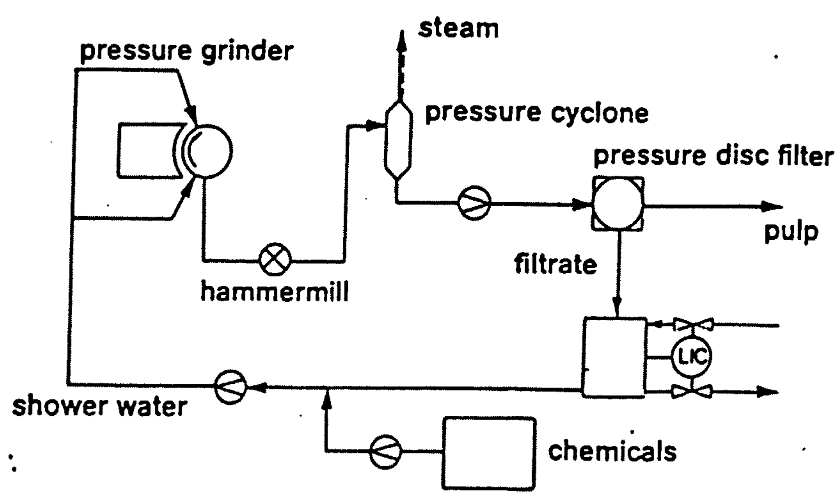


FIGURE 2. PGW pilot process.

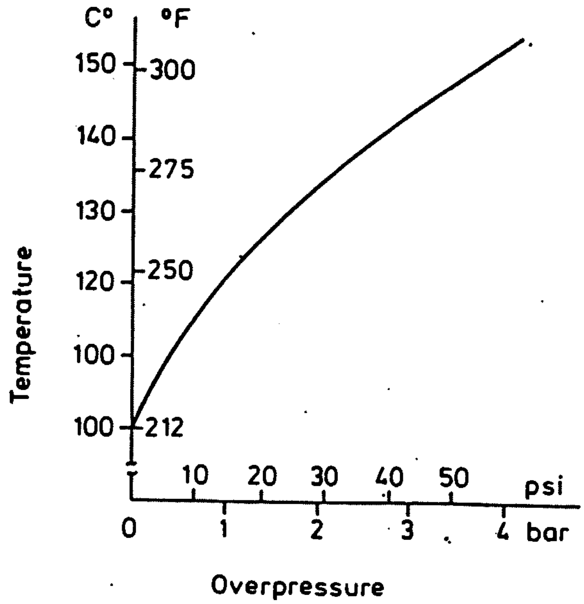


FIGURE 3. Boiling point of water vs overpressure

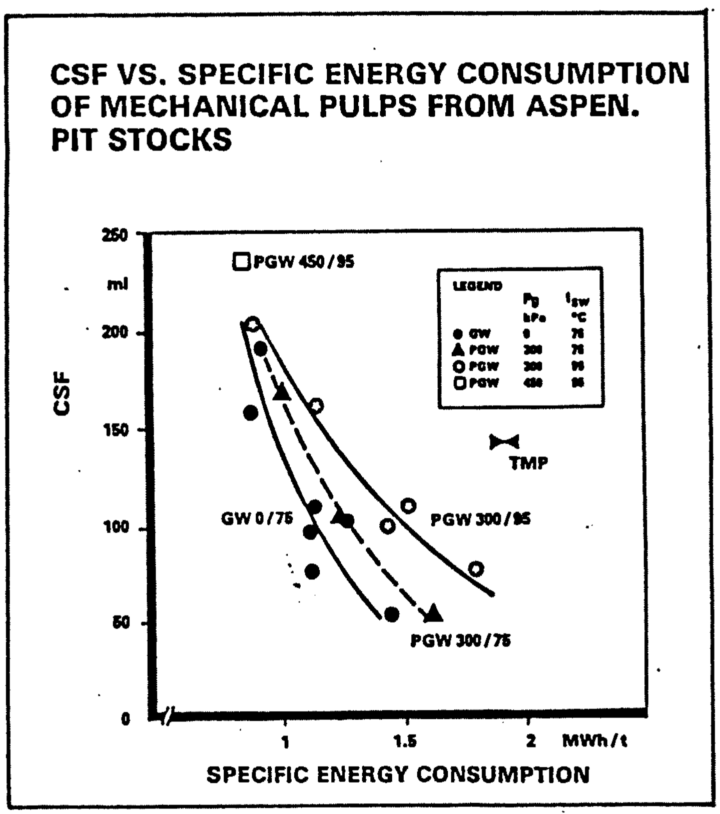


FIGURE 4. CSF vs. Specific energy consumption of mechanical pulps from aspen.

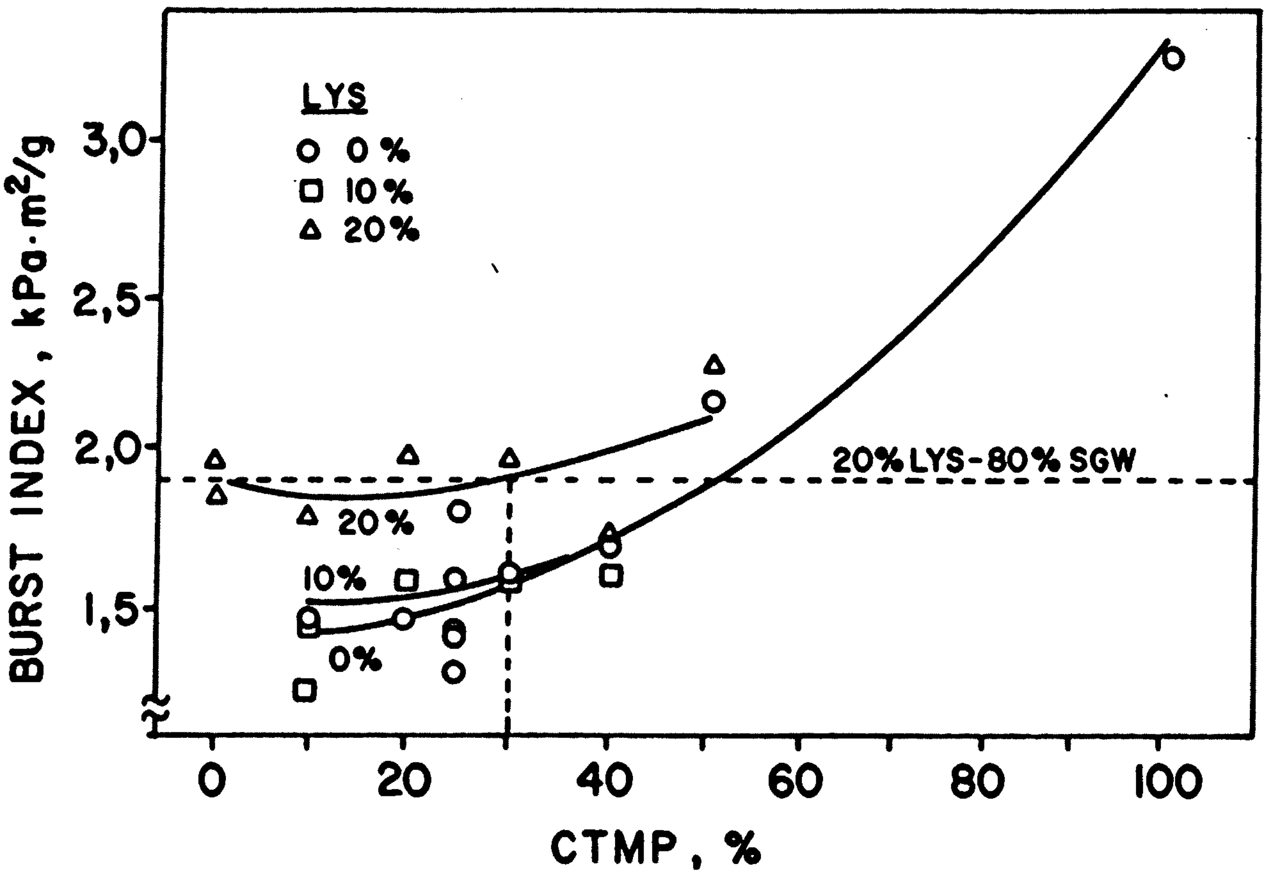


FIGURE 5. Effect of the addition of CTMP on burst strength of newsprint.

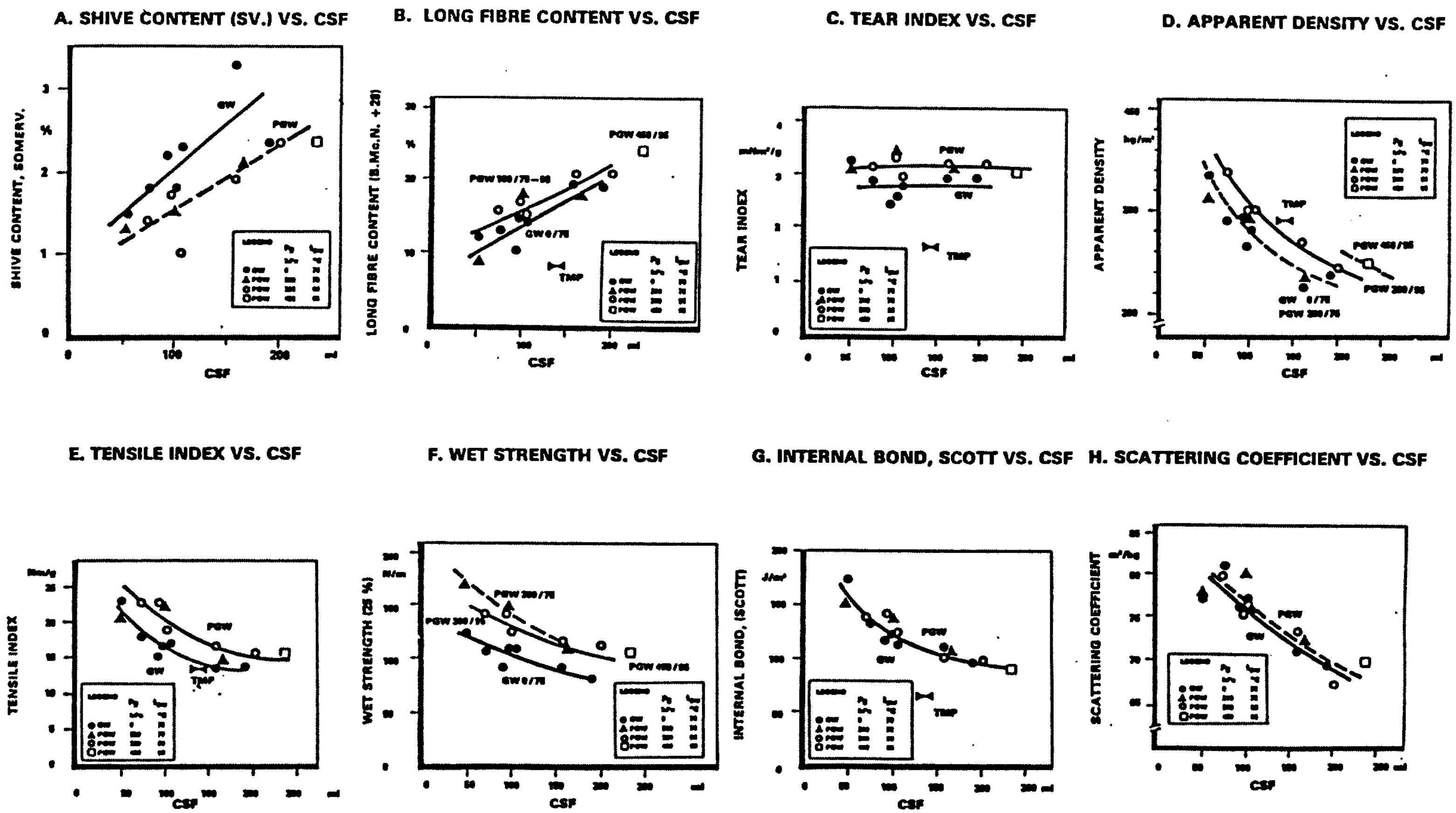
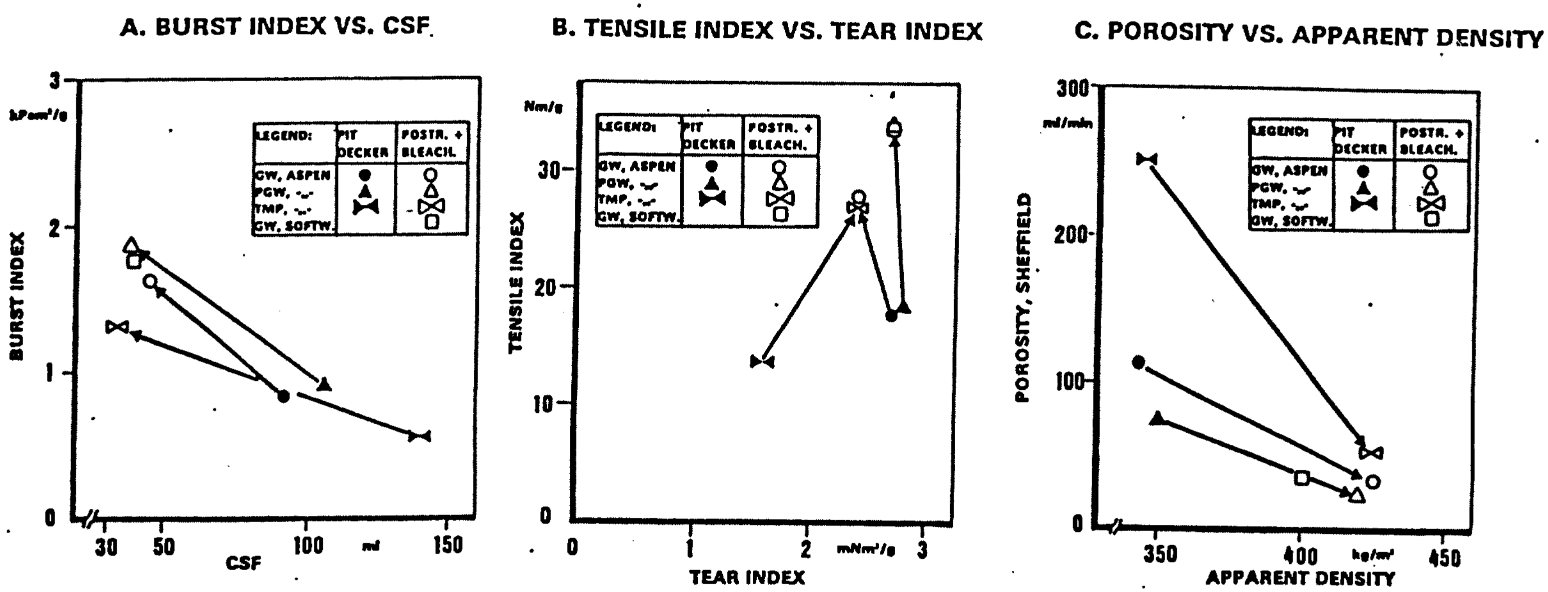


FIGURE 5A - 5H Pulp characteristics vs. CSF of mechanical pulps from aspen



6A 6B 6C

FIGURE 6A, 6B, 6C - Effect of postrefining and peroxide bleaching of mechanical pulps

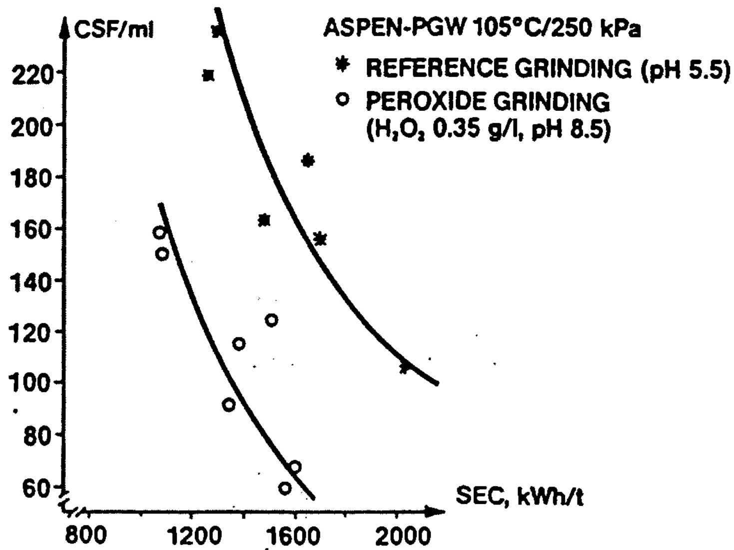


FIGURE 7. Pressurized grinding of aspen; effect of peroxide bleaching chemicals on the relationship between CSF and SEC.

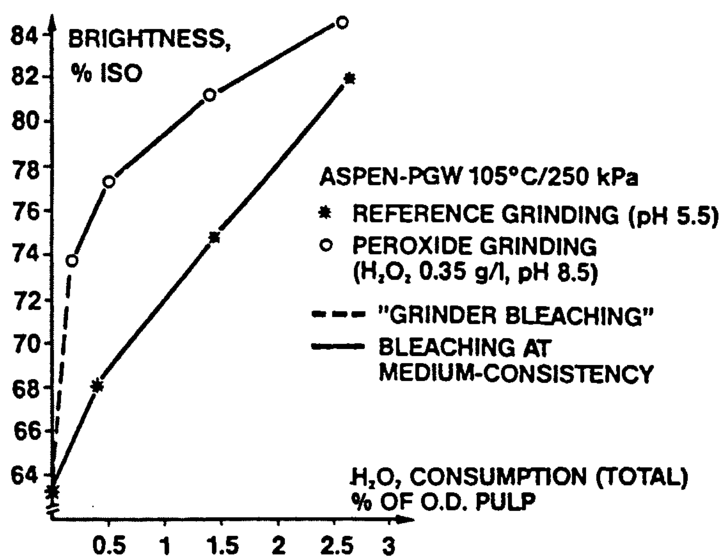


FIGURE 8. Pressurized grinding of aspen; effect of peroxide in grinding on pit pulp and bleached pulp brightness.

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MILL EXPERIENCE IN THE USE OF ASPEN MECHANICAL PULP

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The early work by C. K. Textor in 1956-1957 on the development of the Refiner Mechanical Pulping Process (RMP) showed that, while the all mechanical pulps produced from a variety of hardwoods were of such low strength that they could only be used as filler stocks, a chemical treatment with either cold sodium hydroxide or hot sodium sulfite resulted in the production of more acceptable pulps [1]. Some of his data are summarized in Table I. The two types of pulp are significantly different. The hot sodium sulphite pretreatment produced the stronger pulps but at a lower yield.

In 1963, the Blandin Paper company was completing an extensive program for the startup of their No. 3 paper machine which was designed to produce coated base stock at speeds up to 760 metres per minute. Research studies and information obtained from other mills showed that the cold soda process on aspen would not produce an acceptable pulp for light weight coated paper because of shives, low bulk and low opacity. The normal chemical application was 5-10% caustic based on oven-dry wood. The data also showed that good pulp could be produced from poplar using a mild treatment with a liquor containing sodium sulfite and sodium hydroxide at a concentration that approximately 2% of each chemical was absorbed by the chips [2]. Some of the data are summarized in Table II.

Their research data showed a number of important points:

(a) as the amount of sodium hydroxide consumed increases, the tear and burst indices increase while the bulk, opacity, brightness and bleachability decrease and the power consumption decreases.

(b) the effect of increased sodium sulfite consumption is very small, with a possible increase in bleachability and possibly opacity.

(c) increasing the temperature from 85°C to 138°C produces a much stronger pulp with a very low opacity and very poor bleachability. These pulps are not suitable for printing papers but might be used where strength is needed at the expense of bulk and opacity.

A mill trial confirmed the chemical consumption and the strength properties and that the shive content could be kept down by dividing the power equally between two refining stages. As a result, the commercial production of a chemi-mechanical pulp from aspen was started on October 31st, 1963. The system was described in detail at the Fifth International Mechanical Pulping Conference in 1964 [2].

Very briefly, the process involved a 15-minute pressure impregnation of poplar chips at 85°C and 60 p.s.i.g. The chemical consumption was 1.75% sodium hydroxide and 2.15% sodium sulfite. After refining and centricleaning, the pulp was bleached with 0.75% hydrogen peroxide to improve the pulp brightness from 52 to 69. The pulp was not screened. The furnish for the paper machine was 23% poplar chemi-mechanical pulp, 42% stone groundwood and 35% kraft.

Research work done in the Bauer Co. Laboratory showed that, by using an atmospheric soak at 90°c for 30 minutes instead of a pressurized soak for 15 minutes at 60 p.s.i.g., a higher pulp brightness could be obtained. This eliminated the need for two rotary valves on the soaking tube and the steam pad to produce the required pressure. This data, summarized in Table III, resulted in the installation of a 300 t/d atmospheric impregnating system at the Combined Locks Mill in Wisconsin. The flowsheet is shown in Figure 1. The chips after screening are impregnated in an M and D digester for 30 minutes at atmospheric pressure with a chemical pickup of approximately 2% sodium hydroxide and 2% sodium sulfite. The treated chips are pressed to remove the excess chemical, refined in two stages at high consistency and centricleaned. The pulp, depending upon its end use, went either directly to the paper machine or it was bleached in a single stage peroxide system. The pulp produced was approximately 50% of the furnish used to produce telephone directory and receipt paper. The pulp yield was in the range of 90-92% and the total power consumption was in the range of 1100-1200 kwh/t. The wood used was fresh, ie., not more than 4-6 weeks old, in order to obtain the maximum pulp brightness and good chemical impregnation.

In 1968, a trial was made at Combined Locks to produce newsprint containing 85% poplar chemi-mechanical pulp and 15% reclaimed sulphite pulp from tab cards [4]. The paper produced was comparable to the regular newsprint produced in the north-eastern part of North America. Table IV compares the test results of the trial paper with the averages for 411 samples of regular North American newsprint.

The trial paper had a good opacity and brightness, the tear was higher and the ink penetration was low. The paper was significantly rougher and this could have been due to the relatively high freeness of the poplar pulp, ie. 140 CSF. If the freeness had been lower, i.e., in the range of 90-100 CSF, the newsprint sheet would have been much smoother. The paper ran very well in the pressroom and was comparable to standard newsprint. It is interesting to note that after 5 years, the brightness reversion of the trial paper was significantly less than that of the regular newsprint used in the printing trial.

The Combined Locks Mill has modified its process and is now impregnating the chips with a solution containing sodium hydroxide and hydrogen peroxide. This eliminates the need for a separate bleaching stage. Table V compares the results obtained with the sodium hydroxide-peroxide solution with those obtained with the sodium hydroxide-sodium sulphite pretreatment. The results obtained are very acceptable for their end application but the pulp brightness is lower than what can be obtained by a separate high consistency bleaching stage.

The data discussed thus far is concerned with the utilization of a high percentage of poplar. Bowaters Mersey, in their newsprint mill in Liverpool, Nova Scotia, carried out a trial in which they added different percentages of hardwoods available to the spruce-balsam chips used in their TMP system. The data obtained showed very clearly that some hardwood chips can be refined with spruce-balsam chips with no adverse effect on paper quality or runnability.

Table VI summarizes the pulp quality data. The addition of poplar chips reduced the energy to reach a given freeness, the strength characteristics were reduced slightly while the bulk increased and the shive content decreased. The addition of the birch chips did not show a significant effect until the birch content reached 35%. The addition of the maple chips resulted in the largest reduction in pulp quality. All the pulps were used in a newsprint furnish containing 22% sulfite, 37% TMP and 41% stone groundwood. The maximum hardwood content in the newsprint furnish varied between 13% and 15%.

Blandin Paper is now using 30% poplar TMP with spruce stone groundwood and bleached kraft for their coated paper. Champion International at Sartell, Minnesota is producing TMP from a chip blend containing 20% spruce, 30% balsam and 50% poplar for their lightweight coated paper.

When Ontario Paper modernized their Thorold Mill in 1982, they installed two lines of TMP for a blend of spruce and jack pine chips and one line of CTMP for poplar chips. The system is being modified and they will have one line for spruce/jack pine TMP and two lines for spruce/poplar TMP. The poplar content in the chip furnish is 15-35%. The current newsprint furnish contains 12% spruce/jack pine TMP, 44% spruce/poplar TMP, 28% de-inked newsprint and 16% low yield sulphite. The quality of the spruce/poplar TMP is comparable to that for the spruce/jack pine TMP and the use of poplar in the TMP process has improved the opacity of the newsprint sheet.

There are two alternatives for using poplar in the production of a mechanical pulp - either by direct reduction in a TMP system or by the CTMP process using a chemical pretreatment with sodium hydroxide and sodium sulfite. The choice depends upon the percentage of poplar to be used in the paper furnish and the desired characteristics of the end product.

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Wood Species	Chemical Treatment			Power kwh/t	CSF	Burst Index	Tear Index	Breaking Length	Bulk cm^3/g	Brightness	Opacity
	Chemical	% Absorbed	Pulp Yield								
ASPEN	-	-	-	1450	129	0.7	3.6	1600	2.8	57	98
	Na_2SO_3	4.6	91	930	353	1.0	4.8	2500	2.7	58	92
	NaOH	3.9	94	716	103	3.3	6.6	5800	1.5	44	92
WHITE BIRCH	-	-	-	1092	159	0.3	1.2	1200	2.8	49	98
	Na_2SO_3	5.4	91	877	332	1.2	4.3	3000	2.9	58	94
	NaOH	3.6	90	573	150	2.9	7.1	5000	2.0	37	93
SOFT MAPLE	-	-	-	1199	129	0.6	2.1	1600	2.8	48	98
	Na_2SO_3	6.1	90	877	436	0.5	1.9	1400	3.4	64	91
	NaOH	2.9	94	716	210	1.1	4.2	2600	2.5	46	97
HARD MAPLE	-	-	-	1056	238	0.4	1.9	1300	3.3	44	97
	Na_2SO_3	4.1	92	859	435	0.3	2.0	1300	3.6	60	91
	NaOH	2.1	96	734	139	1.6	4.0	3700	2.3	42	97
COTTONWOOD (OHIO)	-	-	-	1342	83	0.7	2.5	1900	-	52	98
	Na_2SO_3	6.5	93	698	483	0.7	3.1	1900	3.0	48	89
	NaOH	2.6	94	644	94	2.4	6.0	4600	1.7	41	94
RED GUM	-	-	-	877	85	0.2	1.1	1000	2.7	41	99
	Na_2SO_3	5.4	90	573	181	0.5	2.7	1600	2.9	45	88
	NaOH	3.0	91	609	80	1.5	4.7	3900	2.1	32	98

Note: Na_2SO_3 treatment at 130°C, NaOH treatment at room temperature.

TABLE I. Effect of Chemical Pretreatment on Some Hardwood Species

TABLE II. Effect of Process Variables [2]

Run No.	1	2	4	6	8
Digester Conditions					
NaOH conc., g/litre	1.5	1.0	1.1	0.5	1.2
Na_2SO_3 conc., g/litre	14	14	30	30	31
Temperature °C	86	86	86	138	155
Chemical Consumption, %					
NaOH	1.8	1.4	1.4	2.0	2.7
Na_2SO_3	1.9	2.6	4.0	5.6	5.8
Na_2O_2	3.0	2.0	2.0	2.0	2.5
Power Consumption, kwh/ton					
Pressafiner	46	48	41	43	36
411 Refiner	1390	1436	1415	1299	1132
444 Refiner	109	97	111	88	59
Total	1545	1581	1567	1430	1227
Freeness, C.S.F.	145	150	111	140	132
Classification %					
on 14 mesh	2.0	1.9	0.3	0.6	0.4
on 28 mesh	12.3	7.2	7.5	11.8	11.8
on 48 mesh	28.8	27.8	30.8	31.0	32.8
on 100 mesh	22.1	23.6	19.1	21.1	22.3
Through 100 mesh	34.8	39.5	42.3	35.5	32.8
Bulk	2.03	2.15	2.05	1.94	1.70
Tear Index	7.1	5.2	5.7	6.5	6.9
Burst Index	2.3	1.8	2.3	3.1	3.9
Brightness (G.E.)	67.7	67.9	69.4	68.0	65.1
Opacity	91.7	91.6	91.1	87.4	83.7

TABLE III. Poplar Aspen (Populus Tremuloides)

Treatment	Power kwh/ adt	CSF	Burst Index	Tear Index	Breaking Length m	Bulk cm^3/g	Bright-ness GE	Opacity
Direct Reduction	1666	119	0.5	3.4	2340	2.45	61.0	96.5
1.0% NaOH + 1.9% Na_2SO_3 0 psig, 30 min., 196°F	1677	92	1.6	5.3	2940	2.17	58.0	88.5
2.3% NaOH + 1.9% Na_2SO_3 0 psig, 30 min., 180°F	886	119	1.6	6.4	3660	2.17	59.0	87.0
2.2% NaOH, 1.7% Na_2SO_3 60 psig, 15 min., 190°F	1106	107	1.9	6.3	4690	2.02	56.0	88.0

TABLE IV. Aspen Newsprint Trial.

	Aspen Newsprint	Average Values for 414 Northeastern Newsprint Samples
Moisture Content, %	7.0	7.1
Basis weight, lbs/ream	31.9	31.7
Smoothness, felt side	95.9	89.6
Smoothness, wire side	150.5	101.8
Printability, felt side	65.2	67.7
Printability, wire side	60.6	68.3
Printing Opacity	96.5	95.5
Brightness	66.0	66.0
Tear, cross machine	29.4	26.7

TABLE V. Comparison of Sodium Hydroxide/Sodium Sulfite and Sodium Hydroxide/Peroxide Pretreatments

% chemical absorbed				
NaOH	7.2	4.8	4.7	4.0
Na_2SO_3	4.6	6.9	-	-
H_2O_2	-	-	1.7	1.7
Pulp Yield %	83	85	85	88
Refining Power, kwh/t	465	680	660	985
Pulp Freeness, CSF	150	150	150	150
Bulk	1.67	2.15	1.85	2.15
Burst Index	3.4	2.2	3.0	2.0
Tear Index	6.6	6.9	7.2	6.7
Brightness	45	46	69	63

NaOH/Peroxide pretreatment - 90 minutes at 40-60°C

TABLE VI. Hardwood TMP Trials

Trial Number	1			2			3		
Spruce-balsam %	100	84	68	100	79	65	100	83	69
Poplar %	0	16	32	0	0	0	0	0	0
Birch %	0	0	0	0	21	35	0	0	0
Maple %	0	0	0	0	0	0	0	17	31
Freeness CSF	162	128	127	127	123	123	146	125	134
Burst Index	2.4	2.5	2.2	2.6	2.3	2.0	2.5	2.2	1.7
Tear Index	10.8	10.4	8.7	10.1	9.6	7.8	8.5	8.9	7.5
Breaking Length	4640	4520	3940	4530	4040	3180	4360	4210	3990
Bulk	2.98	2.63	2.76	2.57	2.76	2.81	2.69	2.63	2.87
Brightness, Unbleached	53.0	54.5	52.2	51.6	52.7	52.1	51.9	52.4	49.0
Bleached	58.1	61.1	58.0	58.9	60.1	58.2	56.9	58.7	56.6
Shives %	0.56	0.41	0.22	0.32	0.33	0.23	0.59	0.29	0.29
Fibre Classification %									
retained on 14 mesh	10.0	4.8	2.8	7.0	5.3	2.8	6.4	4.1	4.3
retained on 28 mesh	21.4	21.1	18.0	24.5	21.1	17.5	23.9	19.7	17.9
retained on 48 mesh	22.8	22.8	23.2	23.4	21.4	22.5	21.8	21.1	20.2
retained on 100 mesh	12.1	15.7	15.6	15.3	13.2	15.3	13.0	16.8	18.4
passing 100 mesh	33.7	35.6	40.4	23.8	38.9	41.8	34.9	38.3	39.2

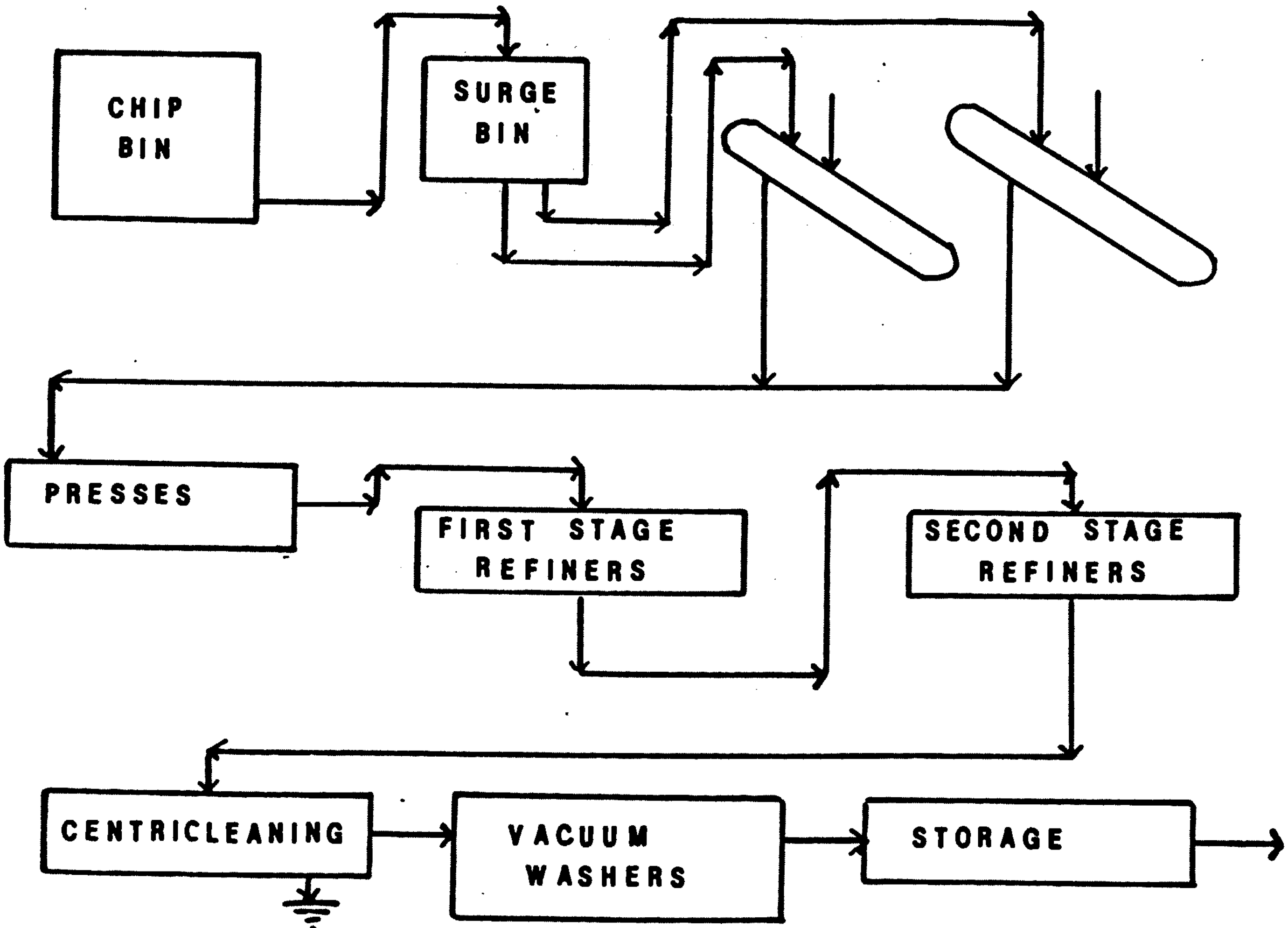

FIGURE 1. CMP System at Appleton Paper Co., Combined Locks, Wisconsin.

EXPLOSION PULPING OF ASPEN

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ABSTRACT

A new ultra-high-yield explosion process has been shown to be excellent for hardwood species such as aspen and birch. Paper properties of exploded aspen or birch pulps were increased by 50% when compared to those of CTMP. Furthermore, defibration and refining energy decreased by 40% to 50%, while the brightness of exploded pulps rose from 5% to 10% in comparison to that of CTMP. Exploded aspen pulp can be bleached to an 85% level with 4% hydrogen peroxide, and the brightness stability was excellent.

Defibration and refining in a laboratory blendor leads to pulps and papers with paper properties and defibration energies almost identical to those obtained on pilot plant-size or industrial refiners.

Finally, aspen or birch fibers are well-suited to reinforce themoplastic polymers. Wood fiber-filled thermoplastic composites have generally surpassed those of glass fiber or mica-filled polymers. The estimated production cost of grafted aspen fibers or sawdust ($150-$500/ton) is more economical than in the case of silane treated mica ($700/ton) or glass fibers ($2,900/ton).

INTRODUCTION

Ultra-high-yield (90%+) chemimechanical (CMP) or chemithermomechanical (CTMP) pulps represent an excellent alternative and complement to rather weak mechanical pulps and rather expensive chemical pulps with a low yield (45-50%). CMP or CTMP pulps combine high yield, low cost and less pollution problems for mechanical and thermomechanical pulps while being considerably stronger. The only major drawback of CMP/CTMP pulps is their relatively high defibration energy varying from 7-12MJ/kg [5] which may be due to insufficient softening of the crystaline cellulosic region.

It has recently been suggested by Kokta et al [1] that the softening of fibers could be accomplished using high-pressure steam cooking. The softening of fibers leads to a decrease in defibration and refining energy for softwood species [2]. The new ultra-high-yield explosion pulping (V-pulping) process, consisting of the chemical impregnation of chips, steam cooking, explosion, refining and bleaching produced pulp with a 90%+ yield and a level of brightness varying from 52% to 58% for softwood. The refining energy of softened steam cooked chips for softwood was roughly 30% to 40% lower than that reported for CMP/CTMP pulps [2].

The first objective of the present work is to further examine the potential of explosion pulping process for hardwood species. The hardwood species, especially aspen are abundant but under utilized in Canada.

For example, in Quebec only, about 5 million cubic meters of aspen and birch are left uncut annually [12].

Shaw [7] has reported that the Waring Blendor is better suited for secondary refining than a laboratory beater PFI. He has shown that the paper properties of blendor-refined pulps are almost identical to those refined on industrial-scale refiners [7]. Therefore, the second objective of this work is to find out how laboratory blendor refining compares to pilot-plant or semi-industrial scale refining, as far as the pulp and paper properties, as well as refining energy, are concerned.

Polymers applications account for a larger and larger share of our daily activities. According to the latest statistics [13], in the U.S. only, the production of thermoplastic polymers was in the range of 70 lbs/person. It was also predicted [14] that the production of thermoplastics will more than double within ten years to reach 150 lbs/person. Polymers strong on a weight basis present in certain cases disadvantages because of their low elastic modulus. Polymers modulus is presently being increased by filling or reinforcing polymers with inorganic fillers such as calcium carbonate, mica, and glass fibers. In 1986, only 1.3% of thermoplastics have been reinforced, but this number will grow tremendously within the next ten years to 30-50% [14] as the application of composites explodes in various industries: car, furniture, construction, toys, shipping, etc.

At the present time, wood fibers are not used to reinforce thermoplastics because they are hydrophylic, thus poorly compatible with the hydrophobic polymer matrix and the fiber-polymer adhesion. Consequently the final composite properties are rather poor.

The problem of incompatibility and poor adhesion can be overcome by chemical modification (grafting) of wood fibers [8-11]. The grafting process implies a chemical surface coating of fibers with a polymer compatible with the matrix.

Compared to inorganic fillers, grafted wood fibers show the following advantages: i) lower cost per volume unit; ii) flexibility during processing; iii) lower equipment abrasion; iv) no health problem during compounding; v) lower density; vi) high ability for surface modification; and vii) use of renewable abundant resources, especially in the form of hardwood fibers or sawdust.

The third and final objective of this work is to point out the potential use of hardwood fibers and sawdust for the reinforcement of polystyrene, polymethylmethacrylate and polyethylene.

EXPERIMENTAL

Materials and Procedures

Birch (*Betula papyfera Marsh*) and aspen (*Populus tremuloides Michx*) were chipped in a CIP industrial refiner. Chips, used for CTMP pulping in a Sunds Defibrator (moisture content about 50%), were presteamed at atmospheric pressure for 10 minutes and then cooked for 5 minutes at 126°C with 0.5% DTPA, 5% Na_2SO_3 and 5% NaOH, and then refined in a Sunds Defibrator.

The chips used in explosion pulping, aspen and birch as well as industrial softwood chips 75% spruce, 20% fir and 5% aspen supplied by Consolidated-Bathurst Ltd., were shredded as in the case of the CMP ultra-high-yield Consol process. Energy required for chip shredding was in the order of 0.096 MJ/kg.

Impregnation

150 g of chips (= 50% siccity) were mixed in plastic bags along with 150 g of a solution made up of different concentrations of chemical products such as Na_2SO_3, DTPA, NaOH, etc. Time of impregnation: 24 hours (softwoods) or 48 hours (hardwoods); temperature of impregnation: 60°C. The percentage of chemicals absorbed by wood chips appear in the Tables.

Refining

Defibration of exploded chips or CTMP chips were done on a pilot-plant scale Sunds Defibrator (capacity 1 000 kg/day) or a semi-industrial scale Bauer Refiner (capacity 4 500 kg/day) at PAPRICAN with consistency varying between 9% and 15% for Sunds refining and 22% for Bauer refining.

Laboratory blendor refining was done using a domestic blendor OSTERIZER B 8614 and a consistency level was 2%. Defibration and refining was energy measured using a wattmetre EW 604.

In certain cases, beating was conducted at a 10% consistency and the refining energy was obtained by dividing the beating energy with factor 3.5 found previously [2] using an atmospheric laboratory beater PFI. For industrial trials, refining was done on an industrial refiner Sprout-Waldron, Cabano, Cascade Paper Co., or two-stage refining was performed on a Sunds Defibrator, Jonquier, Cascade Paper Co.

Property Evaluation

Paper sheets were prepared and tested according to standard CPPA testing methods.

Bleaching

Bleaching was carried out according to previously published procedures [3,4]. The precise bleaching conditions are shown in the Tables.

Cooking

Cooking was done using saturated steam in a laboratory batch reactor built by Stake Tech. Company. The temperature was 190°C, and time of cooking 240 seconds. Cooking was preceded by one minute steam flushing at atmospheric pressure. After cooking, the pressure was instantaneously released and chips which exploded into the release vessel were washed and cooled down with one litre of water, and subsequently refined after being stored in a cold room. Th reported amount of steam used for cooking varied from 0.3 to 0.4 kg of steam for 1 kg of chips [2].

Composites

Wood fibers in the form of mechanical pulp, CTMP, explosion pulp or sawdust were grafted, compression molded and evaluated using the procedures already published [8,9,10,11].

RESULTS AND DISCUSSION

CTMP pulp, with a yield above 90%, is rather difficult to refine. The refining energy varies between 7 and 12 MJ/kg for spruce [5]. In the case of the CTMP of hardwoods, energy is generally lower and varies from 4 to 6 MJ/kg, according to freeness and wood species.

In Table I, pulping conditions, refining energies as well as paper properties are compared for CTMP and exploded pulps for both birch and aspen. Experimental conditions used for CTMP pulping are optimal ones, but conditions used for hardwood explosion pulping are those used for softwood pulping as reported previously [2]. Results in Table I show that the explosion process is very efficient for both birch and aspen. Paper properties are substantially higher in the case of explosion pulps as opposed to CTMP. In the case of birch, property improvements are as follows: burst rose from 1.9 to 3.6, breaking length jumped from 4.2 to 6.7, and tear increased slightly from 6.1 to 6.9. At the same time, refining energy decreased from 5.3 MJ/kg to 2.4 MJ/kg.

Aspen has a similar behavior like birch. Compared to Aspen-CTMP, breaking length increased from 4.5 to 6.3, burst climbed from 2.6 to 3.3 and refining energy dropped from 5.2 to 2.2 MJ/kg or 2.8 MJ/kg when measured on Sunds Defibrator.

Surprisingly, the brightness level of the brown stock of exploded pulp grew from 55.7% to 68% in the case of birch, and from 60.9% to 70% in the case of aspen explosion pulp. On the negative side, the increase in brightness was followed by a decrease in opacity. Finally, in Table IA, the paper properties of aspen pulps are compared for aspen supplied by different paper companies. It is evident that the results are quite reproducible and the paper properties can be further enhanced either by decreasing CSF or by using additional two percents of swelling agent.

TABLE I. Physical Properties of CTMP and Explosion Pulps of Aspen and Birch.

PROCESS	BIRCH CTMP	BIRCH EXPLOSION	ASPEN CTMP	ASPEN EXPLOSION
CHEMICALS (%)	10	8	10	8
TEMPERATURE (°C)	126	190	126	190
TIME (MIN)	5	4	5	4
BURST (kPa•m²/g)	1.9	3.6	2.6	3.3
TEAR (mN•m²/g)	6.1	6.9	7.2	6.9
BREAKING LENGTH (km)	4.2	6.7	4.5	6.3
BRIGHTNESS (%)	55.7	68	60.9	70
OPACITY (%)	94.1	87	91.4	89
CSF (ml)	117	117	119	92
SPECIFIC ENERGY DÉFIBRATION (MJ/kg)	*5.3	2.4	*5.2	2.2
YIELD (%)	90	91.0	92.0	92.1

* SUNDS DEFIBRATOR

The steam cooking process has a potential to become an ideally suited one for hardwoods because it leads to strong, bright papers with a lower refining energy when compared to the CTMP process. In order to ahcieve these results, the oxidative and hydrolytic degradation during high-pressure cooking must be well-controlled: oxidative degradation can be controlled by eliminating oxygen (impregnation; steam flushing) and by the presence of anti-oxydants (such as DTPA, Na_2SO_3, etc.). Hydrolytic degradation can be controlled under alkaline conditions in order to neutralize acids (acetic, formic, etc.) liberated from hemicellulose and lignin. Finally, in order to develop paper properties, the number of hydrophylic groups on fiber surfaces must be increased (ie., by the presence of hydrophylic against such as Na_2SO_3, etc.).

TABLE IA. Paper Properties of CTMP and Explosion Aspen Pulps.

PULP	'CTMP	+ EXPLOSION	+ + EXPLOSION	+ + EXPLOSION	+ + EXPLOSION
CHEMICALS (%)	10	8	8	8	8+2
TEMPERATURE (°C)	126	190	190	190	190
TIME (MIN)	5	4	4	4	4
BURST (kPa•m²/g)	2.6	3.3	3.4	4.6	5.2
TEAR (mN•m²/g)	7.2	6.9	6.7	6.6	6.4
BREAKING LENGTH (km)	4.2	6.3	6.9	8.6	9.3
BRIGHTNESS (%)	60.9	70	66	63	57
OPACITY (%)	91.4	89	84.7	84.6	80
CSF (ml)	119	92	105	38	75
SPECIFIC DEFIBRATION ENERGY (MJ/kg)	*5.2	***2.2	**2.5	**2.6	**1.9
YIELD	92	92.1	92	92	

N.B *SUNDS DEFIBRATOR

** BLENDOR *** PFI

+ CHIPS SUPPLIED BY CONSOLIDATED BATHURST CO., QUEBEC

+ + CHIPS SUPPLIED BY KIMBERLY-CLARK CO., U.S.A.

Sugar and lignosulfonate analysis

Results of the sugar analysis performed on non-washed exploded chips are presented in Table II. The laboratory analysis performed by professor Wayman at the University of Toronto on both aspen and softwoods showed no trace of sugars. These results, in combination with yields above 91%, indicate that there is no hydrolytic degradation of hemicellulose during the short cooking time with pH varying from 9.7 to 6.5. Furthermore, no traces of lignosulfonates were found in the liquor after steam cooking.

In conclusion, the sugar and lignosulfonate analysis confirmed the results obtained during the industrial trials [6].

TABLE II. Sugar Analysis in the Explosion Pulps

	Na_2SO_3 (%)	PRESSURE (psig)	TEMPERATURE (°C)	TIME (sec.)	FREE SUGARS (% g/g du bois)
ASPEN.E	8	200	197	120	0
SPRUCE/FIR	8	200	197	120	0
ASPEN E	8	225	202	360	0
SPRUCE/FIR	8	225	202	360	0

TESTED AT LABORATORY OF PROFESSOR WAYMAN, UNIVERSITY OF TORONTO, NOV. 1986

Bleaching

Conditions used for explosion pulp bleaching were those published recently [4] for the CTMP of birch and aspen. The best results with 4% H_2O_2 bleaching for the CTMP of aspen, a 77% brightness level, were surpassed by 10% for explosion aspen pulp. In that case, the final brightness level reached 87%. The difference can be explained by a higher initial brightness level for explosion pulp: 70% when compared to CTMP aspen (60.9%) (Table III).

In Table IV, bleaching conditions and the effect of time on brightness are shown. Other bleaching conditions for softwood and aspen are presented in Table V.

TABLE III. Effect of Hydrogen Peroxide Concentration on Paper Brightness and Opacity.

	CTMP - ASPEN			EXPLOSION PULP - ASPEN	
% H_2O_2	BRIGHTNESS (%)	OPACITY (%)	% H_2O_2	BRIGHTNESS (%)	OPACITY (%)
0	60.9	91.4	0	69	89
4	77	75	4	87	74.5

TABLE IV. Effect of Time on Brightness (Aspen)*.

PULP	T NOV 86	T NOV 86	T NOV 86	T NOV 86
DTPA (%)	0.1	0.1	0.1	0.1
$MgSO_4$ (%)	0.05	0.05	0.05	0.05
NaOH (%)	4	4	4	4
Na_2SiO_3 (%)	2		2	2
H_2O_2 (%)	4	4	4	4
TEMPERATURE (°C)	70	70	70	70
TIME (min)	60	90	180	240
CONSISTENCY (%)	20	20	20	20
BRIGHTNESS (%)	84.1	85.9	86.2	87.4
BRIGHTNESS GAIN (%)	14.1	15.9	16.2	17.4

N.B. INITIAL BRIGHTNESS: 70%: (8% Na_2SO_3; 4 min, 190°C)

TABLE V. Hydrogen Peroxide Bleaching of Explosion Pulps.

PULP (8%; 190°C; 4 MIN	BLACK SPRUCE	SPRUCE/ FIR		ASPEN
DTPA (%)	0.5	0.5	0.5	0.5
$MgSO_4$(%)	0.05	0.05	0.05	0.05
Na_2SiO_3 (%)	1.0	1.00	0.5	0.5
NaOH (%)	2.0	2.0	4.0	4.0
H_2O_2 (%)	4.0	4.0	4.0	4.0
TEMPERATURE (°C)	80	80	85	80
TIME (MIN)	150	150	150	150
CONSISTENCY (%)	20	20	25	20
BRIGHTNESS (%)				
INITIAL	46.5 (52.5)	49.3 (55.3)	52.4	70 (68)
FINAL	72.9 (78.9)	75.9 (81.9)	79.5	87 (85)
GAIN OF BRIGHTNESS (%)	26.4	26.6	27.1	17 (17)

Brightness stability

Brightness stability of aspen explosion pulp is shown in Table VI. The brightness stability is measured for sheets piled indoors at room temperature.

The initial 70% brightness level decreased within a couple of days to 68.3%, and then remained constant. Bleaching with 4% H_2O_2 led to an 85% brightness level which stayed stable. On the other hand, when the brown stock (70%) was immediately bleached with 4% H_2O_2, brightness reached 87% and then reversed in a couple of days to the same 85% level as in the first case.

TABLE VI. Stability of Brightness (Aspen)

DATE	INITIAL BRIGHTNESS (%)	DATE	FINAL BRIGHTNESS (%)	OPACITY (%)
19-11-86	70.0	20-11-86	70.0	87.2
20-11-86	69.9	30-11-86	68.3	87.2
20-11-86	68.3	31-11-86	68.3	87.2
14-11-86	87.4	19-11-86	87.2	74.6
19-11-86	87.2	20-11-86	85.0	74.6
20-11-86	85.0	22-11-86	84.6	74.6
20-11-86	82.2	25-11-86	82.4	76.4
20-11-86	83.4	25-11-86	83.6	75.8
20-11-86	85.3	25-11-86	85.1	76.0
20-11-86	84.3	25-11-86	84.3	75.7
20-11-86	68.3	25-11-86	68.3	87.2

In Table VIA, the results of brightness stability are presented for softwood. The stability was excellent under measured conditions. The brown stock even increased the brightness, and the bleached papers lost very little brightness.

Tables VIB and VIC show the results of accelerated weathering either at 105°C for 60 minutes or at 60°C for 90 hours without visible light. The color reversion found for explosion softwood pulps is about 30% to 50% lower than that found for typical CTMP.

TABLE VIA. Stability of Brightness of Softwood Explosion Papers.

PULP	INITIAL BRIGHTNESS	DATE	FINAL BRIGHTNESS	DATE
VK47	51.4	(10-01-86)	51.7	(14-01-86)
VK48	52.6	(10-01-86)	53.1	(14-01-86)
VK140	49.5	(25-11-85)	50.8	(05-02-87)
VK35	79.8	(20-12-85)	79.7	(19-06-86)
VK141-6	78.7	(25-11-85)	78.0	(05-02-87)

N.B.BRIGHTNESS STABILITY AT ROOM TEMPERATURE, INTERIOR LIGHT

TABLE VIB. Accelerated Weathering Tests of Explosion Pulps (Hardwood).

CONDITIONS: 105°C; 60 MINUTES, WITHOUT VISIBLE LIGHT

	INITIAL BRIGHTNESS (%)	FINAL BRIGHTNESS (%)	DIF (%)
ASPEN	68.4	67.6	-0.8
	82.1	81.4	-0.7

CONDITIONS: 60°C, WITHOUT VISIBLE LIGHT; 90 HRS.

ASPEN	*INITIAL BRIGHTNESS (%)	FINAL BRIGHTNESS (%)	DIF (%)
	62.43	60.67	-1.76
	62.85	60.95	-1.90
	67.85	65.21	-2.64
	67.49	64.97	-2.49
	72.49	70.52	-1.97
	72.49	70.53	-1.96

* BRIGHTNESS ISO (ABSOLUTE)

TABLE VIC. Accelerated Weathering Tests of Explosion Pulps (Softwoods).

ACCELERATED WEATHERING TESTS OF EXPLOSION PULPS (SOFTWOODS)

CONDITIONS: 105°C; 60 MINUTES, WITHOUT VISIBLE LIGHT

	INITIAL BRIGHTNESS (%)	FINAL BRIGHTNESS (%)	DIF (%)
SPRUCE/FIR	51.4	50.7	-0.7
	59.3	59.0	-0.3
INDUSTRIAL CMP	56.3	55.3	-1.0
	72.0	70.9	-1.1
	73.8	71.5	-2.3
	78.4	76.8	-1.6

CONDITIONS: 60°C, WITHOUT VISIBLE LIGHT; 90 HRS.

SPRUCE/FIR	*INITIAL BRIGHTNESS (%)	FINAL BRIGHTNESS (%)	DIF (%)
	**46.3	45.8	-0.5
INDUSTRIAL CMP	55.8	54.0	-1.8

* BRIGHTNESS ISO (ABSOLUTE)

** THE VALUES WILL INCREASE BY 6-7% WHEN REFINED INDUST.

Effect of refining conditions on brightness

Results in Table VII show that the brightness of pulp refined in a pilot-plant Sunds Defibrator is 5-6% higher than that obtained for pulp beaten on PFI.

We believe that the brightness difference may be attributed to different mechanisms and to time length during refining or beating.

Blendor refining

Shaw has shown [7] that industrial secondary refining could be reproduced on a laboratory scale using a Waring Blendor. He has shown that paper properties of TMP, refined on an industrial JYLIHA-DISC refiner, are almost identical to those obtained after blendor refining at a 2.5% consistency level. (See Table VIII).

TABLE VII. Effect of Refining and Beating on Explosion Pulp Brightness.

		(1.2 g)	(3 g)	Bleached ($4\%\ H_2O_2$)
	PFI	62.9%	64%	
Aspen	Sunds	64.5%	70%	87%
	PFI	46%	48.4%	
Spruce/Fir	Sunds	50%	53%	80%
	Sprout Waldron	43.3%		

TABLE VIII. Defibration with blendor.

	INDUSTRIAL REFINING	BLENDOR
CSF (ml)	**259**	**228**
DRAINAGE, (sec.)	**1.02**	**1.01**
WET PROPERTIES		
STRESS (N/m)	**70**	**74**
STRETCH (%)	**4.0**	**4.3**
CALIPER (mm)	**0.339**	**0.332**
DRY PROPERTIES		
BULK, (cm³/g)	**3.10**	**3.10**
BURST, (kPa•m²/g)	**1.97**	**1.98**
BREAKING LENGTH, (km)	**4.2**	**4.0**
STRETCH, %	**2.2**	**2.5**
TEAR, mN•m²/g	**12.6**	**12.5**

On the other hand, Shaw [7] has demonstrated that PFI beating leads to fiber cutting and tear loss. In general, the values obtained on PFI can be taken only as approximations because they do not represent neither tear properties nor energy obtained on industrial refiners.

Considering that defibration by blendor requires very few chips (30-50 g) compared to a Sunds Defibrator (3000-10000 g) or Bauer refiner (6000-12000 g) and the cost of a blendor ($75) is negligeable as opposed to that of Sunds Defibrator ($250,000), we decided to verify the potential of these techniques for laboratory refining. In addition, we coupled the blendor with precise wattmeter to measure specific energy levels of refining.

The first results of our study appear in Figure 1. In this figure, the variation of specific refining energy and CSF over time are presented for refining exploded aspen chips. In Table IX, the paper properties of pulps refined with a blendor are compared to those heated with PFI. The comparison, done with two CSF levels, indicate that blendor refining leads to similar burst, breaking length and slightly higher tear when the higher CSF is taken into consideration. Paper property values obtained by blendor compares also well to those obtained by refining (Figure 1). In addition, there is also a rather good correlation between refining energies specifically at low freeness (2.92 MJ/kg, Blendor, CSF 117 versus 2.82 MJ/kg, Sunds, CSF 92).

TABLE IX. Blendor Refining versus PFI Beating (Aspen).

REFINING BEATING	PFI EXPLOSION	BLENDOR EXPLOSION	PFI EXPLOSION	BLENDOR EXPLOSION
PROCESS CHEMICALS (%)	8	8	8	8
TEMPERATURE (%)	190	190	190	190
TIME (MIN)	4	4	4	4
YIELD (%)	92.1	92.1	92.1	92.1
CSF (ml)	293	221	193	117
SPECIFIC ENERGY (MJ/kg)	6.44	2.68	8.4	2.92
BURST ($kPa \bullet m^2/g$)	2.67	3.05	3.0	3.34
TEAR ($mN \bullet m^2/g$)	5.54	6.12	5.09	6.40
BREAKING LENGTH (km)	5.31	5.97	5.74	6.60
STRETCH (%)	1.68	1.88	1.81	2.06

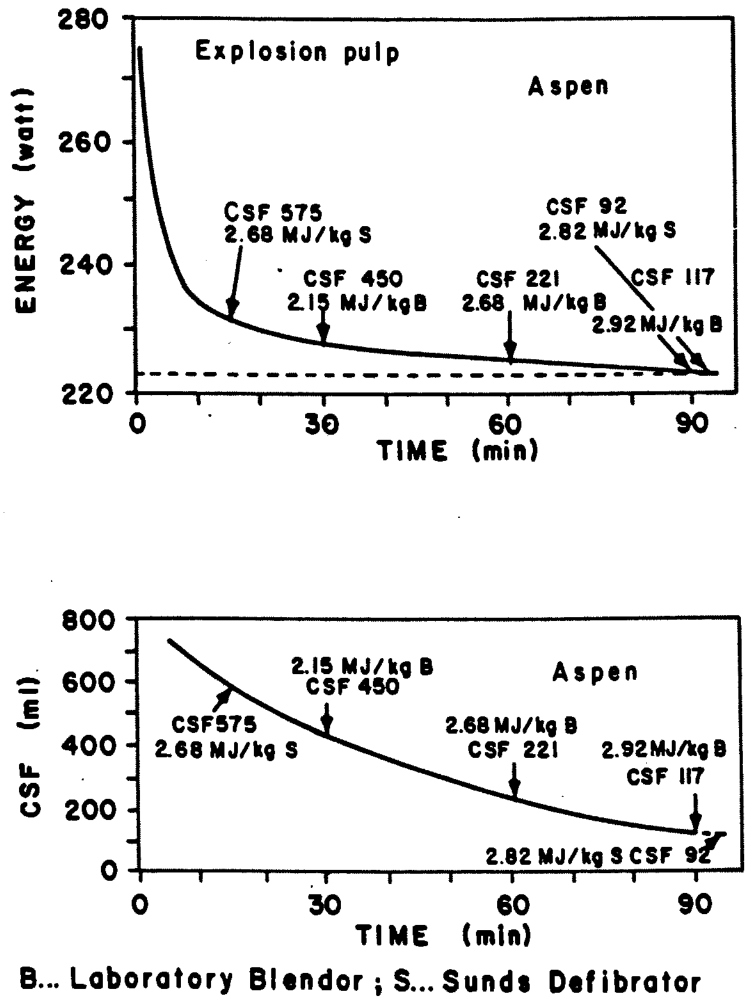


FIGURE 1. Change of Refining Energy and CSF with Time.

In Figure 2, an even more striking correlation exists in the case of softwoods between refining energies obtained by Blendor and Sunds for both high and low CSF.

The most interesting fact is the correlation between the development of CSF and energy. It is obvious that most of the energy (80%) is being used in the first portion of defibration and refining to achieve CSF 700 and only 20% of the energy to decrease CSF to 164. In Table X, the properties of blendor-refined pulps are compared to those of PFI0-beated pulps. In the case of softwoods, PFI beating leads to slightly higher adhesion-dependent properties such as burst, and breaking length, but to sharply lower tear which depends on fiber length. PFI leads to fiber cutting as published by Shaw [7] which is more critical for softwoods than for shorter fiber hardwoods.

TABLE X. Blendor Refining versus PFI Beating (Softwood)

REFINING/ BEATING PROCESS	PFI EXPLOSION	BLENDOR EXPLOSION
CHEMICALS (%)	8	8
TEMPERATURE (°C)	190	190
TIME (MIN)	4	4
YIELD (%)	91.3	91.3
CSF (ml)	155	164
SPECIFIC ENERGY (MJ/kg)	12.5	4.0
BURST (kPa, m²/g)	5.0	4.8
TEAR, (mN•m²/g)	6.1	9.4
BREAKING LENGTH (kg)	7.8	7.3
BRIGHTNESS (%)	47.2 (53)*	48 (54)*
OPACITY (%)	89	91.8

Species 75% SPRUCE; 20% FIR; 5% HARDWOOD.
* AFTER SUNDS REFINING.

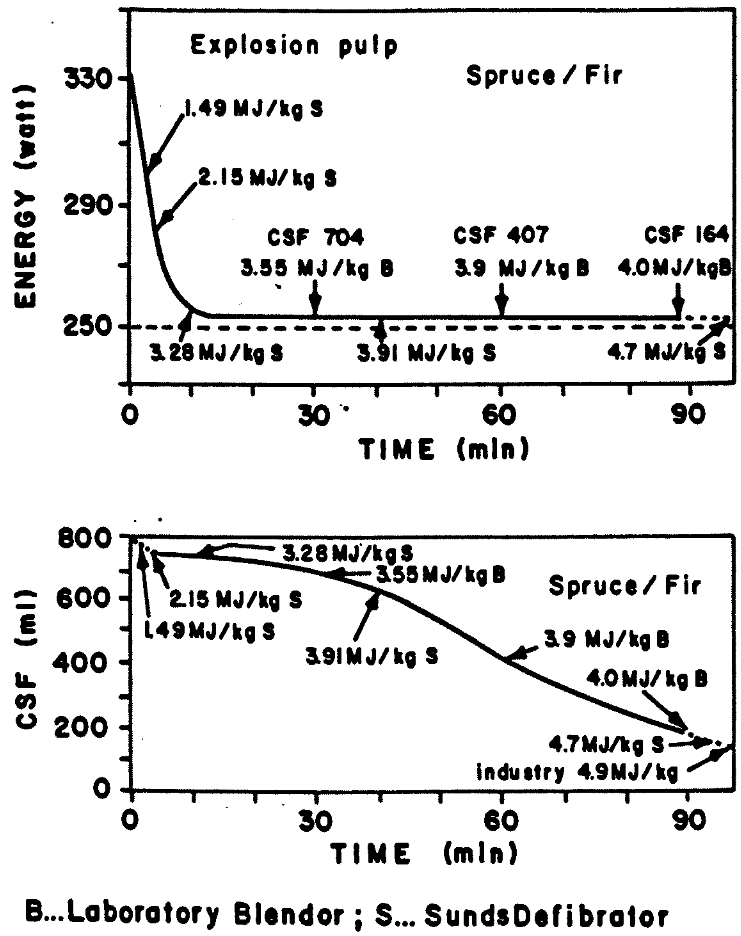
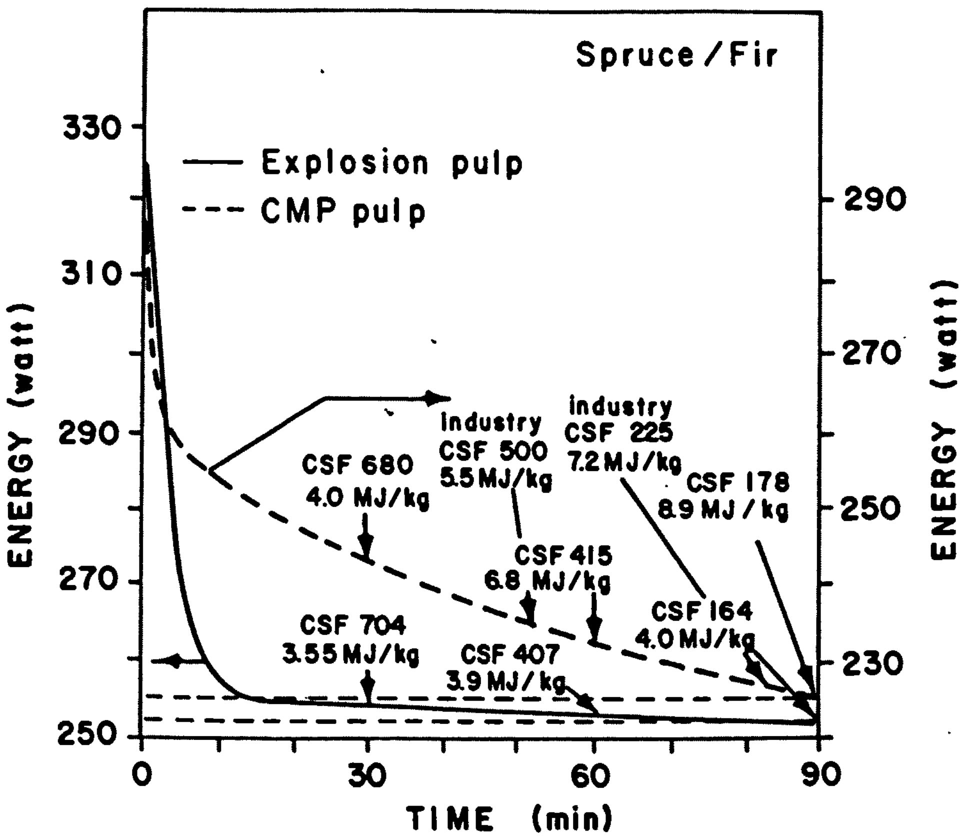


FIGURE 2. Change of Refining Energy and CSF with Time.

In Figure 3, blendor refining curves of softwood explosion chips are compared to those of industrially-cooked CMP chips.

It is very obvious that explosion pulp behaves quite differently than CMP. To decrease CSF, CMP constantly requires energy and at CSF 178 it represents 8.9 MJ/kg compared to refining energy of explosion pulp 4.0 MJ/kg at CSF 164.

In the case of CMP, the values of refining energy obtained on industrial refiners also follow closely the values found during the blendor refining process. The reported industrial values for CMP are 5.5 MJ/kg at CSF 500, 7.2 MJ/kg at CSF 225, and 9.0 MJ at CSF 100.



CMP...13.5% Na_2SO_3; 110 min; 160°C; 87% yield.
EXPLOSION PULP...8% Na_2SO_3; 4 min; 190°C; 91.3% yield.

FIGURE 3. Change of Refining Energy with Time.

In Table XI, blendor-refined explosion pulps are compared to CMP pulps refined in the same way with similar freeness. As far as the refining energy is concerned, explosion pulps are completely different when compared to those of CMP. In the case of CMP, it takes 4.9 MJ/kg to decrease freeness from 680 to 178 (CSF 680: 4.0 MJ/kg; CSF 178: 8.9 MJ/kg). This 4.9 MJ/kg represents a 122% increase in the energy required to go from chips to fibers of CSF 680. For explosion pulps the refining energy at CSF 704, which is 3.55 MJ/kg, will increase only to total 4.0 MJ/kg at CSF 164, ie., only a 13% increase in the energy required to defibrate chips to CSF 704.

In Table XI, the paper properties of explosion and CMP pulps are compared at similar CSF levels.

TABLE XI. Physical Properties of Softwood CMP and Explosion Pulps.

PROCESS	CMP	EXPLOSION	CMP	EXPLOSION
CHEMICALS (%) (Na_2SO_3)	13.5	8	13.5	8
TEMPERATURE (%)	160	190	160	190
TIME (MIN)	110	41	110	41
YIELD (%)	87	91.3	87	91.3
CSF (ml)	178	164	482	407
**SPECIFIC ENERGY (MJ/kg)	8.9	4.0	6.7	3.9
BURST, (kPa•m²/g)	4.1	4.8	2.7	4.0
TEAR, (mN•m²/g)	10.6	9.4	12.9	10.5
BREAKING LENGTH (km)	6.9	7.3	4.7	5.9
BRIGHTNESS (%)	54.6	48.0 (54)***	54.6	48.0 (54)***
OPACITY (%)	88.2	91.8	87.4	92.1

Species 75% SPRUCE: 20% FIR; 5% HARDWOODS

** BLENDOR REFINING

*** AFTER REFINING IN SUNDS

TABLE XII. Paper Properties of CMP and Explosion Pulps.

DEFIBRATOR	BLENDOR *	+ SUNDS	+ + BAUER	SUNDS (1)	SUNDS **	SUNDS (1)
PULP	EXPLOSION	EXPLOSION	EXPLOSION	EXPLOSION	CMP	CMP
CSF (ml)	704	702	687	590	282	72
ENERGY (MJ/kg)	3.6	3.96	4.0	5.0	5.1	8.75
BRIGHTNESS (%)	47.3	51.9	52.1	51.3	57	55.4
OPACITY (%)	92	88.5	88.5	89.2	87.8	86.7
BULK (cm^3/g)	3.48	3.26	2.77	2.78	1.77	1.84
POROSITY (ml/min) (ml/min)	5302	5140	4980	4600	1585	54
BURST ($mN \cdot m^2/g$)	2.34	2.54	2.56	2.81	1.77	2.79
BREAKING LENGTH (km)	3.7	4.37	3.7	5.3	3.5	5.5
STRETCH (%)	1.54	1.58	1.67	1.68	2.25	2.4
TEAR	13.8	14.5	13.8	11.7	10.1	6.4

** EXPLOSION: 8% Na_2SO_3; 190°C; 4 min, (75% SPRUCE; 20% FIR; 5% ASPEN) YIELD: 91.3%.

** CMP: 13% Na_2SO_3; 160°C; 110 min; (75% SPRUCE: 20% FIR; 5% ASPEN) YIELD: 87%.

+ SUNDS: SUNDS DEFIBRATOR, 1000 kg/day UQTR

+ + BAUER: BAUER DEFIBRATOR, 4500 kg/day, PAPRICAN

(1) 2 STAGE REFINING

In the first part of Table XIII, refining energies of industrially prepared exploded chips are compared for pilot-plant Sunds and industrial scale refining.

The values obtained are quite similar:

2.59 Sunds versus 2.88 industry, and

4.68 Sunds versus 4.9 industry.

In the second part of Table XIII, refining energies of laboratory prepared exploded chips are compared for pilot plant Sunds and blendor laboratory scale refining.

Again, there is a very good comparison between one-stage Sunds refining and Blendor defibration:

3.91, CSF 484, Sunds versus 3.89, CSF 407, Blendor

4.61, CSF 114, Sunds versus 4.0, CSF 164, Blendor

Based on these results, we are in favour of blendor-laboratory refining which correlates quite well with the paper properties as well as energy results found on pilot-plant, semi-industrial or industrial-scale installations.

TABLE XIII. Refining Energies of Explosion Pulps.

INDUSTRY	EXPLOSION PULP	CSF (ml)	PILOT PLANT ENERGY (MJ/kg)	REFINING INDUSTRY CSF (ml)	ENERGY (MJ/kg)	BLENDOR
	V-C500	560	2.59	467 (Sprout-waldron) Cascade	2.88	——
AITKIN STAKETECH 0.9% Na_2SO_3	V-C350	322	3.96			
206%C	V-C100	95	4.68	101 (Sunds Cascade)	4.9	——
		CSF (ml)	ENERGY (MJ/kg)			
LABORATORY 8% Na_2SO_3	V-(8,4)	745	3.28	——		
190°C	V-(8,4)	484	3.91			CSF 407 3.89
4 min						CSF 164 4.0
	V-(8,4)	114	4.61	——		

Species: SOFTWOOD, 75% SPRUCE: 20% FIR; 5% HARDWOOD

Wood fiber reinforced composites

As was mentioned in the introduction, wood fibers are quite suitable for the reinforcement of thermoplastics because they are short and have high modulus as well as high tensile strength.

In Table XIV, the advantages of wood fibers are summarized when compared with presently-used inorganic fillers. The economical advantage of wood fibers as reinforcers is indicated in Table XV.

TABLE XIV. Use of Wood Fibers as Reinforcement in Thermoplastic Composites

ADVANTAGES:

- low price
- flexibility during production
- lower density
- lower equipment abrasion
- low health hazard
- renewable resource

TABLE XV. Pricing Range of Various Fibers

Grafted Aspen (Birch) CTMP Fibers	\$450 - 550
Grafted Aspen (Birch) Explosion Fibers	\$400 - 500
Grafted Aspen (Birch) Sawdust Spruce, Fir	\$100 - 200
Treated Mica	\$700 - 750
Glass Fibers	\$2,900 - 3,100

The enormous potential of wood fibers is further enhanced by the fact that even the cheapest sawdust is strong enough to substantially reinforce (and not only fill) thermoplastics.

In Table XVI, the reinforcement potential of grafted aspen, fir and spruce fibers are compared. The study, performed with sawdust, indicate that aspen fibers of Mesh size 60 are excellent reinforcers of polystyrene [8].

In Table XVII, the reinforcement characteristics of grafted aspen or birch are compared to polymethylmethacrylate (PMMA) reinforced with either mica or very expensive glass fibers. From these results, there is no doubt that the wood fibers as a reinforcement agent are even better than glass fibers [10].

TABLE XVI. Physical Properties Improvement of Polystyrene Composites with 30% of Fibers

	Modulus	Energy	Breaking Length
Aspen	+49%	+67%	+92%
Fir	+40%	+58%	+92%
Spruce	+33%	+36%	+56%

TABLE XVII. Mechanical Properties of Grafted Birch or Aspen - PMMA Composites

Polymer	Filler	Weight Fraction of filler (%)	Stress (MPa)	Elongation (%)	Modulus (MPa)	Energy (KJ/m^2)
PMMA	0	0	12	4.5	267	2
	Birch	10	60	12	518	32
	Aspen	10	68	13	523	42
	Mica	10	14	4	377	2
	Glass	10	19	4	494	2
	Birch	30	50	9	560	19
	Aspen	30	53	9	586	21
	Mica	30	25	4.5	564	4
	Glass	30	31	5.0	610	6

Finally, in Table XVIII, the composites of linear low-density polyethylene (LLDPE) reinforced with aspen fibers are compared again to those reinforced with mica or glass fibers. As in the case of PMMA, the wood fibers are equal or better than expensive glass fibers [11]. The excellent reinforcing behavior of aspen wood fibers were also confirmed for extreme conditions in the case of LLDPE [9].

TABLE XVIII. Mechanical Properties of Grated Aspen Polyethylene Composites.

Polymer	Filler	Weight Fraction of filler (%)	Stress (MPa)	Elongation (%)	Modulus (MPa)	Energy (KJ/m^2)
LLDPE	0	0	14.8	34.6	43.5	37.1
	Aspen	20	23.2	39.2	59.1	40.9
	Mica	20	20.1	20	100.5	22.2
	Glass	20	15.2	29	52.8	17.1
	Aspen	40	34.9	30.6	114.1	42.4
	Mica	40	22.0	09	238.7	6.7
	Glass	40	12.2	19	65.1	20.9

CONCLUSION

- The new ultra-high-yield explosion pulping process is excellent for aspen or birch pulping because it leads to stronger and brighter papers with less refining energy when compared to conventional CMP/CTMP processes.
- Laboratory-scale blendor refining is an excellent technique leading to pulp which produces papers comparable to those obtained after pilot-plant or industrial scale refining.
- The refining energy obtained by blendor is comparable to that obtained by pilot-plant or semi-industrial scale refiners.
- Wood fibers or sawdust have reinforcement potential for polystyrene, polymethylmethacrylate and polyethylene.

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SOME PAPERMAKING PROPERTIES OF BLEACHED NEUTRAL SULPHITE - ANTHRAQUINONE ASPEN PULP

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SUMMARY

Samples of aspen chips from the Lac St-Jean region of Quebec were pulped and bleached in the laboratory. The novel neutral sulphite-anthraquinone (NSAQ) pulping technique was used. The total pulp yield was 62.0%. The screened pulp Kappa number was 16.7. The pulp was subsequently bleached in two-stages: medium-consistency oxygen followed by chlorine dioxide. The final pulp brightness was 88.4 pts Elrepho. The pulp strengths were tested and compared with those of commercial hardwood kraft pulps (vix., Canadian aspen, Brazilian eucalyptus and Korean mixed hardwood).

Preliminary test results showed that aspen NSAQ pulp had strength characteristics which are comparable to the hardwood kraft pulps evaluated. The aspen pulps (NSAQ as well as kraft) were characterized by high sheet density. The corresponding opacity was found to be somewhat lower than the Brazilian and Korean pulps tested.

INTRODUCTION

Anthraquinone-catalyzed sulphite pulping under alkaline conditions have been frequently cited to be possible alternative to conventional kraft pulping. Neutral sulphite-anthraquinone (NSAQ) usually denotes operating under mildly alkaline conditions.

NSAQ pulping techniques have been reported by various workers to be useful for the production of very acceptable grades of bleached as well as linerboard pulp from softwoods. Recently, several studies have been made on the NSAQ pulping of aspen [1,2]. The findings were generally favourable: higher yield (ca. 60%) and higher unbleached brightness (ca. 60-65 pts) than kraft pulp. NSAQ appears to be an exceptional pulping technique for aspen, in the preparation of full chemical pulp. CEDED-bleached NSAQ aspen pulp was also shown to have comparable physical strengths as CEDED-bleached kraft pulp [2].

Because of the exceptional high brightness of the unbleached NSAQ aspen pulp, it was thought that a simpler bleaching sequence might be practicable for the production of full-bleached pulp.

OBJECTIVE

The objective of the present study is to compare selected papermaking properties (e.g, physical strength and opacity) of 2-stage bleached aspen NSAQ and several commercial hardwood kraft pulps.

EXPERIMENTAL

Samples of aspen chips from the Lac St-Jean region of Quebec were pulped in a 20-litre batch digester. The neutral sulphite-anthraquinone (NSAQ) pulping technique was used. The total pulp yield was 62.0%. The screened rejects were 0.75%. The Kappa number of the screened pulp was 16.7.

The screened pulp was subsequently bleached in 2-stages: medium-consistency oxygen followed by chlorine dioxide. The final pulp brightness was 88.4 pts Elrepho and the pulp viscosity was 18.3 mPa.s.

The 2-stage bleached aspen NSAQ pulp strengths were tested using standard Tappi and CPPA/TS methods. The results were compared with those of commercial hardwood karft pulps which are currently available in Korea. The commercial hardwood kraft pulps used are listed in Table I.

TABLE I. Commercial Hardwood Kraft Pulps Tested

Source	Wood Species	0.5% CED Viscosity mPa.s	Brightness pts Elrepho
Canada	Aspen	27.5	89.2
Korea	Mixed Hardwoods*	26.7	87.2
Brazil	Eucalyptus	18.4	90.2

*including Korean oak and Australian eucalyptus

RESULTS AND DISCUSSION

Wood Morphology

The basic dimensions of the aspen and eucalyptus fibres and vessel elements are compared in Table II. Note that the aspen fibres are somewhat more slender, and they have thinner cell walls. These features suggest that paper with very good printing properties could be made without difficulty.

TABLE II. Comparative Fibre Dimensions [3-6].

	Aspen (Populus tremuloides)	Eucalyptus (Eucalyptus saligna, E. grandis, E. urophylla)
Fibre		
Length, mm	0.4-1.9	0.75-1.30
Width, um	10-27	15-20
Wall Thickness, um	2-3	3-6
Vessel Element		
Length, mm	0.50	0.33
Width, um	60-70	120

Papermaking Properties

Production of paper requires pulp with a precise balance of physical as well as chemical properties. It is generally recognized that no one parameter of physical strength alone determines the ultimate acceptability of the pulp as usable papermaking fibres.

Table III gives an overall comparison of papermaking properties of the four pulps, in the pulp drainage range of 25 to 31 deg SR. This range is used routinely in many Far East papermills for the production of wood-free printing and writing paper.

TABLE III. COMPARATIVE PULP PROPERTIES.

	NSAQ	Kraft		
	Aspen	Aspen	Mixed HWD	Eucalyptus
25 deg SR				
PFI rev.	0	<25	50	180
Sheet Density, g/cm^3	0.654	0.592	0.500	0.521
Tear Index, $mN.m^2/g$	7.16	6.47	4.32	4.91
Breaking Length, km	4.60	2.80	2.20	3.30
Opacity, %	75	77	80	80
31 deg SR				
PFI rev.	700	350	450	525
Sheet Density, g/cm^3	0.714	0.658	0.532	0.552
Tear Index, $mN.m^2/g$	7.16	8.14	6.77	7.36
Breaking Length, km	6.80	5.30	3.80	4.80
Opacity, %	71	74	79	79

1. Tear and Tensile Strengths

The present test results showed that aspen NSAQ pulp has a generally better combination of tear-tensile strength than the three commercial hardwood kraft pulps evaluated. Figure 1 shows that in the pulp drainage range of 25 to 35 deg SR, the product of tear index and tensile index is higher for the aspen NSAQ pulp. Indeed, this pulp at 25 deg SR has the same strength property as the Brazilian eucalyptus pulp at 30 deg SR and the Korean pulp at 34 deg SR.

2. Sheet Density

High sheet density generally leads to higher sheet smoothness. Figure 2 illustrates the unusally high sheet density of the aspen NSAQ pulp in the pulp drainage range of practical interest. The high sheet density of the aspen NSAQ could be achieved with little or no refining (see Figure 3). Note that the Brazilian and Korean pulps are somwhat bulkier (ie., lower sheet density). Consequently, the sheet roughness is expected to be higher.

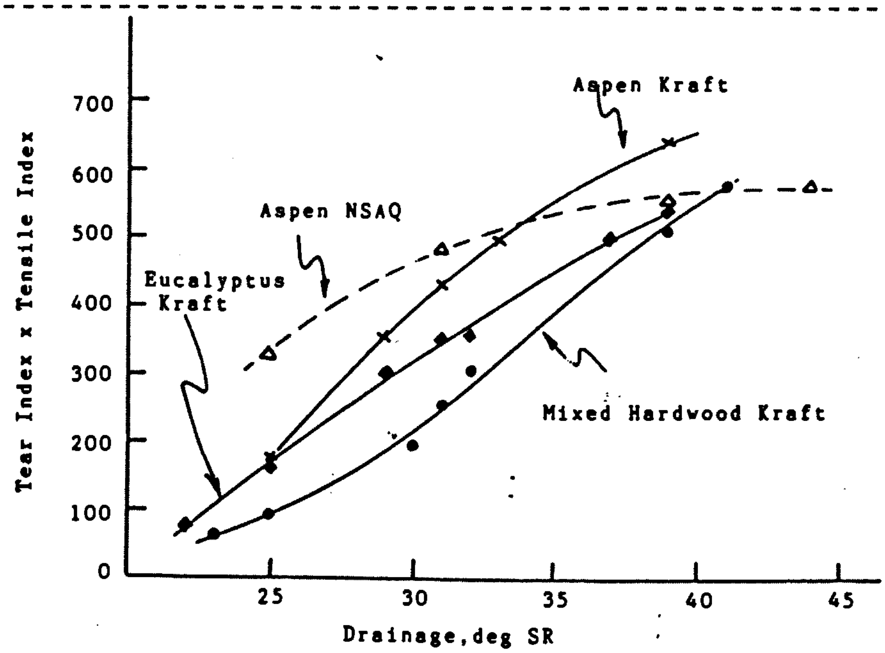
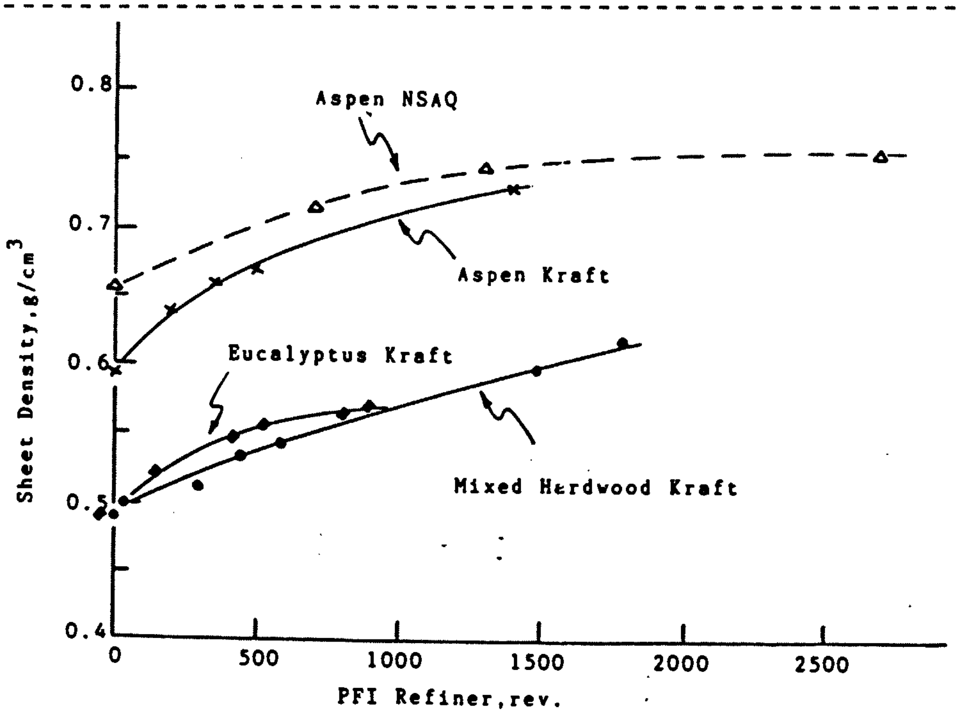


FIGURE 1. Strength Property of NSAQ and Kraft Pulps.



FIGURES 2. Refining of NSAQ and Kraft Pulps.

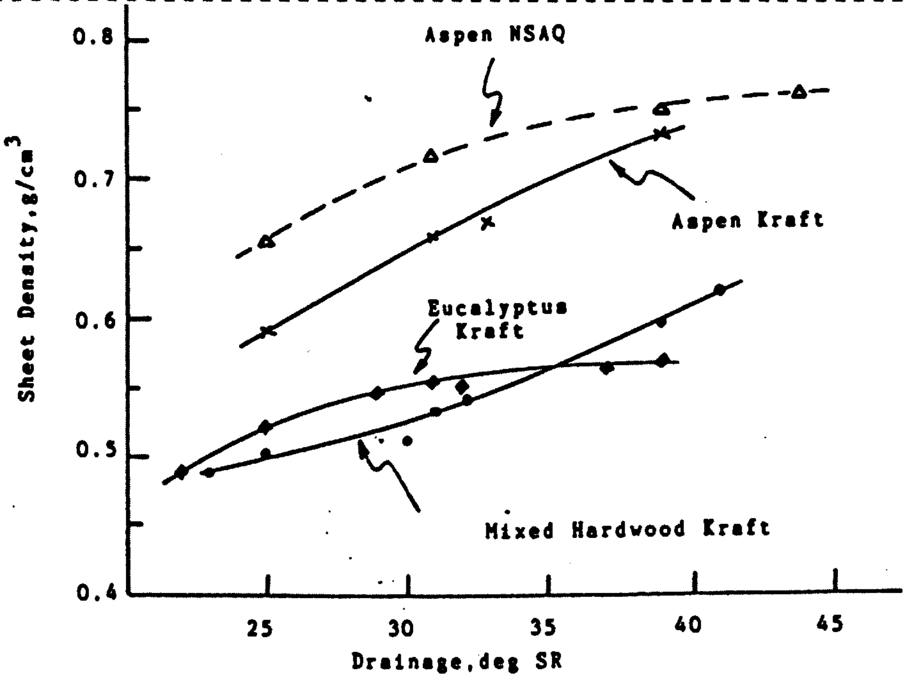


FIGURE 3. Relationship between Sheet Density and Drainage of NSAQ and Kraft Pulps

3. <u>Opacity</u>

Unfortuantely, higher sheet density results in lower opacity. As shown in Figure 4, the aspen pulps (kraft as well as NSAQ) have lower opacities than the other two pulps tested. Depending on the specific grades of paper produced, this lower opacity may have limited adverse impact, eg., in production of paper which is heavily filled, and coated.

CONCLUDING REMARKS

Aspen NSAQ pulp produced in the laboratory has shown to have papermaking properties which are comparable to the three commercial hardwood (aspen, mixed hardwoods and eucalyptus) kraft pulps tested. With its higher yield and easy bleachability, aspen NSAQ pulp holds considerable promise to be a very cost-effective pulp which could substitute fully for traditional hardwood kraft pulps, in paper production.

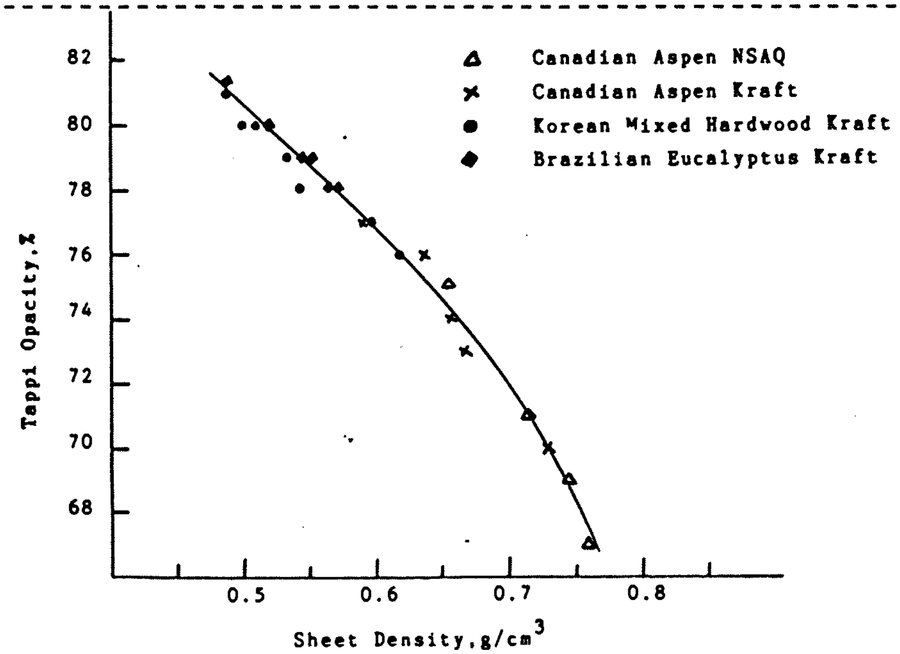


FIGURE 4. Opacity of NSAQ and Kraft Pulps.

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ESTER PULPING OF ASPEN

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Biodyne Chemicals has concentrated its research on ester pulping of aspen. This has been because of our location in the state of Wisconsin and the large amount of aspen pulped in that state. The State of Wisconsin Department of Development has given Biodyne a reimbursable grant under which most of Biodyne's aspen work has been done. That work not funded by the State of Wisconsin has been funded by Biodyne investment capital and by pulp company contracts.

Ester pulping has shown excellent delignificaton of aspen and the pulp has good strength properties. The ability of the ethyl acetate - acetic acid - water system to form two liquid phases in some concentration regions enables liquid extraction to be utilized in the spent solvent recovery system.

We have studied the removal of lignin from spent liquor and have defined these parameters required to precipate lignin in particulate powder form, rather than the all too familiar sticky gum- like material. The fact that ester pulping uses no sulfur compounds assures not only no sulfur pollution but also assures that any recovered lignin is completely sulfur-free.

While the potential for recovery of chemical by-products from the ester pulping process is high, Biodyne has first attacked the problem of producing paper making pulp. The economic viability of the process will initially stand on the basis of burning all by-products as fuel. By-products such as lignin, organic acids, esters, furfural, and sugars can all be made and recovered.

This paper presents some of our more interesting aspen pulping results which we feel indicate what ester pulping can achieve. We have performed small scale laboratory cooks (100 ml and one liter) at the University of Wisconsin - Madison and larger scale cooks (50 liter) at Tennessee Valley Authority facilities in Muscle Shoals, Alabama.

The good selectivity of ester pulping is illustrated in Figure 1. The spread of the data does not define a single line, so two have been drawn to help guide your eyes. It is to be noted that a yield of 50% at a Kappa of ten or less was achieved in these single stage cooks. These low Kappa numbers indicate bleaching requirements will be eased for these pulps. This is expected to reduce both bleaching costs and environmental load. Preliminary bleaching tests by both Biodyne and independent laboratories have been encouraging.

The spread of the data in Figure 1 is at least parially caused by unavoidable variability in washing efficiency. Thorough washing of the defibered pulp in solvent is very important because the recovered lignin is insoluble in water. The effect of inadequate washing is shown by the 50-liter digester results in Figure 1. These experiments washed the undisintegrated cooked chips while they were still in the digester. We feel quite certain that we were unable to wash out some of the spent liquor in the chips. The lignin in this residual liquor remained with the pulp, raising the Kappa Number.

Figure 2 illustrates the effect of increased cooking time on yield and Kappa Number. Unlike many pulping systems, prolonged cooking times continue to reduce lignin content while yield tends to level off and approach a constant value. Clearly, the solvent aids the selective removal of lignin from the wood for as long as four hours without solubilizing large amounts of fiber. While not shown on Figure 2, higher temperatures give lower yields and Kappa Numbers at the same cook times.

Some typical aspen pulp properties which have been achieved are shown in Table 1. The inspection results reported in this table were measured at Fox Valley Technical Institute in Appleton, Wisconsin using handsheets made at the University of Wisconsin-Madison. The pulp was produced at the University of Wisconsin-Madison using run-of-the-mill aspen chips furnished by a Wisconsin pulp mill.

Comparisons between handsheets shown on this table must be done carefully because a wide range of cooking conditions is represented. The first run on the table is actually a composite pulp from ten runs in the one-liter digester made under the same conditions. Using a composite pulp sample from that many runs decreased variations due to uncontrolled differences in the chip sample or random experimental error. The rest of the data represents single runs in the one-liter digester under a wide variety of pulping conditions.

Biodyne has succeeded in producing what we consider a commercially valuable pulp. Research has also been conducted on the recovery of the spent liquor. All solvent pulping systems require excellent recovery and recycle of solvent components to be economically viable. Ester pulping is no exception.

The solubility and conditions for the removal of the lignin are particularly important. We have found that there are conditions under which the lignin can be precipitated as a particulate powder. This not only decreases the cost of handling the lignin, but also has the potential for increasing the recovered materials value.

The recovery of acetic acid by liquid-liquid extraction is old technology. Modifying this technology to the recovery of our spent liquor has required us to measure the equilibrium exhibited by our particular system with all of the various components present. We have found that using the ability of our solvent mixture to form two liquid phases enhances our separation process.

Biodyne's research is turning now more to the pulping of woods other than aspen, principally pine where we have some very encouraging initial results. For aspen, we have done much in the laboratory and the focus should now change to specific applications and pilot unit work.

TABLE 1. Aspen Pulp Properties.

Yield %	Kappa	Freeness CSF	Bulk cc/g	Breaking Length km	Tensile Index *	Burst Index **	Tear Index ***	Fold
55.0	13	320	1.09	7.44	73.0	3.71	4.88	345
58.0	35	530	1.26	4.57	44.9	1.88	4.85	11
55.0	18	325	1.10	7.54	73.9	3.55	4.91	53
62.0	38	530	1.24	4.70	46.1	1.84	5.29	9
51.0	9	350	1.10	7.46	73.2	3.26	5.10	215
75.0	69	490	1.39	3.49	34.2	1.67	3.79	5
48.0	3	250	1.06	7.33	71.8	3.50	4.01	431

* N.m/g
** $kPa.m^2/g$
*** $MN.m^2/g$

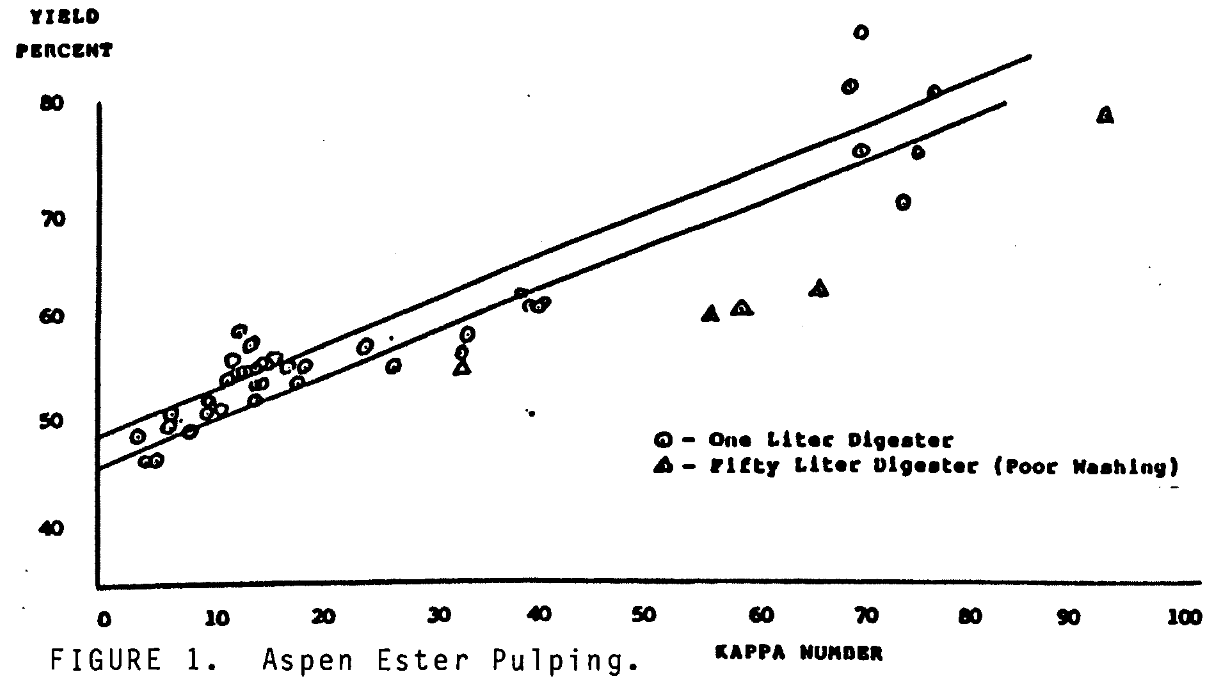

FIGURE 1. Aspen Ester Pulping.

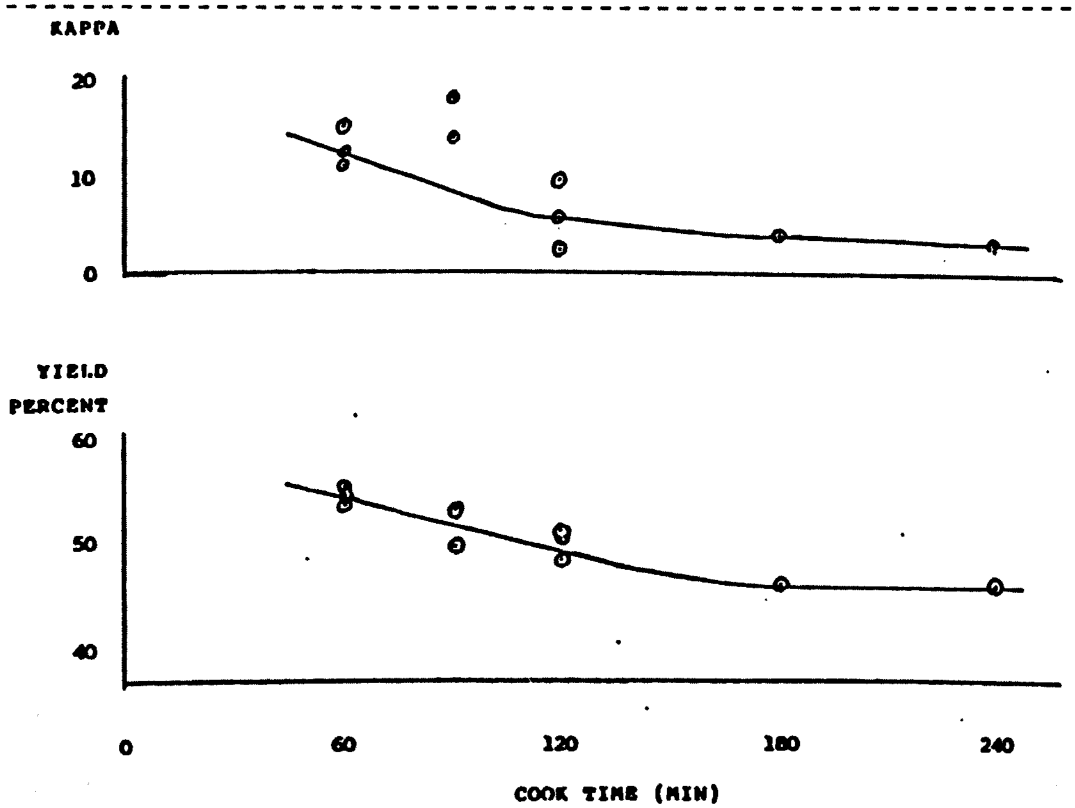

FIGURE 2. Yield and Kappa at Constant Temperature Aspen Wood Chips.

SOLVENT PULPING

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The beginning of solvent pulping dates back to 1931 (Kleinert and Tayenthal, 1931). More recently, studies have been concentrated on the use of three types of solvent systems:

a. Aqueous alcohols, such as methanol, ethanol or butanol ("alcohol pulping").

b. Acetic acid - ethyl acetate ("ester pulping", Young and Baierl, 1985).

c. Aqueous phenol ("phenol pulping", Sachetto et al., 1983).

In this paper, only the first two types of solvent systems will be discussed.

Recently, Aziz and McDonough compared the effects various solvent pulping methods on aspen and other pulpwood species (1987). While aspen could be readily pulped down to below kappa 10 with good viscosity retention using ester pulping, such hardwood species as red oak and eucalypt gave under similar conditions pulps above kappa 30 with reduced viscosity. On the other hand, white spruce and southern pine solvent pulps remained invariably above kappa 100 level. These results parallel closely alcohol pulping results obtained in our and other laboratories on a variety of pulpwood species and suggest that the solvent system used has no profound effect on the course of delignification. Secondly, the uniquely favorable response of aspen and other poplar species to solvent pulping is convincingly demonstrated by the results.

The authors also compared the properties of solvent pulps with conventional pulps. For aspen, ester- and alcohol processes appear to produce pulps with similar properties, with the possible exception of $MgCl_2$-catalyzed alcohol pulps for which improved strength characteristics have been claimed (Paszner and Chang, 1981). Compared with sulfite pulps, the yields and strength properties of aspen solvent pulps are clearly better. Under circumstances, yields of solvent pulps may exceed those of kraft pulps, but their tensile- and burst strengths are somewhat and tear strengths significantly lower than those of kraft pulps. In summary, the potential of solvent pulping of aspen and other poplar species as well as such hardwood species as birch and sweetgum is to be taken seriously.

It is important to observe, however, that wide variaton in the chemical composition of aspen- and other poplar woods is an annoying obstacle in conducting systematic pulping studies. Numerous examples from the literature can be cited to illustrate this generally overlooked characteristic. For example, the alpha cellulose contents of poplar stem woods vary from 40-53% (Jayme 1951; Timell 1957) and kraft pulp yields, from 52-65% (Jayme et al. 1951). Interestingly enough, the correlation of these values with tension wood content was found to be very poor. In order to determine whether this variation existed between individual trees or within a single tree, we selected and felled two 20-year old black cottonwood (P. trichocarpa) trees and sampled individual growth rings in an arbitrarily selected radial direction (Cole et al. 1984). The lignin-free kraft pulp yields, alpha cellulose- and total lignin contents for these two trees are shown as a function of growth ring number in Figure 1. A wide and irregular compositional variation is apparent for tree A, the alpha cellulose varying from 40-54%, for example. In contrast, the composition of tree B was relatively constant.

The effect of compositional variation of cottonwood chips from various sources on the yield-kappa relationship of solvent pulps is illustrated in Figure 2 (Cole 1983). When wood material of even composition is pulped, the experimental points lie reasonably close to a single line (10-year old tree, black triangles). Consequently, all our kinetic studies were performed using such homogenous chip material.

The pattern of solvent delignification (Tirtowidjojo et al.) is similar to kraft delignification where the first order "bulk delignification" is followed by a slower "residual delignification" phase (Figure 3). Also, the transition from bulk to residual delignification occurs at lower residual lignin contents at higher reaction temperatures, as it does in kraft delignification.

Catalyst-free solvent pulping at @200°C has often been considered to be the preferential mode of operation. Our results contradict this opinion (Figure 4). When 0.01 MH_2SO_4 is used as catalyst, not only can the pulping be performed at 30°C lower temperature, but also the transition to residual delignification occurs at a lower residual lignin content.

Figure 5 shows bulk delignification rate constant as a function of catalyst concentration in the temperature range 130-170°C. A rapid increase in reaction rate results from the increase of catalyst concentration up to 0.02 molarity, but further increase has only a modest accelerating effect. Consequently, optimum catalyst concentration is limited to the narrow concentration range 0.01 to 0.02 M sulfuric acid. Higher catalyst concentrations accelerate more cellulose degradation than delignification.

The initial concave forms of the curves in Figure 5 are caused by the neutralizing effects of small amounts of ash- and protein components present in wood. These components can be removed by leaching microchips successively with dilute NaOH, dilute acetic acid and water. As a consequence of the "deashing" treatment, a nearly linear relationship is established between bulk delignification rate and catalyst concentration in the low concentration range

(Figure 6). Using the data obtained in this catalyst range, the activation energy for alcohol pulping can be estimated and comes out to be 80.3 kJ/mol (Tirtowidjojo et al. 1987). The magnitude of the activation energy suggests strongly the rate determining chemical reaction in solvent pulping to be the solvolytic cleavage of alpha-aryl ether bonds in the lignin matrix (Meshgini 1982).

A significant acceleration of the delignification rate can be achieved by carrying out the pulping in a flow-through reactor in which the pulping liquor is continuously replaced by fresh liquor. The effect is illustrated in Figure 7 which compares the kinetics of batch- and flow-through runs, both conducted at 150°C using 0.01 M sulfuric acid as catalyst. An acceleration of the delignification rate by a factor of 3.9 was observed in the flow-through reactor run. However, the major part of this rate difference is actually due to the neutralizing action of ash components in the batch reactor experiment. When this factor is eliminated by deashing, the acceleration factor becomes 1.8 - still indicating a significant difference. It seems probable that, in the batch reactor experiments, a part of dissolved lignin becomes irreversibly reabsorbed on the fibers upon cooling the reactor.

Overall, the flow-through mode of reactor operation has a beneficial effect upon the delignification process. This is illustrated by molecular weight values for isolated solvent lignins and -fibers, based on careful determinations carried out by Dr. Fernand Pla in Grenoble, France (Table 1). It can be seen that, at the same level of delignificaton, both pulp fibers and isolated lignins obtained in a flow-through reactor are less degraded.

The solubility of solvent lignins isolated from cottonwood pulpings in methanol-water mixtures of varying composition is shown in Figure 8 (Titowidjojo 1984). When the volume fraction of methanol is brought down below 0.5, the solubility of solvent lignins is drastically reduced. This characteristic limits the reduction of the organic alcohol component both in pulping as well as pulp washing liquors, although the solubility limit can be improved by increasing the temperature.

Comments on the Industrial Application of the Solvent Pulping Process

The results obtained in our studies indicate that the use of an acidic catalyst, such as 0.01-0.02 M sulfuric acid, is required in alcohol pulping in order to reduce digestor temperature and -pressure and to promote near-complete delignification. Secondly, the pulping operation should be continuous and performed in a countercurrent fashion. Under these premises, alcohol pulping may be operated at as low temperature range as 145-155°C. Thirdly, pulp washing should be completed within the digestor, because of the solubility properties of solvent lignins. A hi-heat wash zone with sufficiently long residence time (3-4 hours) ought to be satisfactory, if it is assumed that washing efficiency equal to that of Kamyr hi-heat wash zones (7 to 11 Norden number) can be reached. This arrangement would allow for solvent recovery from washed pulp by a combination of vapor flash and steaming, after the pulp leaves the digestor. It may be possible that either horizontal tube- or inclined tube digestors may turn out to be better suited for solvent pulping than Kamyr type vertical digestors.

The tendency of solvent lignins to form tarry materials adhering to metal surfaces is a foreseeable problem in the alcohol recovery from spent pulping liquors. Perhaps these problems can be minimized if the exiting spent liquor is rapidly brought down to near-ambient temperature in a succession of flash tanks with concurrent precipitation of solvent lignin in a filterable form.

Two separate applications can be envisaged for aspen- and poplar solvent pulps: A) Fully bleached paper-grade pulps, and B) Dissolving pulps.

For paper grade pulps, the target kappa number should probably be in the range 10-15. It was mentioned earlier that solvent pulps are obtained in higher yields and with better strength properties than corresponding sulfite pulps. It should be added that, at least in theory, solvent pulping can be operated with no atmospheric nor aqueous emissions. It may also be possible that a combination of oxygen bleaching with a single chlorine dioxide stage will turn out to be satisfactory for the production of bleached pulps.

The production of dissolving pulps requires increased acid catalyst concentration and, in all likelihood, kappa range 5-7 can be reached. Consequently, a chlorination-free bleaching sequence consisting of hot alkali refining followed by a single chlorine dioxide stage may turn out to be applicable. It should be emphasized that solvent pulps have the unique and important advantage of being totally extractive-free.

The by-product potential of solvent pulping is real. The isolated solvent lignin is not only an excellent solid boiler fuel, but may also find application as an additive to phenolic adhesives. It can be also converted to sulfonated lignin derivatives. The spent liquor from aspen pulping contains significant amounts of p-hydroxybenzoic acid which may be isolatable. The dissolved carbohydrates consist mainly of xylose which may be used as a feedstock for fermentation processes (methane, protein, etc.) or converted to xylitol.

From the present stage of knowledge, solvent pulping of aspen emerges as an interesting and novel process with definite application potential. On the other hand, novelty alone is no merit, and hard and objective pilot plant data are required before realistic comparisons can be made with conventional pulping processes.

TABLE 1. Molecular weights of organosolv lignins and pulp fibers.

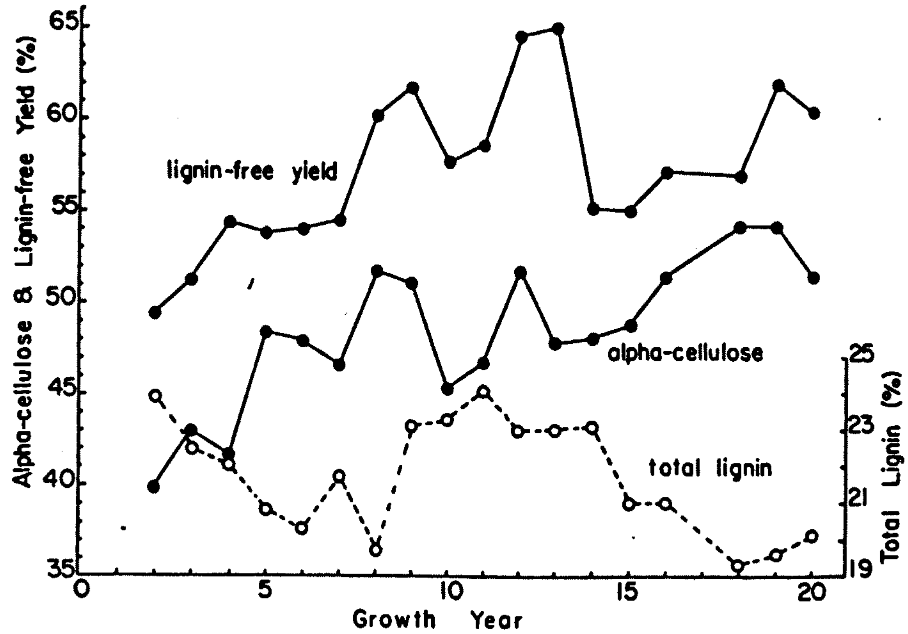
A. Organosolv Lignins

Sample	Catalyst, MH_2SO_4	Reactor type	Reaction Temp.	$M_w \cdot 10^3$	$M_n \cdot 10^3$	M_w/M_n
I	0.01	Batch	170°	9.43	0.98	9.7
II	0.05	Batch	170°	3.30	0.84	4.0
III	0.01	Flow-thru	150°	50.20	7.85	6.4

B. Pulp Fibers

Sample	Reactor type	Pulp Kappa	$N^{(a)}$	$DP_w^{(b)}$	DP_n	DP_w/DP_n
I	Batch	7.8	3.80	1445	435	2.8
II	Batch	4.5	1.05	190	70	3.3
III	Flow-thru	8.4	7.50	1600	990	1.6

(a) Intrinsic viscosity of holocellulose in cupriethylene diamine at 20°C±0.01°C; (b) Determined by LALLS static method applied to holocellulose tricarbanilates; (c) Determined by Size Exclusion Chromatography applied to holocellulose tricarbanilates (Unit wt. = 519).



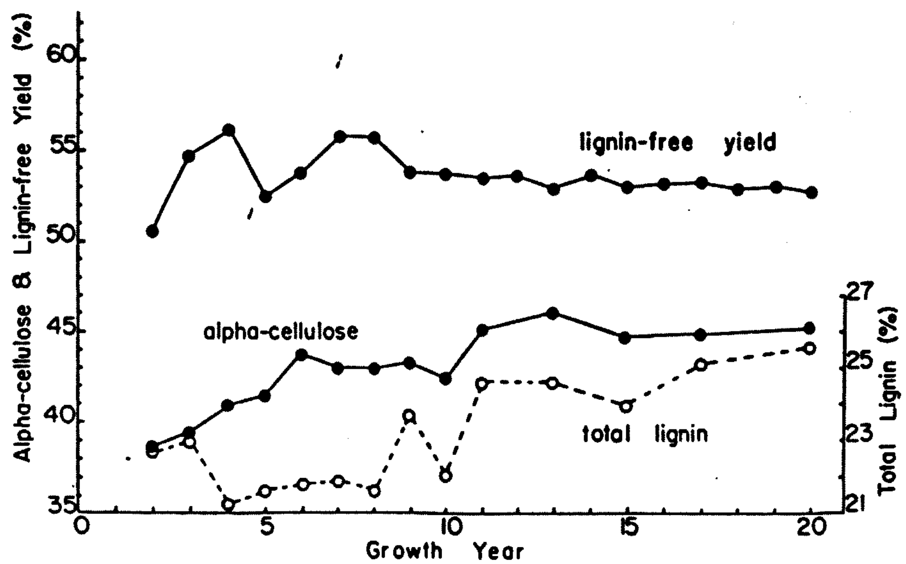


FIGURE 1. Lignin-free kraft pulp yields, and alpha-cellulose- and lignin contents of selected annual increments of two 20- year old black cottonwood trees. Sampling done along an arbitrarily selected radial direction from a disc cut at the breast height level. Both trees were free of tension wood. Tree A is an example of large compositional variation, whereas Tree B possesses relatively even chemical composition.

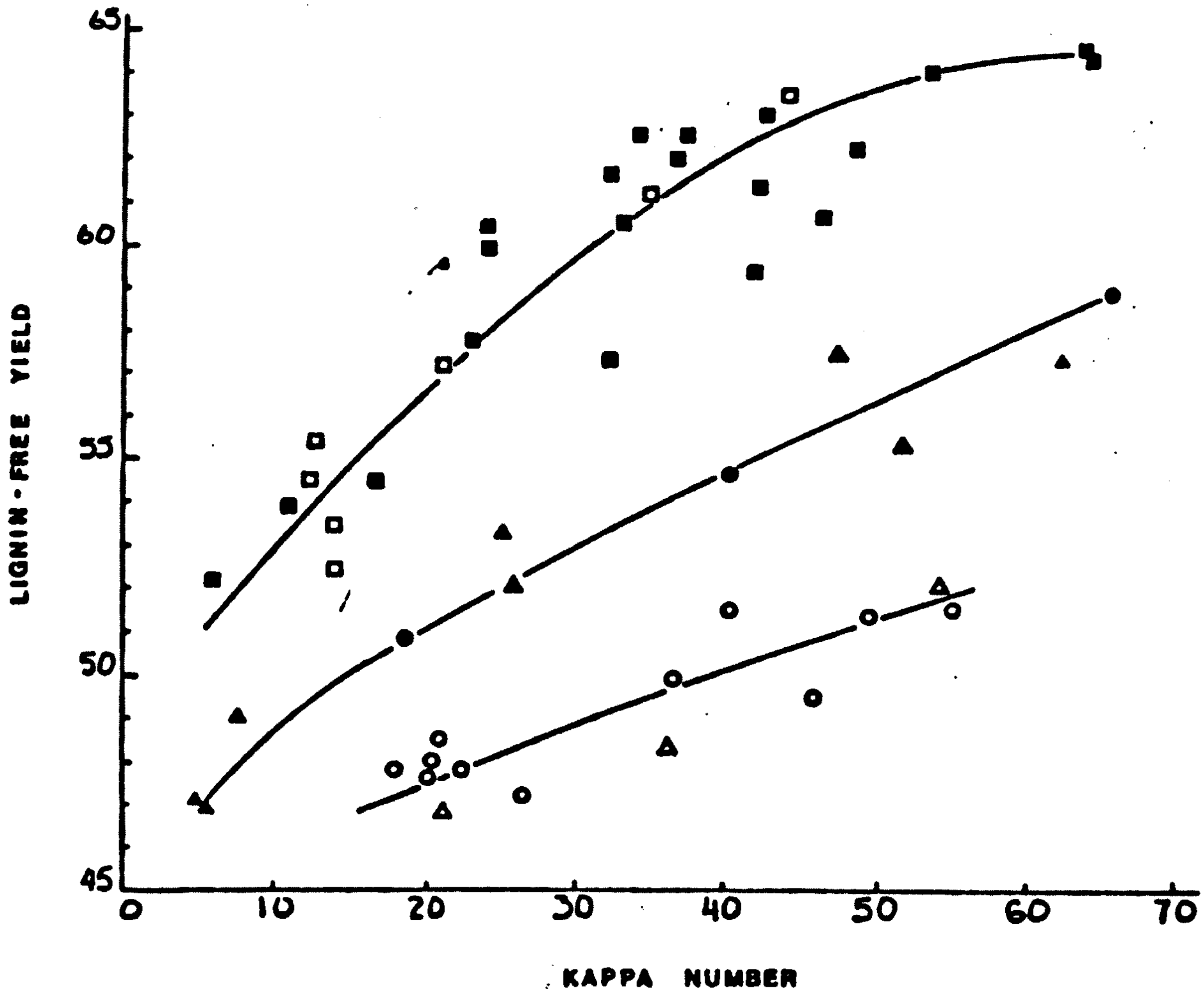


FIGURE 2. Solvent pulp yields (lignin-free) as a function of kappa number for cottonwood chips from various sources. -<u>Squares</u>: Industrial cottonwood chips (Crown-Zellerbach Co., Camas, WA.). -<u>Triangles</u>: Chips from a single 10-year old tree. -<u>Circles</u>: Wafers from another 10-year old tree. -<u>Filled symbols</u>: Solvent methanol-water. -<u>Open symbols</u>: Solvent ethanol-water.

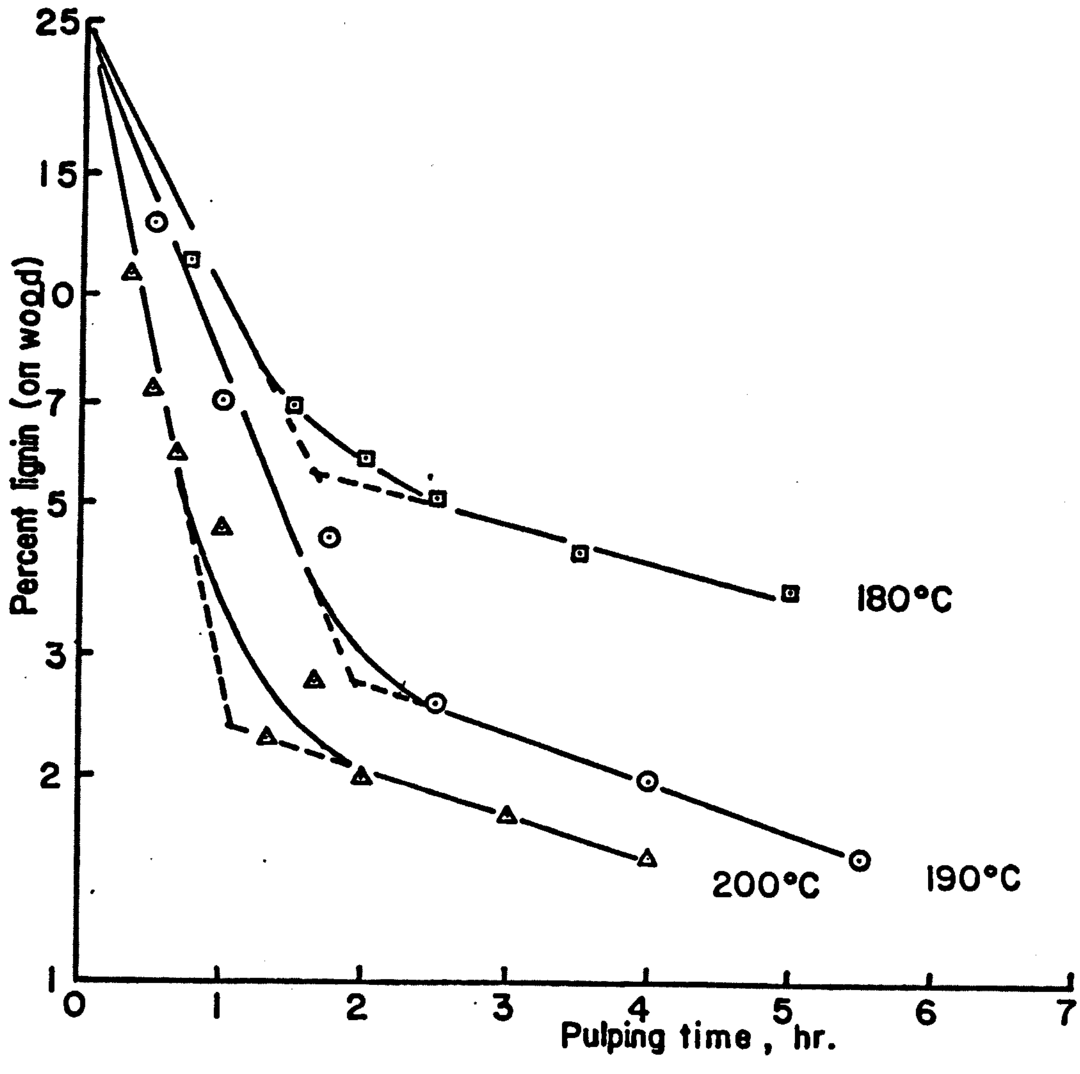


FIGURE 3. First-order rate plots for the delignification of cottonwood in 70:30 v/v methanol-water.

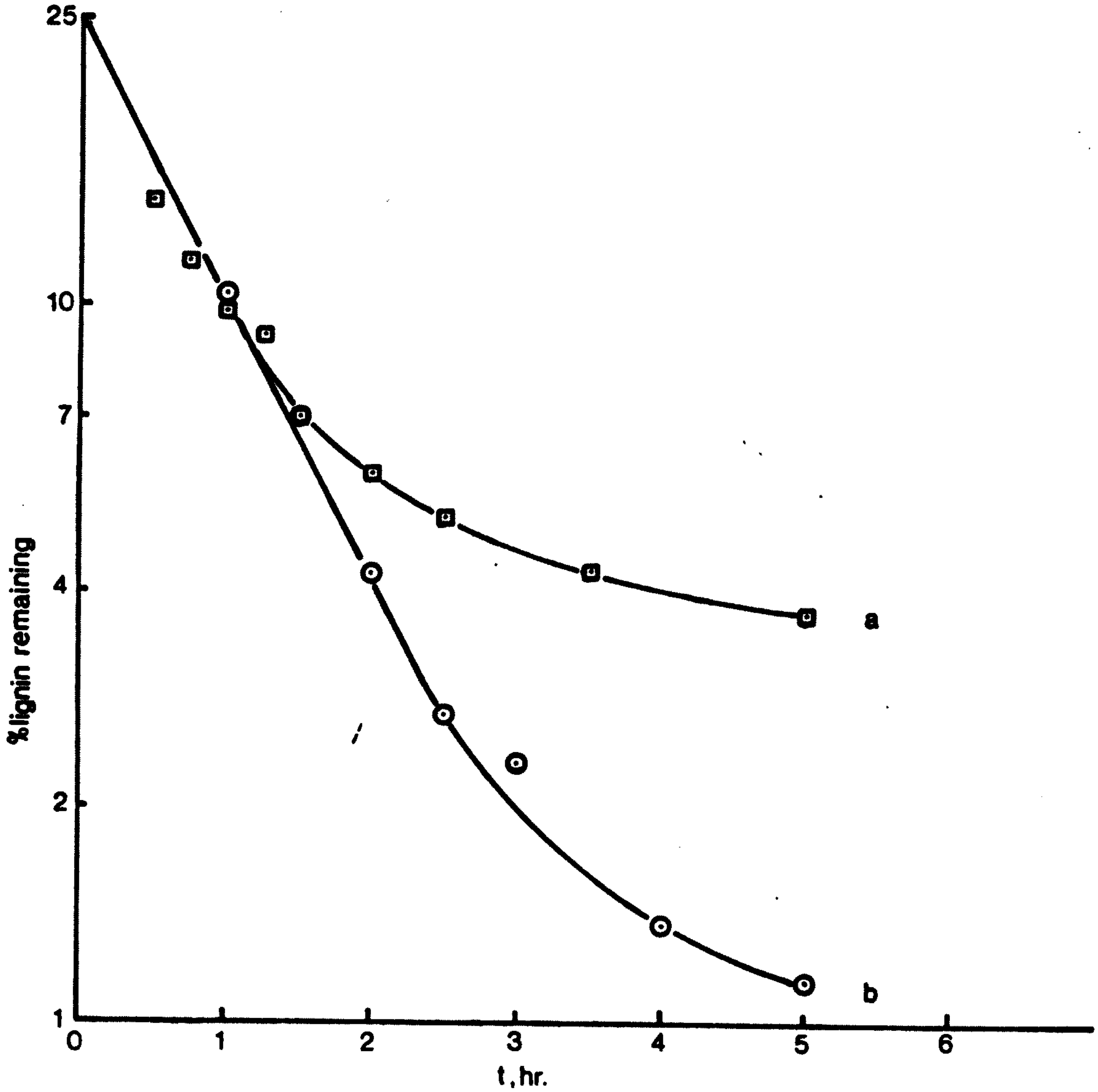


FIGURE 4. Catalyzed versus uncatalyzed delignification in 70:30 v/v methanol-water. Curve a): Run at 180° without catalyst. Curve b): Run at 150° using 0.01 M sulfuric acid as catalyst.

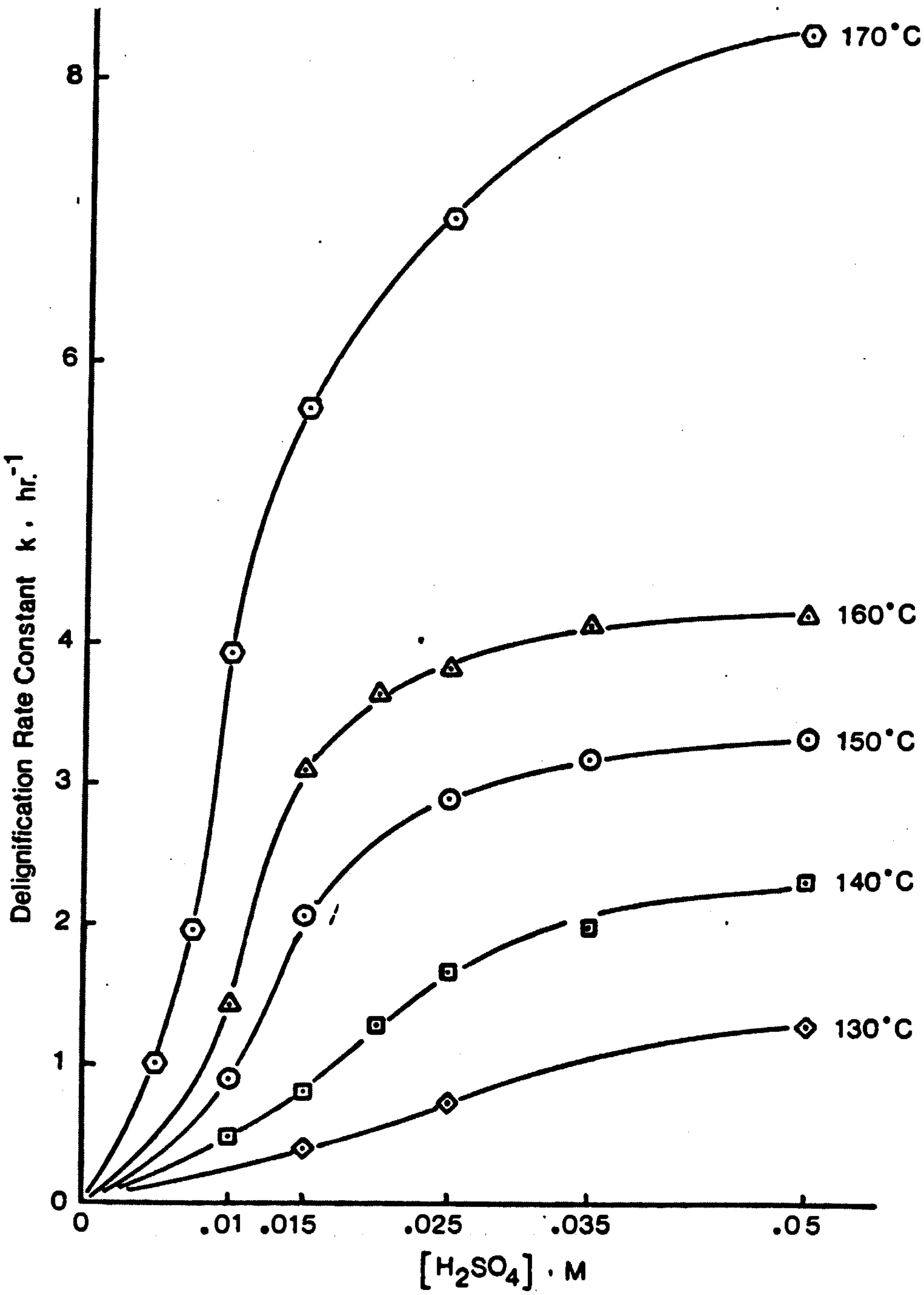


FIGURE 5. Bulk delignificaton rate constant in solvent pulping of cottonwood as a function of catalyst concentration.

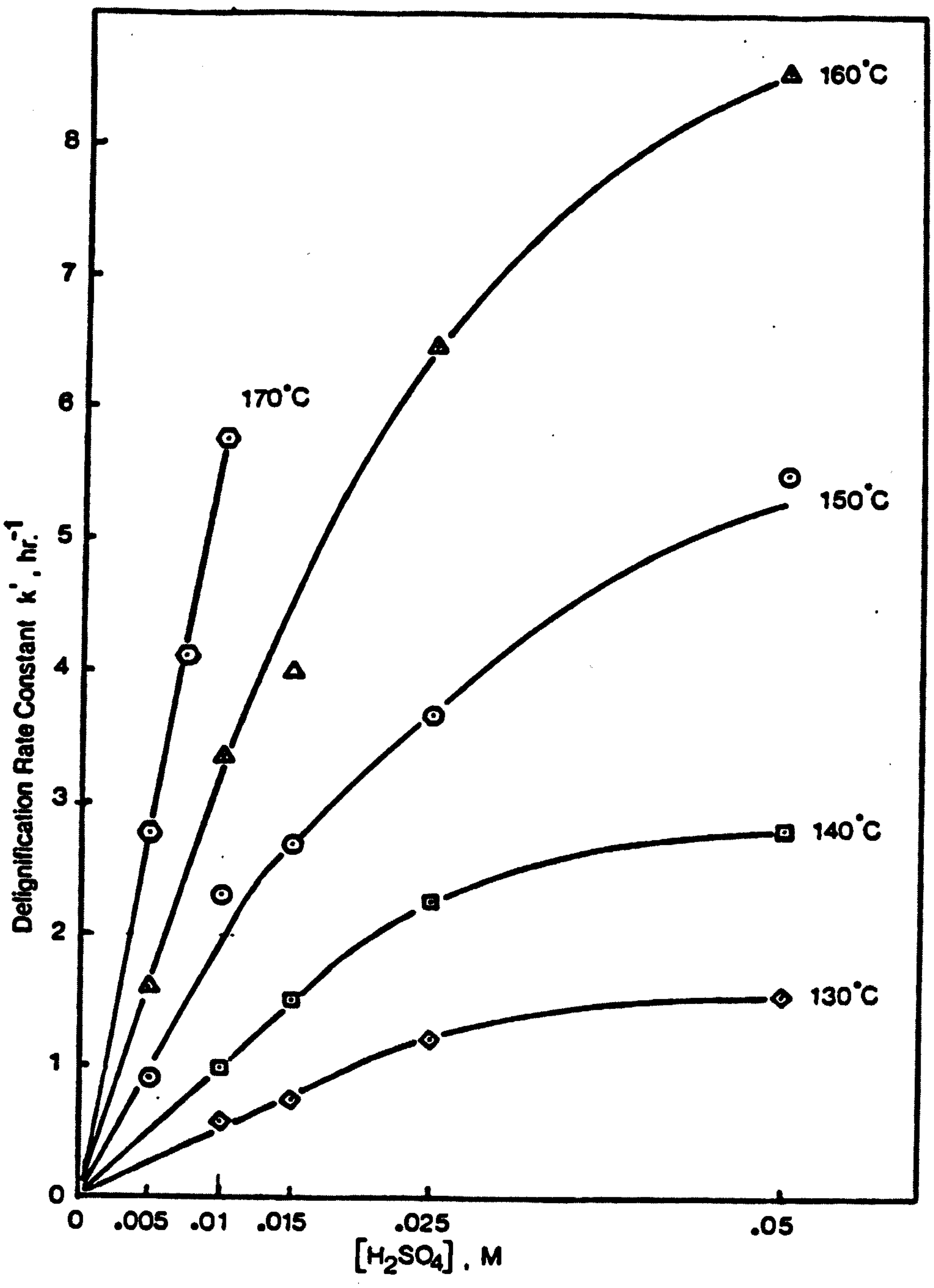


FIGURE 6. Effect of deashing on the bulk delignification rate - catalyst concentration relationship.

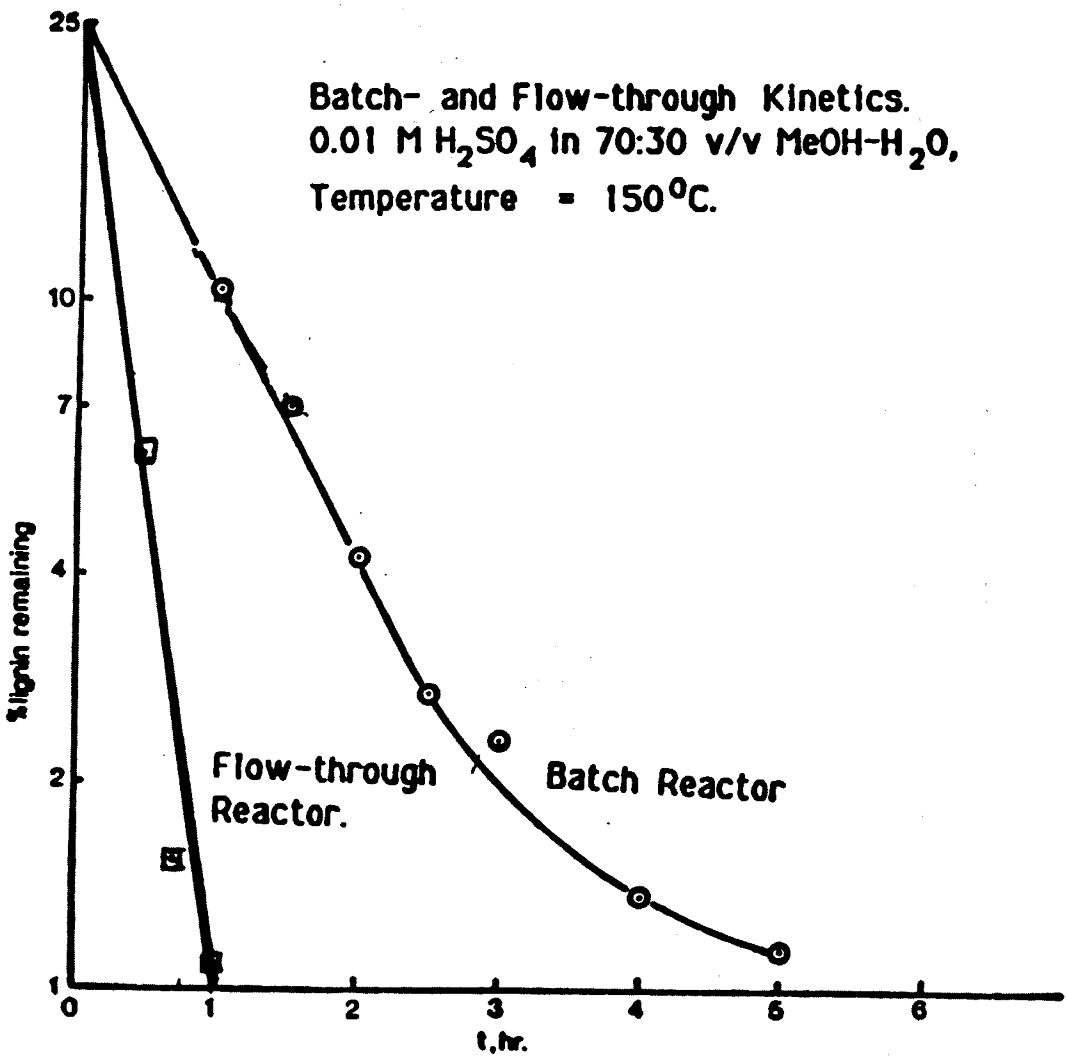


FIGURE 7. Accelerated delignification rate observed for pulping carried out in a flow-through reactor.

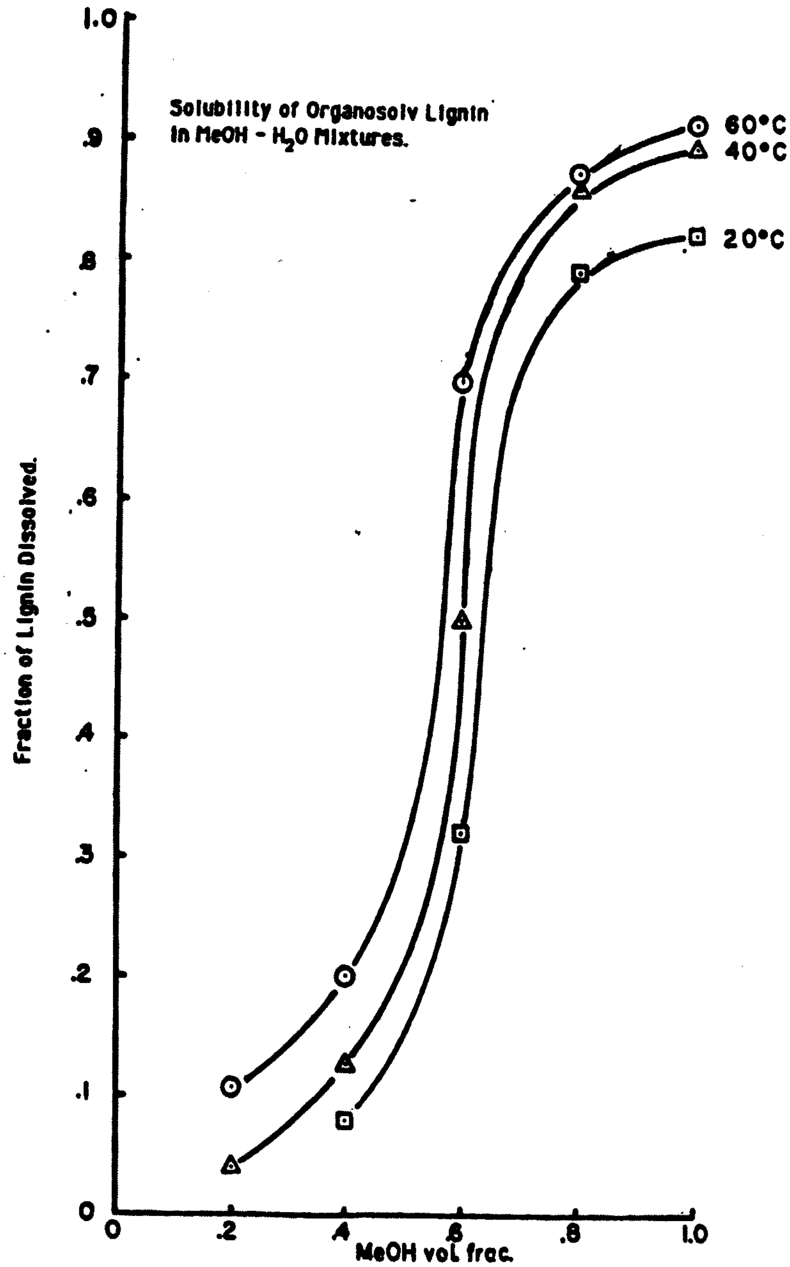


FIGURE 8. Solubility of cottonwood organosolv lignin in methanol-water mixtures.

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ASPEN-BASED CHEMICALS

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ABSTRACT

Forintek Canada Corp. is currently conducting a broad-based research program on the ways and means of improving the utilization of forest residues.

In particular, a research project is in progress on the evaluation of decadent timber (eg., aspen) as feedstock for the production of fuels and chemicals. The basis of the laboratory approach is the separation and refining of wood fibre through controlled biological processes.

NOTE: The presentation on this topic was ommitted from the proceedings since the author failed to submit any written report to date. Thus, for further information on this topic interested parties are advised to contact the author directly.

TOURS OF FOREST PRODUCTS LABORATORIES AT THE ALBERTA RESEARCH COUNCIL

L. BACH
MANAGER
FOREST PRODUCTS GROUP
ALBERTA RESEARCH COUNCIL
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Forest Products Program

Guide to the

Panel Development Laboratory

This laboratory is equipped with four panel presses for the research and development (R&D) of panel products. These facilities are available for use by and for industrial clients as well as in-house R&D.

The laboratory presses and auxiliary equipment are capable of processing chips, wafers, strands and fibrous wood materials from the reduced form (chips, fibres, etc.) to the finished panel. Testing of the product according to various specifications such as ASTM or CSA can then be carried out in-house by the Testing Laboratory.

Chip or Fibre Preparation

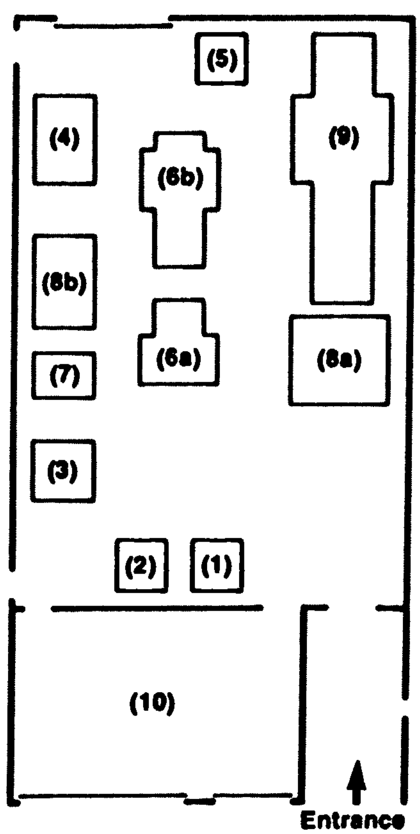
Drying and preparation

- A large walk-in (electrically heated) drying oven with a six tray wheel rack is available for drying the raw materials. (1)
- Two sizes of shaker screens for grading chip or stranded wood are available. One unit is 30" x 30" while the other is a pilot size 24" x 72" unit. (2)
- Two resin blenders for adding wax and resins to the furnish are available. These units are drum type blenders which can be fitted with a hot wax spraying apparatus.
- One of the blenders is for use with a powder resin (3), while the second is a pilot-scale liquid resin blender fitted with a spinning disc liquid resin distributor. (4)

Mat Formers and Presses

The four presses in the laboratory are graded in size so that development work can be conducted from a small scale preliminary investigation to the full-size panel product level. The equipment includes:

- A 12" x 12" electrically heated hydraulic press capable of producing 100 tons of force or 1100 psi on a 12" x 12" board. The mat is either laid up by hand for this unit or it may be produced on a mat former and cut to size. (5)
Programmable controls are used in the unit for product reproducibility.
- A 28" x 52" electrically heated hydraulic press with a capacity of 500 tons force or 680 psi on a 28" x 52" pressed board. (6a)
Programmable controls for heat, pressure, displacement and time are used on this unit in order to permit reproducible cycles.
This unit includes a former with picker rolls similar to a plant unit which produces a random orientation. It also has a removable orienter which can orient the strands in a crosswise direction. Longitudinal orientation can be attained by changing the orientation of the caul plate (perpendicular to the rolls). (6b)
Variable speed drives are used on the metering belt, picker rolls, orienting heads, and caul drive.
A weigh scale is mounted on the caul drive so that continuous weight monitoring can be conducted for reproducibility.
- A 34" x 34" steam heated hydraulic press with a capacity of 380 tons or 660 psi on a 34" x 34" pressed board. This unit is fitted with platens which can be used to inject steam into the mat. The mat can be formed by hand or on the former associated with the 28" x 52" press. (7)
- A 4' x 8' (nominal) hydraulic press with a capacity of 2000 tons or 660 psi on a 58" x 104" pressed board. (8a) This unit is heated by steam produced on a 150 kW steam boiler with a capacity of 600 psi saturated steam. (8b)
The furnish may be formed in a random waferboard or an oriented strandboard with an orienter (9) similar to that used in Alberta OSB plants. All motor drives on the former and orienter are variable speed to give flexibility in selecting conditions.



A small laboratory (10) is associated with this area where small-scale testing of the products can be conducted. However, full-scale testing of the product can also be done in the testing laboratory.

For further information

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ALBERTA RESEARCH COUNCIL

TESTING LABORATORY

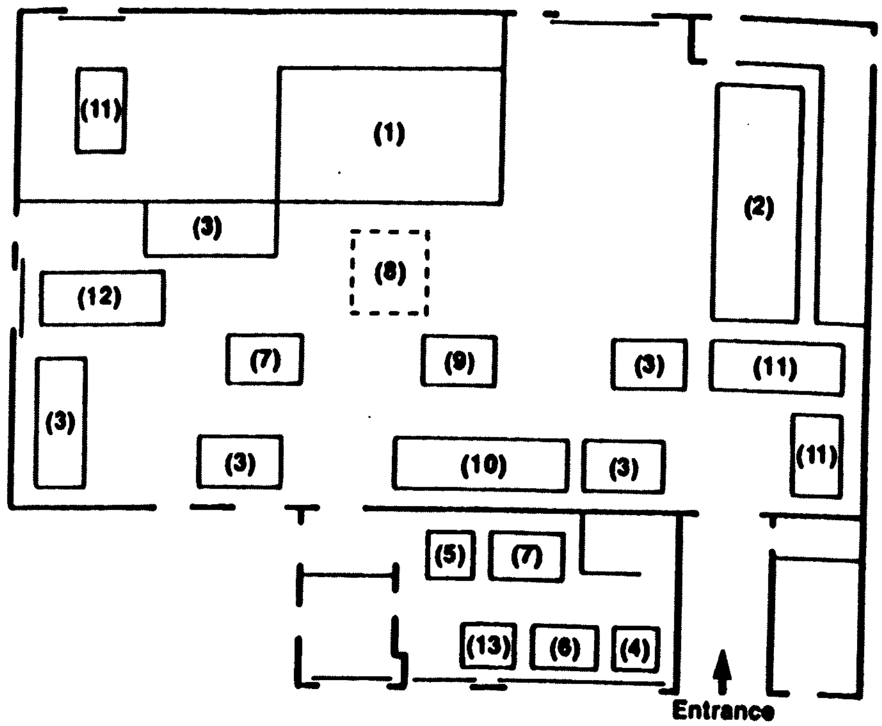
PRINTED MATERIAL

Forest Products Program

Guide to the

Testing Laboratory

Product evaluations are conducted for industrial clients and for the Forest Products Research Program. The laboratory has been certified by the Standards Council of Canada and Canada Mortgage and Housing Corporation.



Sample Preparation and Conditioning

Sample Preparation **(1)**

- Samples are cut, identified, weighed, measured and all data recorded.

Sample Conditioning

- The samples are stored in conditioning rooms under controlled temperature and humidity conditions to stabilize moisture content. **(2)** This is very important as the strength of wood depends on its moisture content.
- Boil tanks, vacuum and pressure vessel, steam tank, ovens, cooling baths and conditioning (soak) tank. **(3)** These provide various combinations of temperature and humidity that, when applied in cycles, simulate actual exposure to the weather. The ovens are also used to dry the samples which aids in determining moisture content.

Small Sample Testing

Instron Universal Testing Machine **(4)**

- Samples are subjected to bending or tension forces to calculate Modulus of Rupture (MOR) and Modulus of Elasticity (MOE) or Internal Bond.

Globe Shear Tester **(5)**

- Samples are subjected to shear forces to determine internal shear stresses at the failure load.

Vibration Testing **(6)**

- Samples are subjected to a vibrating force and their resonance is measured. The samples' stiffness and MOE are then calculated.

Linear Expansion **(7)**

- Samples that have been subjected to varying temperature and humidity conditions can be checked for dimensional stability (swelling).

Creep Tests **(8)**

- Samples are loaded continuously for long periods of time. Deflection is measured as a function of time.

Large Sample Testing

Machine Stress Rating (MSR) **(9)**

- A method that determines a panel's stiffness by nondestructive methods. This test apparatus can be installed in-line in a manufacturing plant to grade all panels in terms of strength and stiffness.

Post Flexure Machine **(10)**

- Full-size panels are subjected to a pure moment to calculate MOE and MOR. The testing conforms to ASTM D3043.

A.P.A. Test Floor **(11)**

- These two setups conform to A.P.A. standards. The test floors simulate both static and impact concentrated loads on an actual floor or roof panel component.

Stressed Skin Tester **(12)**

- A test apparatus which subjects the stressed skin panel to either a uniformly distributed load or a series of point loads. The MOR and MOE of the panel are calculated from the data collected.

Data Processing and Management

Recording Data **(13)**

- Personal computers are used to record data, reducing human error. However, before the output from the electronic measuring device is sent to the computer, a visual verification is made by a technologist.

Reporting Data

- A spread sheet program calculates all necessary sample properties from the input data and produces a table suitable for inserting into a formal report.

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ALBERTA RESEARCH COUNCIL

BIOTECHNOLOGY LABORATORY

PRINTED MATERIAL

Biotechnology

Biotechnology at the Alberta Research Council

The Alberta Research Council's $6 million biotechnology pilot plant reflects burgeoning interest in the practical applications of biotechnology on the part of both the scientific and business communities in Alberta and throughout North America.

Since 1983, the Alberta Research Council's biotechnology research has attracted widespread attention for its dimension and quality in three major areas:

- microbiology, fermentation and scale-up;
- plant cell culture and crop improvement for cold-hardiness;
- genetic engineering.

Located in the Alberta Research Council's headquarters and laboratory building, adjacent to the Edmonton Research and Development Park, the biotechnology complex houses spacious laboratory and plant growth facilities as well as Canada's most sophisticated fermentation pilot plant.

The biotechnology pilot plant

Incorporating computer-controlled equipment and processes, the biotechnology pilot plant is designed to act as a valuable bridge between laboratory research and the production of new products. Its facilities and personnel are dedicated to meeting the piloting and scale-up needs of industry.

The biotechnology pilot plant focuses on developing efficient biotechnological processes to help companies bring their products to commercial production, quickly and economically. The ultimate goal is to encourage the development of new biotechnology operations in Alberta. These companies could produce a broad range of agricultural, chemical processing and health care products.

The pilot plant offers local, national and international clients a comprehensive range of capabilities:

- advanced computerized equipment and processes;
- a pool of scientific and technical expertise reflecting excellence in a variety of fields:
  - microbiology;
  - bacterial physiology;
  - biochemistry;
  - biochemical engineering;
  - fermentation, extraction and purification techniques;
  - computer science;
- commitment to serving the practical needs of private sector biotechnological concerns;
- a flexible approach to contract arrangements and provision of consulting services, with the best interests of the client in mind;
- capacity to accommodate several industry contracts simultaneously.

This rare resource in the province is competitive with comparable piloting and scale-up assistance from other organizations around the world.

Pilot fermentation facility

The 1000 square metre fermentation facility includes a range of fermenters up to 2600 litres. All fermentations are conducted under exacting conditions designed to ensure consistent product quality.

All equipment reflects the most advanced technology available for biotechnology piloting, including centrifuges, lyophilizer, concentrators, large-scale columns for purification of protein, mass spectrometer, computer and analog-to-digital converter interface system. The use of sterile transfer lines ensures totally enclosed transfer between various pieces of equipment. Uniform instrumentation is used on all equipment.

At the heart of the pilot plant, the VAX 11/730 computer offers extensive feedback control to improve the efficiency and speed of the scale-up stage of process development.

Partnership with Industry

The Alberta Research Council's biotechnology research includes in-house investigations aimed at developing new and improved technologies, but its prime focus is contract research. It assists a growing number of biotechnology industries through consultation, laboratory studies, and piloting and scale-up resources.

This approach has started to attract widespread industry interest. For instance, the Alberta Research Council completed a contract with the Canadian subsidiary of a biotechnology company based in Berkeley, California to develop the technology for commercial scale production of an ice-inducing bacteria used in snow making. In another project, for the Canadian biotechnology company ens BIO LOGICALS Inc., a method for the large-scale production of a food color from plant cell cultures has been developed. Engineering and testing services have also been provided to Pegasus Industrial Specialties Ltd., of Toronto, for the development of all-glass, low-shear, tower loop fermentors.

Related activities

The value of the biotechnology pilot plant to industry is enhanced through its close links with other biotechnology research activities at the Alberta Research Council and Alberta's universities.

In addition to the fermentation and scale-up operations, there are biotechnology projects in other areas:

- crop improvement using tissue culture techniques for developing frost-resistant wheat and alfalfa breeding stock;
- genetic engineering to develop proteins for the pharmaceuticals industry.

The biotechnology pilot plant is equipped with a full range of fermentation and downstream processing equipment, ranging from process volumes of 1.5 litres up to 1500 litres in 10-fold increments. The pilot plant is equipped to handle several independent projects simultaneously.

QUESTIONS AND ANSWERS

FOLLOWING PRESENTATIONS

QUESTIONS AND ANSWERS

The questions (Q) and answers (A) following each presentation are given below:

1) Alberta's Aspen/Poplar Resource - David Morgan

Q: Why is black poplar much worse than aspen?

A: Well, it's not necessarily worse, the thing is that we just don't have a use for the poplar right now. In other words, where there is a mixed stand we have a market for aspen but we don't have one for the poplar.

Q: Is black poplar deliberately excluded from oriented strand board mills, and can someone tell me the reason why that is?

A: The mills presently don't use very much black poplar, let's say not more than 5 percent. I agree that it is technically feasible to make oriented strandboard with black poplar, however, there are certainly technical problems with black poplar such as drying and gluing. But it can be used for oriented strandboard. It's technically feasible. Economics, we're not quite sure how it comes out.

Q: From a pulping point of view, is there any difference between aspen and black poplar?

A: No, the fiber characteristics and the wood chemistry are largely the same between black poplar and trembling aspen, for most mechanical processes it probably doesn't make many difference. There's a higher content of collapsible fibers that might fall apart in the pulping process. Also, there is no difference between aspen and poplar as far as solvent pulping is concerned.

2) Aspen Utilization in Canada - Threats and Opportunities - Daniel H. Breck

Q: Are you including secondary fiber in your calculations for the paper machines?

A: Yes. We have a total of 70 million tonnes of paper and paperboard produced. Of that, only 28 million tonnes is virgin fiber, which is represented by the high and low-yield pulps, but all of that secondary fiber and the whole fiber filler and virgin fiber has to go on to a paper machine someplace so in order to meet this increase in demand, we have to build. I am putting these equivalents because I just said 150 thousand tonnes. There are a lot of paper machines that make 40 and 50 thousand tonnes and a new linerboard machine would never make 150 thousand tonnes. It would be three times that big. So I just picked a number in the middle.

Q: How do these kraft pulping situations compare to that of Canada?

A: It is in the order of magnitude of what Canada produces right now. That's quite significant because we have been the fiber basket of the world for the last 20 years.

Q: Are you making any allowance for improvements, modernization and upgrading?

A: The numbers I am using in some of these assumptions anybody can argue with, but if I cut them in half, if I say I am 100 percent off, I am still sitting with numbers that are quite impressive. I don't care how big my errors are, modernization only represents about a 5 to 15 percent increase in the total. So it isn't going to make much of a difference.

Q: What is the cost of such a mill?

A: Around half a billion dollars.

Q: What do you consider to be a good return on investment?

A: Every company has got a different threshold level that they look at within their organization. Some people say an 18 percent ROI is satisfactory. Other companies--if you talk to those in Hong Kong--are not interested in anything like that and other companies that have got more of a governmental input might go for much lower numbers. It varies.

Q: Is Eucalyptus superior to birch?

A: Actually until a year and a half ago birch was No. 1. That was because the eucalyptus wasn't available. There are grades where maple and birch are still superior to eucalyptus.

Q: Why wouldn't you think maple would be better than aspen?

A: It is the major hardwood pulp coming out of Scandinavia. It isn't a big one in North America in terms of quantity. Birch is No. 2, really. I put maple there because quite often it gets thrown into the same area. Maple has got a very unique niche just because of its collapsibility and it can go into things like photographic paper and things like that. I think aspen will move into some of those grades but when you get into a lot of the paper and paperboard grades, the aspen is not going to move up to the euclyptus because of the thin wall, things that we want for other properties. The thin wall fibers, they tend to collapse and don't give you the bulks, the opacities, the things that the eucalyptus does.

Q: In a birch/maple pulp blend, would birch be the most important since the fibers of maple are too fine?

A: Maple and birch don't sell as a blend. They are actually completely different in their fiber morphologies but they are considered as northern hardwood krafts and they sell at about the same price range. If I wanted to be more accurate, you could scratch the maple off because it isn't a real large tonnage but it commands a good price.

Q: What is the potential for the tropical rain forest hardwoods?

A: The tropical rain forest hardwood potential is very, very low. The problem in the tropics is that there are so many species with such a wide variation in quality. You could always make linerboard or lower grade papers from them.

Q: What is the relative position of aspen for the high-yield mechanical pulp technologies of today?

A: Aspen is by far the most sought after, the best fiber from a morphological point of view and from a brightness/extractives point of view. It is the best in the world. Behind aspen and quite a ways down is birch. Birch gives you a very bright pulp but it has a very stiff fiber and it is much more difficult to make a high-yield pulp from it. Your plantation eucalyptus is not too far off that and in the same league. The high-yield pulp from eucalyptus today is probably in the same position as kraft pulp from eucalyptus was a couple of years ago. I think that quality wise, it is actually somewhere between aspen and birch and quite close to aspen.

Q: Could you draw a straight line correlation between fiber quality and wood density for mechanical pulps?

A: Yes. Example, if we take a species with 0.23 density, the wood makes good pulp from a technical point of view but the cost of fiber would be too high.

Q: How does this relate to aspen?

A: From a technical point of view for kraft pulping, aspen is not going to be the most sought after fiber in the world. It is going to be second, at the most, and possibly third from a worldwide general demand. From a mechancial pulping point of view, it is the most sought species and it has the greatest potential.

Q: What is the fiber availability and what is its cost?

A: We did a calculation based on the number of kraft mills that are going to be built, the number of high-yield pulps, the cubic meters of wood per tonne of pulp in order to get these type of things. We have added them up. We have come up with a rough figure of about 310 million cubic meters per year that are going to be required by the year 2000 in order to meet this demand. Now, that is a lot of wood and the foresters here can put that into perspective of how many hectares are required in order to grow that type of material.

Q: Have you factored that down by the amount of secondary fiber in that 70 million tonnes?

A: That is just for virgin fiber. That is the million cubic meters of wood.

Q: Do you see the southern U.S. providing half of that 70 million tonnes?

A: Southern U.S. is going to provide a very large percentage of it.

Q: In Alberta, what percentage would you say is clear, good aspen and what percentage is cull that has been affected by rot?

A: If you're looking at OSB, then you have quite a high percentage of your forest that is usable because a little bit of decay and incipient decay is not a problem, and stain is no problem. From a kraft point of view, you can put a rotten log into a kraft mill. A lot of the rot comes out in the chipping and the screening and the rest dissolves in the process. In the mechanical pulp process the condition of the logs is very important.

Q: What is the economics of using low grade aspen?

A: It costs too much in comparison to clear aspen wood.

Q: What will happen 20 years from now, especially if you need more additional tonnage of pine?

A: This is a concern in the industry. What you're saying is correct that the small land holder is not going back and putting the money in because he's looking at 25 years or 20 years before they're doing any recovery of that investment.

Q: What is the solution concerning fiber shortage?

A: The way it's done right now, I agree, it's a problem, but let's look at the future. Let's don't say it can't because too many people have said it already, and all of a sudden they wake up and find out somebody did it, and then it's too late. Remember lots of things can be done when you are getting 80 cubic meter of wood from a hectare of land.

Q: Are tropical hardwoods with high extractive contents suited for pulping?

A: Any lignocellulosic material will make pulp. There is no lignocellulosic that will not make pulp, especially with the kraft process. You can put anything into it and you can make pulp. I'm not debating that point, but the quality of the pulps and the economics associated with it are a different story.

3) Chemical Pulping of Aspen: Possibilities and Realities - J. Martin MacLeod

Q: What is the brightness of brownstock kraft aspen pulp?

A: The brightness of unbleached kraft pulp is normally in the mid 30s ISO.

Q: You are presenting the tear and breaking lengths but I couldn't see the burst value, do you have them?

A: The burst index for that type of pulp is on the order of six.

4) <u>Overview of High-Yield Pulping of Aspen - Kwei N. Law, Marcel Lapointe, Sung-Nien Lo and Jacques Valade</u>

Q: What would be the brightness value for aspen pulp to be used for newsprint?

A: It would be 57 180.

Q: What would be the opacity?

A: It would be around 85-86. It will--even if let's say at the moment I had bad, bad brightness, I had 44, the opacity was 86, I had good opacity, let's say I had good brightness with the trial before but I had 85 opacity. So it means that the relation of the big impact of reducing the opacity in the conformability of the fiber, it's not mostly the colour. So it means you're losing one part if you have higher brightness or lower brightness, you get exactly the same opacity.

Q: How long do you think it would be before the newsprint mills in Three Rivers start to use poplar CTMP?

A: Well, I think they'll go to aspen when the Minister of Energy and Resources will cut their allocation. Are they ready to cut the allowance, not at the moment. They would rather use or cut more wood than can be sustained. But since the mill, let's say a few trials been done in Tembeck and in Sweden, well it's a matter of time now that all the Canadian poplar has to go there.

5) <u>Innovations for Hardwood Utilization: Catalysed Organosolv Pulp and Saccharification - Laszlo Paszner and Peter H.J. Cho</u>

Q: What is the main feature of organosolv pulping process for aspen?

A: The pulping time is very short--less than 20 minutes-- and the yield is 15.1. Higher as compared with kraft, while the recovery of lignin and sugars is easy.

Q: How do you see this technology applicable to aspen?

A: The integration of organosolv pulping and saccharification would maximize the value of return from aspen.

6) <u>Pitch Control During the Production of Aspen Kraft Pulp - Larry H. Allen</u>

Q: Would we expect to see the same types of problems with aspen and pitch in the higher-yield pulps as you have in kraft?

A: Yes, I think you would, pulps like CTMP have a tremendous advantage in that the temperatures are very high and the resin is not very viscous, it is quite runny, so you don't see an awful lot of deposition in a CTMP pulp mill usually. If that stock gets colder as you approach the paper machine, that's where you would expect to see more problems.

The pH at which the cook is made is very important. I was interested in some of the pH effects that Marcel showed just earlier that around pH 6 this is the initial pH of the cooking liquor. That seems to be sort of a breaking point. If you get above that, then you can actually, if you have a wash or a thickening of the pulp followed by revolution or something like that downstream of the digester, you can get rid of an awful lot of resin that way.

Q: Would washing help?

A: Yes, if there is a washing, it would be a real advantage. There is lots of evidence of this in the literature.

7) <u>Korean Paper Makers' Interest in Aspen Kraft Pulp - A. Wong</u>

Q: If the price of eucalyptus drops, because it is artificially high right now, do you think they would say we are not at all interested in the aspen, or will they go back to the eucalyptus?

A: Yes, they will be very interested in aspen as a regualr supply even if the eucalyptus price starts to drop because nobody wants to depend only on one fiber source for obvious reasons. I think the market is there. It is secure. The question is, can anybody supply it?

Q: The Koreans like aspen better than southern hardwood?

A: Aspen is more uniform because there is only one single species involved whereas southern hardwood, you might have five to ten. I think the Koreans would say, yes, they would like to have a single species, preferably aspen.

Q: How does your observation relate to the surface quality of CTMP aspen newsprint?

A: Aspen is a good fiber and besides newsprint, aspen CTMP has a place for certain grades like lower grade computer paper, for example.

Q: Could you characterize the CTMP of eucalyptus to see how it relates to aspen?

A: Just a comment. In the Far East everybody is busy planting eucalyptus and various species but nobody is planting aspen. Mr. Jackson will provide more information on this tomorrow.

8) <u>High-Yield Pulp from North American Aspen - Michael Jackson</u>

Q: Is there any economic advantage to replace stone goundwood with aspen CTMP?

A: With regard to newsprint, I discussed the replacement of stone groundwood with CTMP talking about a situation where there was no softwood available. I also tried to indicate the total flexibility of the CTMP process in producing a product suitable for a wide range of end uses. One extreme suitable is a replacement pulp for purely mechanical pulps, but at the other extreme, suitable as a partial or complete replacement pulp for bleached hardwood chemical pulps.

Q: Did you have any running problem in you newsprint trial?

A: The newsprint was made at the Montorsh Paper Mill in Messier in Sweden and that mill, at the time these trials were done, contained two relatively old paper machines capable of running up to no more than 2,000 feet per minute. Both machines had open drawers on them, but I think that had we reduced the kraft content below 15 percent, then we would have seen a problem with wet runnability on the machine but at the 15 percent level and the relatively low speed of that machine compared to what one considers is normal by today's standards, it was not a problem at the 15 percent kraft inclusion level in the product.

Q: If aspen CTMP fibers are so nice, why do we use stone groundwood?

A: CTMP of aspen, may have a very nice quality of sheet but we will never get the same printing speed that we have with stone groundwood. Pure mechanical pulp, stone groundwood or RMP or TMP or whatever, will obviously make a positive contribution to the printing properties partly because of the bulk, partly because of the formation characteristics of the material and partly because of experience that we have if we know the way it prints.

Q: Is there any relation between fiber break and ink absorbency?

A: It relates directly to specific surface area available for producing the property profile.

9) Aspen Pressure Goundwood Pulp - Gordon Mitchell

10) Mill Experience in the Use of Aspen Mechanical Pulp - Ray Leask

Q: Could someone put forward dollars on a percentage of peroxide on pulp so that it -- either that or a percentage of manufacturing costs for one of the grades?

A: A rough number for peroxide alone is around \$25 to \$35 per percent brightness. In one specific case we were looking at bleaching because we had a lot of de-inked newsprint in the furnish, and there were indications at that time we might have to use around 3 percent peroxide, and we were calculating it was going to cost us about \$60 a tonne.

Q: What is the minimum opacity level that we really need?

A: Well, one thing I should comment on, the trial was made at Combined Locks. They did add a little bit of talc (1 and 2 percent) and then this actually brought the opacity up to where it was acceptable.

Q: Could you comment on the strength properties of bleached stone groundwood aspen versus bleach CTMP aspen?

A: In my presentation I was talking about several groundwoods. One was conventional groundwood which has about the same specific energy requirement as TMP and has similar characteristics in terms of strength properties. The improvement came in PGW where in order to become more competitive the addition of alkaline peroxide was made to the hot loop shower loop within the grinder case. So you have in situ prebleaching if you like with small peroxide additional which is continuously in recycle with that residual being carried around as dead load in that loop, if you like, but active chemically. The strength properties that were seen were a significant improvement in both, in all of the properties and at the same time the scattering coefficient at pH's below 8.5 was still protected and was equivalent to groundwood. I don't want to get into a shooting match between TMP and PGW.

Q: What is the consumption of peroxide when you do add it to the grinding pad?

A: It's between 0.2 and 0.4 percent on O.D. basis.

Q: It's as low as that?

A: Yes, the reaction time, the reaction is protected somewhat by environment which is a low air, low oxygen content. It's driven by high temperature, and the dwell time of chemical contact which would be something less than five minutes in the loop.

Q: What is the pH?

A: Well, the pH is 8.5, we found that to be fairly optimal.

Q: When and where was the pH measures?

A: It was the pH of the shower water which is going into the grinder at 3,000 gallons per minute. You've got 3,000 gallons a minute of water being added into the grinder case with four showers, and so the pulp sees that environment instantaneously at the point of fibrilation and continues through that at 1 1/2 percent consistency to the point through the shedder, which is a hammer mill, to the cyclone, through the blow valve of the cyclone, and then it goes through the pressure washer thickener loop when it's thickened to 15 percent consistency, and that residual chemical in the filtrate or lake water is returned back to the grinder.

Q: Do you think you are bleaching with this low pH because you have so high temperature because of normal condition, is it the final pH you can reach about 9.5 or 10.10 because otherwise your colour stability or brightness may suffer and you're in the range in which nobody goes, and maybe that you have the combination of a low pH and high temperature and somehow compensate?

A: There was no brilliance to it at all, we fell into it. There's not a lot of science involved in this. It's just luck in the shell chemistry.

11) Explosion Pulping of Aspen - Bohuslav V. Kokta

Q: Could you describe the mechanics of your process? Is this like an aspen or the masonite process?

A: No, in the masonite process itself, you use one minute of pre-steaming. After that, you use two minutes at about 35 atmospheric pressure before exploding it to increase the pressure. You double the pressure and you explode the chips and the chips themselves are 266 degrees. If you try to refine the chips to prepare a so-called bed lag stock you will never end up with good pulp and paper properties. You end up with a burst varying from 0.3 to 1, brightness varying from 12 to 15 and breaking length varying from 0.5 to 1.

In case of aspen process, it was shown that aspen itself gives you some good properties but up to temperature 160 degree celsius. If you would like to have some chemical pre-treatment, the temperature recommended is 130 degrees celsuis. Comparing 130 degrees celsius to 190, you have a difference in reaction rate 62 times higher at 190 degrees celsius and the pressure itself is four times as high. You are completely in a different range and you are working at temperature which is at a higher temperature than softening of the lignin. If you go below 170, you are still having the deposition of lignin on the surface and you are not at the official softening temperature of lignin which is 180 but they are above this temperature.

To protect the fibers, we have to do several things. We have to protect the fiber against the hydrolysis of hemicellulose. To do this, you have to eliminate or compensate for acid and this you do with alkaline condition with enough free hydroxide to compensate for the acid. We have to do it in such a condition you don't have the high degradation of cellulose. It means that we have to keep the final degree of polymerization above the critical value. This will protect the properties.

We should protect everything against oxydegradation at this high temperature. To do this, we have to be sure that the chips coming inside don't bring too much air. They bring itself enough anti-oxident which may be the sodium sulphide and you will like to develop also the paper properties. We should put some hydrophilic agent which itself will bring us the properties to the value which we have seen and doing this work at this high pressure, the steam can enter the inside of fibers and explosion is permitted. Only by this explosion, can we improve the properties by 20 to 30 percent. If we cook it and raise the pressure and you explode the chip, we have the difference of 30 to 40 percent in properties.

By softening of the chips, we decrease the refining energy necessary after. We have some experiments done at two quarters for 260 degree to measure the refining condition and the refining condition is very low, it is from 0.2 to 1 megajoule at this high temperature.

Q: If you compare the production costs of explosion pulping, how does it compare, let's say, per tonne with the other chemical pulps?

A: What I can tell you, I am not an expert on economic evaluation, but according to the evaluation done by the company IMAC, they came out with cost of this explosion part about 30 percent lower than cost of kraft pulp.

Q: This doesn't include the higher recovery?

A: The total cost of explosion pulp will be 30 percent cheaper than kraft pulp. The cost of producing the steam itself is the energy requirement which is from 0.5 to 1 megajoule for the steam. You use from 300 to 400 kilogram of steam for 1000 kilogram of pulp.

We are using also the shredded chips not the normal, regular chips. The shredding of chips in industrial installation, it takes 0.09.6 or 0.1 megajoule per kilogram or 1.01 gigajoule. That is according to the value what we got from the consultant.

Q: How do you shred them?

A: They were shredded at Consolidated-Bathurst.

Q: What is the outlook for commercialization?

A: Stake Technology has developed a high pressure continuous reactor. They have been working with Dr. Kokta and obtained exclusive rights to this process. Stake Technology believes it is a totally new pulping process able to produce a very unique pulp and has a great potential in the industry.

Q: How does the energy and yield figures compare to the industrial situation?

A: We have measured the yields many times for the condition given and we have found also that for softwood this 2 percent of sodium hydroxide, it went by 2 percent down with the yield. It can be that they go down one year from 92 to 90 hardwood which is not probable because you have a different chemical composition and the sodium hydroxide doesn't affect the hardwood as far as the yield goes as much as it affects softwood.

Now, I agree with you, we cannot compare the energy given from blendor with industrial refiners. What we have done is compare it with the first thing what we could get to refiner with four an a half tonne which was in our disposition. Industrial refiner, we have compared the correlation between the refining with PFI divided by 3.5 as far as the energy is concerned between the Sunds pilot plant, and between the values achieved either on Sprout-Waldron or on double stage refining with Sunds Defibrator.

As far as aspen is concerned, we haven't done so far any industrial trials.

Q: You have yields of around 90 to 92 percent yet you said you can detect no free sugars and you can detect no lignin sulphonates. Where is the other 8 or 10 percent of the substance going?

A: I haven't analyzed it. I only tell you what we have found out and what we measured.

Q: The extractive content of aspen is not 10 percent and what happened to sugars and the lignin?

A: It may be something which we cannot detect as sugar or which we cannot detect as lignin sulphonate and they have to be measured somehow. There will be more information in the proceedings.

12) <u>Some Papermaking Properties of Bleached Neutral Sulphite-Anthraquinone Aspen Pulp - Al Wong</u>

Q: What would be the production cost of NSAQ in comparing with other types of pulp and why a smaller pulp mill?

A: Well, I'll answer the second question first. The cost of conventional kraft is getting so high and the returns are getting somewhat questionable that it's hard to raise half a billion dollars to build a kraft pulp mill today. It's a lot easier for me to go out there and raise perhaps 100 million.

As far as the first question is concerned, I don't have the numbers with me, but it will be included in the proceedings. It is going to be slightly lower costs than kraft. It depends on the final configuration, but there is enough new elements to this process to give good cost benefit ratio.

Q: Have you calculated the capital cost special reference the recovery furnace?

A: Recently I was involved in the detailed engineer design for an NSAQ mill 300 tonnes a day, came in at $70 million Canadian, with 90 percent brand new equipment. We were looking at Thomlinson furnace. It is not the giant one we're accustomed to in a kraft mill, but a stripped down package. So we went on this design, and we costed it out, went to separate suppliers, and we're very confident of this engineering design that were put together in collaboration with other engineering companies and the owner of the mill turns out at very realistic cost. So you can calculate the number of dollars per daily tonne. It's lower than kraft.

Q: Can you comment on the other process you are working on?

A: It's being patented, so I can't talk about it at this time.

Q: Have you or do you have any results on actually taking the oxygen delignification approach by stopping at higher kappa numbers and sticking the oxygen in at that stage and doing perhaps one- or two-stage bleaching and getting into the 90s in ISO brightness?

A: Yes, it's in the works. This work was actually done in 1985. The reason why it hasn't been brought forward is because we're working with another company to develop this design. So if you look at the Canadian Pulp and Paper Journal April 1985 you will see my article in there. I thought just single-stage peroxide was interesting. I did not see in the literature, and neither did oxygen dioxide in the same two steps which we thought was interesting enough.

Q: Did you actually evaluate the strength properties, or the viscosity of the pulps you produced by the OD process and by the oxygen?

A: Yeah, the OD process is actually on these two slides on bleach pulp, bleach aspen CTMP.

Q: This is in regard to the slides was you had data on bleached eucalyptus pulp, I assume that was commercial bleached eucalyptus pulp?

A: Yeah, that's from Brazil.

13) Ester Pulping of Aspen - Donald E. Smith

Q: Is the recovery a problem? Is it something that's technically solvable, or is it similar to other solvent-type extraction methods that have been in use in the past?

A: I'm not sure of the question is it solvable. I think it's feasible, yes. On paper it looks feasible, but until you've run a pilot plant and done it, you're never sure. But, yes, it looks feasible on paper.

Q: What have you actually done on the solvent recovery side of it? Have you tried to model any of the processes you'll need for that? Have you got any technical information that looks at that side of it at all?

A: The only thing we've done is what I mentioned was the liquid-liquid equilibrium studies on the extraction of acetic acid from the pulping liquor with the ethyl acetate, and what that equilibrium is from which you can make calculations again how many extraction stages you need, solvent, ratios and so forth. That work has been done, and we have also done work on those conditions required to separate and precipitate the lignin in particular powder form, and that we have done in the laboratory.

Q: What kind of scale laboratory pilot on industrial?

A: It's all bench scale laboratory work.

Q: Did you wash in the digester?

A: No, I said not -- we did not wash in the digester. At TVA, we were forced to do it in the digester because they didn't have facilities to do it any other way, and no matter what we did, we didn't get very good washing. But in the smaller scale we were able to defiber and wash in solvent and then we have gotten good results.

Q: After completion did you smell some acetic acid remaining in the pulp?

A: You mean after we washed in the laboratory, oh, yes, it's gone, we can't smell. We could at the TVA but not in the laboratory.

Q: Could you comment a little bit more about washing. You wash with your solvent, right?

A: Yes.

Q: How many times and so forth, and how much additional solvent would that require in addition to the cooking and then at some point you have to go into an aqueous system?

A: In the laboratory we have had to wash it quite thoroughly with more solvent than you would require or could stand in a commercial operation, but we have made calculations that have assumed that the amount of washing you can stand is the make-up solvent on the way to your digester. So you have to make that balance and then calculate how many stages you require to wash thoroughly enough to get all of the residual liquor out before you can go forward. And in the commercial operation, in those studies, we would not necessarily wash with the same composition of liquor as goes into the digester. But we have calculated that we will require something on the order of six stages, six pressure washer stages, which is on the order of two of those Romney & Palmer three stage washers in series. Once you have removed the acetic acid from your pulp, you can then remove the last of the ethyl acetate with water or by heat steaming and then you have to wash the acid off. Getting the last of the ethyl acetate off can be done either with washing or steaming. Right now it looks like we have to use heat to get it off.

Q: What are you going to do with that?

A: That has to join your recovery system of your spent liquor, and the whole thing has to be recovered.

Q: I notice your bulk value is kind of low. Is there some way you can manipulate that to get higher values?

A: I don't know. You'll notice also, that the lower bulk are also the stronger ones.

Q: Could I ask what the optical properties such as opacity or brightness are?

A: We know very little about the optical properties.

Q: I know you haven't done that much work, but do the pulps appear white?

A: No, they're not white, they're a light brown.

Q: So, brightness is probably quite low?

A: That's right. You can see that. As I say, I have those top sheets you can see, and they're low, they're light brown.

14) <u>Solvent Pulping - Kyosti V. Sarkanen</u>

Q: You were showing that 0 to 20 might be the juvenile stages, is this correct?

A: There is no juvenile stage.

Q: What have you got on the poplar?

A: We got excited and were carried away about this thing. We have the super trees which give us over 60 percent kraft pulping so let's get the clones and reproduce them. We got this thing and there was no indication in the young stems whether it was going to be this kind of super tree or not. But I think this is real and we have looked at the literature and it is true for aspen and we are slightly disappointed that people don't point it out. There is a great danger of comparing apples and oranges. I mean the high alphacellulose aspen with the low alphacellulose.

Q: What about reaction wood?

A: It is not tension wood. That's what we suspected and when we looked with the microscope for that celladinous layer, we didn't find it. There were no indications in the high alphacellulose rates of the presence of tension.

Q: Were these chemical contents based on a single determination.

A: No. The person who did that came up with that herself, so we didn't go into that. For the average composition she did make five parallel determinations of this and we got the same values.

15) <u>Aspen-Based Chemicals - John N. Saddler</u>

Q: Should good quality aspen be used for your chemical conversion by micororganisms?

A: It could be but perhaps the emphasis should be put on residues and low grade wood.

MESSAGE FROM THE SPEAKERS TO WORKSHOP

Each speaker, based on what they have heard from each other and the audience, gave a short brief on their topic concerning the following areas:

(i) technical viability;
(ii) economic viability;
(iii) industrial potential, and;
(iv) further research and development

in connection with aspen utilization.

DAVID MORGAN - Nothing further to add.

DANIEL H. BRECK - Nothing further to add.

J. MARTIN MACLEOD

Jackson just gave you a challenge but, in fact, there is already a mill in Alberta that pulps aspen, it only does it some of the time. It is a kraft mill in Grande Prairie that is run by Procter & Gamble. There is another mill east of you in the same band in Prince Albert that makes considerably more and you go farther east and then there is a mill that makes a hell of a lot of aspen pulp. So it is already a commercial reality but what you want to see is new commercial realities. One of those that is clearly coming is the mill that is going to be at Whitecourt. It has been decades and decades in waiting but the technology is finally here to have a mechanical pulp mill that makes aspen CTMP part of its' time and it will start using the resource in that sense.

I personally think that a lot more attention needs to be given to the side of it that this particular workshop does not address but the previous one did. I regret that I wasn't at that. I didn't know about it but I think the key lies as much there as what we have talked about in the last two days.

They have to do with how do you deal with the standing timber that is out there now because we can talk about the huge resource but we have to talk about a useable huge resource and we also have to give some very serious consideration to what we want in its place decades later because that is part of our job too.

MARCEL LAPOINTE

The University of Quebec wants to tell you we think that the future of the Province of Quebec, Canada, and Alberta is in fast growing trees.

In newsprint, the University of Quebec wants to say to you, to manufacture newsprint with two types of fiber, long types of fiber, approximately 20 percent and 80 percent of a short fiber or filling fiber. Remember, aspen can grow fast.

In Quebec, the people like this stone groundwood pulp and to be able to push them out of the spruce stone groundwood pulp, well they need a little bit of incentive. So, instead of going 20 percent equivalent long fiber and 80 percent short fiber, we will put in a little bit of aspen CTMP to replace this low-yield sulphite to 10 percent. How should we increase? We think that the second step should be the replacement of the rest of the 70 percent. How or why will they do that is because as the time comes, well the standard newsprint won't be a good product to sell. So you have to put more, more, more of that short fiber in to get better, better, and better surface. And since you have lower opacity, you have to put more, more, and more filler. So we're getting back to a specialty newsprint sheet that will be our future.

So what are the companies doing at the moment? Well, nobody uses it so that's a good start, but Tembeck is making bleached CTMP of aspen. We hope that the manufacturer of newsprint will buy unbleached CTMP of aspen, try it, if it works they build a plant.

Birch is another fast growing species and we feel that 20 percent long fiber can be replaced with birch fiber. The dream of the University of Quebec is to bring the forest to the mill and have them work on fast growing trees.

PETER H.J. CHO

Organosolv pulping has a good potential for commercialization. Since the minimum economic size is about 50 tonnes a day and $35 million, western provinces like British Columbia or Alberta, we hope certainly will see one of the first solvent pulping mills in operation in a few years.

There is a pilot plant in Brazil to produce ethanol for automobile fuels. The initial results are very good and they want to scale up more than ten times larger pilot plants. We will continue the research on follow-up processes. For example, we will continue to study on lignin for application and also we will do a very simple bleaching process based on two or three stages.

LARRY ALLEN - Nothing further to add.

MICHAEL JACKSON

I think you have a very useful resource, and in Alberta, it is totally under-utilized and if you don't want the industry to expand in areas totally alien to us in the southern States and so on, it is about time you built a mill here.

GORDON MITCHELL

The comments I would have from our perspective in the industry, there is a lot of young engineers involved in an old technology giving it new life and I would just suggest to you that Canada, as a mnufacturer and exporter of primary products, fully bleached kraft pulp, newsprint and specially groundwood grades, has a focus in the world market and as Dan has put so eloquently, we need to address the very important market factors of availability and reliability of that supply for the world market particularly from the perspective of a Canadian living in the States. I have little sympathy for the situation Canada is in now. We saw it coming, we are party to it and we let it happen, so I would suggest to you that while we are pursuing the excellence of process development in aspen utilization that we ensure that it is in those basic marketable commodities that the world looks to Canada to supply.

I would suggest to you that you avoid the myopia of CTMP. It is not an appropriate solution for many grades, it is not the appropriate solution for all grades. A technical myopia is a problem that a lot of senior managers have right now and I would suggest to you that for groundwood replacement, you might try groundwood. It is the supporting substrate for most of the TMP sheets in Canada. Of course, TMP and the CTMP is getting most of the technical credit for it.

If you look at British Columbia, my own province, I wonder what would happen to their newsprint sheets at Alberni and Powell River if you shut down the groundwood mill. How competitive would they be on a U.S. market?

At what point in time do you start to address where your product value is coming from and address an equal amount of research into that old technology which is being refreshed in other areas of the world and Canada can't ignore that development of technology.

RAY LEASK

Short and to the point. I feel that a lot of the mills are starting to use more poplar and different end applications and I think actually what we have to do, we have to keep track of these new trials, getting good operating data in pulp quality and data on the effect of the poplar consumption on paper machine operation. This is going to mean pulp evaluations and fairly detailed analysis. I think there is tremendous potential in this area.

BOHUSLAV V. KOKTA

In the second part of my presentation, I mentioned that wood fiber is really very good for reinforcing of thermoplastics. Since about three years, we tried to find it out whether they are really good and we tried to make it under extreme conditions. Now, we arrive as far as this project, to the stage that we can recommend if for companies to try it on high scale and if they will find enough market, I believe that they will start. They will put it into production especially the companies which have compounded equipment.

As far as the explosion process, we have not learned too too many things. We are still learning every day. We are every day trying to find out how does it apply not only to aspen. We have some indication that it work very well for larch. We have received the pulp which is about 50 percent stronger by explosion and about 5 percent brighter after explosion than lignin CTMP process and we have also succeeded partially at initial stage to find out if it works on Jack pine and we have been getting, again, the properties which are about 50 percent stronger than using our standard CTMP process.

In the case of alkalines, we have started to do some preliminary studies and alkaline process shows the similar properties like aspen. How far or how fast it is going to be commercialized or is it going to commercialized, I think this is based probably on the economic evaluations and I believe the process should be economical with small production units. It can be economical according to the evaluation in the units which are having the capacity between 100 and 150 tonnes per day.

Being economical at this size, they won't need very high capital investment and they may be probably much more easy than to build bigger kraft pulp mills or even the CTMP plant which will need 200 tonnes per day production or more and I believe that the initial cost may be in the range of $50 million comparing to $500 million for initial costs for a big kraft mills and if it is a question of capital, this may be some driving force behind application.

DONALD E. SMITH

I think that Biodyne has a process for solvent extraction of hardwood aspen, in particular, but all hardwoods to produce an economically viable paper making pulp and byproducts of very interesting chemicals ranging from acids, esters, sugars, furfural and lignin. We think that this is economically feasible mainly for many reasons environmental and others but the main economic reason for it is the low capital cost and the small size of the minimum economically viable plant.

KYOSTI V. SARKANEN

In order to try to put things in perspective in my own mind, I have been most impressed by the tremendous progress which has been revealed in the field of high-yield pulps. I don't want to differentiate between these. As a matter of fact I, myself, am working on cottonwood CTMP peroxide bleach. The problem which is still there is, of course, the photo chemical discolouration and the 85 brightness does not give any guarantee that that will stay very long in sunlight. I think that we are economically optimistic that that problem will be solved very soon.

Comparing this, we are not working on organosolv when trying to compare these two things. There is no question, I agree with Don Smith, that what has been demonstrated, that there is a feasibility to develop an industrial economical process. The thing which I don't see is the compelling need for the development of such a process. I mean, what basic need would this fulfill which the conventional processes would not fulfill. That's why I must be skeptical in that respect.

I did not discuss the possibilities which have, in the area of byproducts, kept the old fashioned sulphite pulping living much beyond its age really. So there are many factors which would change the picture in organosolv pulping and I hope that there will be sufficient funds to continue that activity. I can't give it a high priority.

JOHN N. SADDLER

Really what I would be interested in from this audience if anyone else can think of something better to do with decayed aspen, I would really appreciate it so we can change our resource focus. Really, what we are trying to address, are resources always being the residue whether it is sawdust. When we look at the size of the material after just going through Scandinavia last year, I was amazed how much the environmental constraints were pushing their work. I think we have been living too long in the fact that we are a huge country out here which is just dumping a lot of this stuff. A lot of the economics of what we are doing are coming from anticipated environmental reasons and I know it is old fashioned or outdated, but we still think that we are going after the bulk products, something such as ethanol. Canada -- liquid fuel, 97 percent of Canada's liquid fuel comes from petroleum. We import 50 percent of our petroleum right now so Alberta seems to be a natural niche for bringing all these technologies together.

To my big amazement, it is not amazing, but working in forest product for ten years now is how this industry thinks 2 x 4's and waferboards. As soon as you move into something else, you can forget it.

So one of my concerns is that people are going to market any of these other products. As far as I can see, the forest products industry is getting less and less. There is concrete, steel and plastic replacing it. Until we start making rockets out of wood, I don't see the market expanding.

A. WONG

I think basically what we see here is that the aspen trees are waiting and waiting out in the forest and technology largely available. You can go to a high-yield machanical route or a more classical chemical pulping route. I think the key here is that how do you get to that next step of commercialization. How do you get that low quick push and have somebody start building this mill.

My own opinion is that because of the various grades of aspen wood available out there decayed, partially decayed and so forth, I think in the long run it is going to have to be several types of pulp products and paper products made using several different processes. That is, I guess, probably the final outcome for development of aspen in Alberta.

SUMMARY

by the

ORGANIZATION COMMITTEE

The main objective of the workshop was to bring together knowledgable people to exchange information on the utilization of aspen/poplar for pulps, chemicals and high-technology composites. The speakers, without any exceptions, provided the audience with excellent presentations in following four broad areas, namely: (i) high yield pulps, (ii) low yield pulps, (iii) novel pulps and (iv) chemicals/composites. A short summary and comments by the Organization Commitee from Alberta's point of view on these areas, are given below:

(i) High Yield Pulps

In Alberta there is a large amount of aspen in various states of growth and the possibility of planting aspen that is going to grow very rapidly. These are two separate issues, one, we are going to try and recover if it doesn't have a cost effect associated with it other than the logging cost.

If we look at projections on market demand, around 300 million cubic meters annually by the year 2000. We have in Alberta, 12 million cubic meters of aspen and across Canada 70 million cubic meters. This indicates that we are in an elastic position. We are sensitive to things that can occur outside of Canada. The total demand and the amount of fiber that is out there is much larger than what we have so that we are sensitive to changes that can occur in other areas of the world. We are not a large breadbasket where we control them. We won't control them. So we have to be very much aware of what other people are doing and what their advantages/disadvantages are.

From the technical point of view, there are a number of hurdles that we have to look at; capital, the quality of the products that we are going to make and the availability cost of our raw material. These are things all of which have been addressed in various aspects throughout the last two days and I think there have been some very good points brought forward to answer some of the potentials or the possibilities.

The high-yield pulps in their various states are commercially being used. So we are not talking about a new type of technology which is not at our grasp to be used to be economical today. We have a number of mills, as Mr. Leask said, that are making various grades of paper from different types of aspen.

We have processes which have been developed for the last 110 years and have come to some very rapid developments in the last few years, but they are not bench top processes. We have methods of converting raw materials from chips into very good products. The range of products that can be made, both proven on the commercial scales by the mills that are operating now, both integrated and non-integrated, and in the laboratory will produce a pulp from an aspen that will certainly cover a wide range.

As technologists, engineers and scientists are trying to optimize the characteristics of the processes, we should look at the marketplace and find out what does that market really want? Once we have this then the process can be fine tuned accordingly.

Within the stone groundwood processes, there have been a number of developments which are allowing raw materials in the roundwood form to be utilized. Now, we are talking about an aspen resource in Canada which, to a major extent, is available in roundwood form as opposed to much of the rest of the pulp and paper industry which is entirely dependent on chip residues. The roundwood pulp can be used to make some very good products.

The points that have been brought up are capital costs, operating costs, and technologies. From a capital cost, the various processes have been brought forward, explosion pulping, etc. that can possibly reduce the economy scale of mills and the capital cost per tonne. Both of them are very critical to being able to meet the world demands.

The economy scale, there is a question mark here I see on a face, is how big we would have to build it before it is really economically viable. These 500 tonne and 1000 tonne a day mills require a large land base. If you can build a number of 50 tonne a day mills and they are economically viable, it allows a number of them to be put in very strategic places where you can take advantage of a natural resource that is concentrated. It cuts down the cost of your product considerably. The yield advantages are going to allow more pulp to be produced from that resource and cut down the cost of the product.

We have seen changes in the energy costs. If we can get processes that will reduce energy cost and make it more efficient, then we could become more cost competitive with the rest of the world. We also have seen that there may be ways of reducing the cost of chemicals in order to produce these high brightness, high cost pulps. The cost of making a fully bleached pulp and all of the ones that have been presented in the last two days is in the order of $70 per tonne. If you could cut that down, it will put the product in a better position cost wise on the market.

From a research point of view, we have to get a better handle on how these various processes are going to be applied to some of the species that are available. Alberta has stated that about 30 percent of their hardwood resource is black poplar. We don't know anything about that, how balsam poplar responds to some of these things.

We also want to look at the negative side of all the various processes and find out how we can offset those negative points. One thing was brought out today, the use of fillers. Now, fillers in a number of products have actually negative factors associated with them also. There is research being done in Scandinavia where the mechanical pulp we are talking about can be used in conjunction with fillers and make a better product.

Then last but not least, let's keep our eyes open on the market and the competition. Things that he brought up on eucalyptus, some of the other species that might come up, may blow certain projects or processes out of the water on the long term. There's a good growth potential in CTMP aspen. I think there's room for several more of the Millar Western type pulping to get into place and capture that market window and to make it still within reasonable economic range.

Once you start putting in too many modifications, too many changes, then you start inflating this thing to the level of close to a kraft mill, then you lose your competitiveness. The biggest hang-up in the CTMP aspen is this decay in wood. It's got to be dealt with somehow. Sure you can just select all the good stuff out, but what about the other stuff you end up logging anyway? So some other means of disposal or some other product line has to be considered.

In mechanical pulps there are good prospects for the next five to ten years. It's going to nip away at the traditional softwood and hardwood chemical pulp market. There's no question that with hardwood and softwood chemical pulp absolute tonnage will continue to grow but their market share might be a little bit smaller, whereas the mechanical or chemimechanical aspen pulp, for example, will be taking away their market share.

(ii) Low Yield Pulp

As far as the kraft pulp is concerned, which is really the predominant technology for making chemical pulp, it's a well-established technology, it's been around for many years, and it's being practiced today for the production of market pulp and also production of slush pulp for integrated manufacturing of printing and writing paper.

Aspen pulp is well-accepted in the marketplace so nobody has to run around the world trying to sell aspen pulp. People know that, they like it, and if the price is right, they will buy it.

There are some minor technical improvements one could make to enhance the mill productivity, in my opinion. Things like pitch deposits, cleanliness of the pulp, which originates from some of the problems associated with bark removal during the winter months.

Concerning development prospects, it is difficult to see that in the foreseeable future somebody is going to construct a large market kraft pulp mill. In Alberta there is a chance since the resource is available, however, the cost is too high. We're talking about world scale 800 to 1,000 tonnes a day requiring something like $400 to $500 million. It's very difficult to justify a new mill but it is not impossible.

In the foreseeable future, in Alberta, the two existing kraft mills are expected to increase their production slightly to get into hardwood aspen pulp. Simply, it's got to be some other technology, lower cost that can make a chemical pulp substitute or similar product so it has to be based on an entirely different technology perhaps.

To make use of the aspen resources that have various degrees of defects you're probably going to end up with a mixture of processes. No single process will predominate. In fact, that is a dangerous approach because if that market turns you have to shut down the whole province. So there could be several different grades made, even the commodity products such as liner board or corregating medium that would take balsam poplar and all the really defective wood, and you have the higher grade product which makes OSB and super high grade bleached CTMP.

(iii) Novel Pulps

The solvent pulping is very interesting. It's been around for many, many years. It's getting new life lately with people talking about catalyzed solvent pulping and ester pulping.

Based on what we believe, it's not a definitive work, but very interesting work because there isn't too much difference between the various solvent systems. By and largely effective, they can do a job, they can give you somewhat higher yield at lower kappa number. In some cases, a catalyst is very highly recommended, in others it is absolutely essential.

The major hurdle in solvent pulping systems is really the separation of solvent from pulp and its subsequent economics of the solvent recovery circuit, in particular, to the solubilized wood fractions. Explosion pulping looks interesting from the capital cost energy requirement and pulp quality points of view. It requires piloting by knowledgable pulp producers prior to full commercialization.

(iv) Chemicals

It's easy to say that we're going to make lignin carbohydrates furfural. Where are we going to sell it? If we look at the lignin market today it's a very volatile market. There's only a few big players, and there's an abundance of lignin products that has to fight against other competition. So, even if we have a lignin on stream low price, we can't find a home for it. We've got to identify the specific customer, who's going to buy it, why he should buy it. This is an unknown lignin, whereas sulphonated lignin we have some knowledge on. It's been worked on for many years with superplastics, concrete, oil well drilling mud and so forth.

We can look at even the example of sulphonated lignin or lignin sulphite entry into the board business as an adhesive. People are still struggling trying to get that first foot into the door despite to say there's going to be a severe petroleum shortage and everybody has to get off phenol formaldehyde. It's not here and the lignin hasn't gone anywhere yet, but there is some potential.

The other area that should be mentioned here is polymer grafting onto aspen cellulose fibers. The use of these grafted fibers has potential application in pulp and paper production as well as in high technology composites. The application of grafted materials is very much in the R&D stage, however, it could offer the optimum use of certain petrochemicals and aspen fiber in Alberta.

CONCLUDING REMARKS

by
J.A. Brennan

Just one or two concluding comments, primarily to thank the people who made this conference a success. In terms of analyzing whether or not we might have achieved our objectives for this workshop, I think perhaps we might have to view that over a period of time.

In terms of exposing the various pulping technologies which could utilize the significant aspen resource in Alberta, I think we've been very successful in meeting the objective of this workshop. Perhaps a little disappointment for me was that there was a lack of interchange between the industry, (the using, the operating and pulp industry) and those involved in the pulping technologies and the research.

To the speakers who provided excellent presentations on outstanding topics, thank you very much.

To the organizing committee who worked hard to make this workshop successful, again thank you.

The input from the audience was very good and thank you for your valuable participation.

My gratitude is also extended to the Alberta Research Council for providing us with this excellent facility and for the interesting tours.

Our intention is to print the proceedings as soon as possible so I encourage the speakers to provide us with their paper without much delay.

Thank you to all for the excellent workshop and have a safe journey home.