

**PULPING EVALUATION
OF
ASPEN CLONES AND HYBRID POPLARS**

Garrie Styan
G.E. Styan & Associates Ltd.,
22116 Old Yale Road, Langley, B.C. V2Z 1B5

Randy Lowe
Econotech Services Ltd.
852 Derwent Way, New Westminster, B.C. V3M 5R1

1996

This is a joint publication of the Canadian Forest Service
and Land and Forest Service pursuant to the
Canada-Alberta Partnership Agreement in Forestry

Project No.8005A-2-143

DISCLAIMER

The study on which this report is based was funded in part under the Canada-Alberta Partnership Agreement in Forestry.

The views, conclusions, and recommendations are those of the authors. The exclusion of certain manufactured products does not necessarily imply disapproval nor does the mention of other products necessarily imply endorsement by the Canadian Forest Service or Land and Forest Services.

(c) Minister of Supply and Services Canada 1996
Catalogue No.: Fo42-91/143-1996E
ISBN: 0-662-24717-5

Additional copies of this publication are available
at no charge from:

Canadian Forest Service
Natural Resources Canada
Northern Forestry Centre
5320 - 122nd Street
Edmonton, Alberta
T6H 3S5
Telephone: (403) 435-7210

or

Land and Forest Service
Alberta Environmental Protection
10th Floor, Bramalea Building
9920 - 108 Street
Edmonton, Alberta
T5K 2M4
Telephone: (403) 427-3551

ABSTRACT

The objective of this study was to determine the pulping characteristics and pulp properties of some selected aspen clones and poplar hybrids relative to the existing commercially harvested trembling aspen in Alberta. Two aspen clones and two hybrid poplars with significantly higher MAIs than that of the presently commercially harvested aspen/poplar were selected for testing; the wood characteristics were measured and kraft pulping and bleaching were carried out in laboratory pulping equipment. With the exception of one poplar sample that was grown in a dry climate, the overall yields (standing tree to bleached pulp) and pulp qualities were better or comparable to the commercially harvested aspen. The study demonstrates that the pulping of aspen clones and some poplar hybrids that are harvested at or before maturity compare favourably with the mature aspen commercially harvested for BKP. In particular, young aspen and poplar grown as shelterbelt or on private woodlots for commercial harvest should be a profitable business and a desirable source of fibre for Alberta's pulp mills.

ACKNOWLEDGMENTS

The authors appreciate the contributions of and working relationship with Russ Bohning and Dave Cheyne of the Canadian Forest Service (Edmonton, Alberta) and Dan McPherson and Doug Sklar of Alberta-Pacific Industries Inc. (Athabasca, Alberta).

TABLE OF CONTENTS

| | Page |
|---|------|
| INTRODUCTION | 1 |
| THE WOOD RESOURCE | 2 |
| PROCESSING | 5 |
| Pulping | 5 |
| Bleaching | 6 |
| PULP QUALITY | 7 |
| COMMERCIAL SIGNIFICANCE | 10 |
| Economics of Wood Supply | 10 |
| Pulping and Bleaching | 11 |
| Pulp Properties | 12 |
| CONCLUSIONS | 13 |
| GLOSSARY | 15 |
| APPENDIX I | 17 |
| Econotech Services Limited's Detailed Laboratory Trials | |

LIST OF TABLES

| | Page |
|---|------|
| 1. Age of Hardwood Clones and Estimated MAIs | 2 |
| 2. Size and Bark Content of Selected Log Bolts | 3 |
| 3. Properties of Wood Samples | 3 |
| 4. Comparative Properties of Hardwoods Commonly Used for Kraft Pulp | 4 |
| 5. Brightness of Aspen and Poplar Wood Chips | 4 |
| 6. Comparative Kraft Pulping Factors | 5 |
| 7. Chemical Requirements for Bleaching | 6 |
| 8. Comparative Unbleached Pulp Characteristics | 7 |
| 9. Comparative BKP Characteristics of Selected Aspen/Poplar | 8 |
| 10. Comparison of Commercial Hardwood BKPs | 8 |

INTRODUCTION

Alberta forest products industry has grown substantially over the past decade and is continuing to grow at a healthy pace. Most of this recent growth has been based on aspen. The products include BKP, BCTMP and OSB. Alberta has three world scale aspen pulp mills, two BKP (Alberta-Pacific Industries Ltd. and Daishowa-Marubeni Industries Ltd.) and one BCTMP (Millar Western Industries Ltd. at Whitecourt). In addition, it has three operating OSB plants, one in start-up (Tolko Industries at High Prairie) and one due to start-up in early 1996 (Ainsworth Lumber Co. Ltd. at Grande Prairie).

A potential major advantage of aspen and poplar is the ability for genetic breeding in order to improve the growth rate (MAI) through intense forest management and tree/clone selection. This potential to increase the future long term harvest of aspen/poplar will be needed to sustain growth. A major program is underway in Alberta in terms of assessing growth rates of various aspen clones and poplar species in various locations. This study is based on assessing the preliminary economics and pulping characteristics of two aspen samples (September Lake and Meadow Creek) and two poplar species (Northwest poplar and Walker poplar). The latter two samples were on poplars from shelterbelts.

From a business perspective, there are three major objectives that the Industry, Canadian Forest Service and Alberta Forest Service would like the program to achieve on a long term basis:

1. To encourage the planting of aspen and poplar as a shelterbelt for the grain farmers to supplement income, and as private woodlots on marginal agriculture land as a significant income source.
2. To develop in Alberta the most cost effective aspen/poplar forest for pulpwood.
3. To develop an aspen/poplar forest that results in further significant growth opportunities for Alberta.

The objective of this specific study is "to evaluate a number of aspen/poplar clones for quality and economics as a fiber source for pulp compared with the trembling aspen used in the present commercial pulp mills."

The work presented in this report is a joint effort of Econotech Services Ltd. (ESL) and G.E. Styan & Associates Ltd. (GES). Econotech was responsible for carrying out and reporting the laboratory scale trials, and GES was responsible for the commercial significance. However, the design of the laboratory work and the evaluation of the technical results were done on a collaborative basis. Econotech's report is presented as a separate appendix which is referred to extensively throughout the text of the report.

THE WOOD RESOURCE

The present age distribution for trembling aspen used at the Al-Pac BKP mill ranges from 50 to 100 years. The age factor is an important aspect of growth, particularly for aspen which matures at an early age (70 to 80 years). At 70 years the growth rate of aspen would slow significantly, and at 80 plus years it would essentially be zero. Growth rates of timber are usually recorded on an annual volume basis for a unit of land; one such measure is the mean annual increment (MAI or m³/ha/yr). Over the next decade the estimated average age of the harvested aspen is about 100 years. This would represent largely overmature aspen which would essentially have a zero MAI at the instantaneous time of harvest, possibly even a negative MAI due to wood losses from decay. Overmature aspen stands could be as high as 30% in decayed wood. This decayed wood represents a loss in fiber from the viewpoint of forest products and economic wealth. However, on average for the presently harvested aspen the estimated MAI is about 2.5 m³/ha/yr¹ up to 70 to 80 years (that is, up to maturity).

The samples selected for the pulping study have the following age and estimated MAI's (Table 1).

Table 1. Age of Harvested Clones and Estimated MAI's

| | Presently Harvested Aspen | Sept. Lake Aspen | Meadow Crk. Aspen | Northwest Poplar | Walker Poplar |
|----------------------------------|---------------------------|------------------|-------------------|------------------|---------------|
| Tree Age (years) | 70 - 80 | 58 | 62 | 18 | 27 |
| MAI's* (average throughout life) | 2.5 | 4 | 4 | 8 | 8 |

* m³/ha/yr

Source: Al-Pac

The target rotation for harvest is in the range of 18 to 25 years. It is obvious that a major driving force is the potential for significantly higher sustainable yields from a given land base.

¹ Estimated MAI from Al-Pac

The average diameter and bark content for the four log samples are given in Table 2 (see also page 2 of Appendix).

Table 2. Size and Bark Content of Selected Log Bolts

| | Sept. Lake Aspen | Meadow Crk. Aspen | Northwest Poplar | Walker Poplar |
|--|---------------------|-------------------------|---------------------|------------------|
| Tree Age, yr | 58 | 62 | 18 | 27 |
| Average Log Diameter, cm | 19.8 | 20.1 | 25.2 | 24.8 |
| Log Volume per m Length, L | 30.8 | 31.7 | 49.9 | 48.3 |
| Average Bark Content on Log, % o.d. Basis | 14.3 | 15.5 | 14.3 | 16.7 |

All log samples came from comparable geographic regions in terms of weather conditions with the exception of the Walker poplar which came from a drier climate (southern Saskatchewan). This could explain its higher bark content and the higher density (see Table 3 and page 3 of Appendix).

Table 3. Properties of Wood Samples

| | Sept. Lake Aspen | Meadow Crk. Aspen | Northwest Poplar | Walker Poplar | Mill Chips |
|--------------------|---------------------|-------------------------|---------------------|------------------|---------------|
| DCM Extractives, % | 2.11 | 2.14 | 1.44 | 1.68 | - |
| Density, g/ml | 0.351 | 0.352 | 0.339 | 0.379 | 0.366 |
| Wood Brightness, % | | | | | |
| Fresh | 65.5 | 64.1 | 64.9 | 64.1 | - |
| Aged, one wk | 64.8 | 64.5 | 62.0 | 65.4 | - |
| WAFL, mm | 0.98 | 1.07 | 0.99 | 0.92 | 0.96 |

There is nothing to indicate in the basic wood properties that there would be any significant difference in the pulping results, particularly when compared with the physical properties of other hardwoods (Table 4).

Table 4. Comparative Properties of Hardwoods Commonly Used for Kraft Pulp

| | Plantation Eucalyptus | U.S. South ¹ Hardwood | Birch | Aspen |
|----------------------------|-----------------------|----------------------------------|-------|-------|
| Water Solubles, % | 4.6 | 3.7 | 2 | 2 - 3 |
| Density, kg/m ³ | 530 | 450 - 550 | 510 | 370 |
| Lignin Content, % | 22.6 | 24.7 | 18.2 | 18.2 |

¹ Gums and Oaks

One of the very positive features of aspen and birch is the low proportion by weight of vessel elements. The vessel elements probably correlate with the percent lignin.

The only potential negative from the measurements was that one determination of aged brightness (from two tests) showed a 4.4 point drop after one week of aging (the other showed a 1.5 point drop) for Northwest poplar (see Table 5). Visually both poplar samples appeared to be slightly darker after aging compared with the aspen clones. Obviously, it was basically only a surface effect for the Walker poplar.

Table 5. Brightness of Aspen and Poplar Chips

| | Aspen | | Poplar | |
|---------------------------------------|------------|-------------|-----------|--------|
| | Sept. Lake | Meadow Crk. | Northwest | Walker |
| Fresh | 65.5 | 64.1 | 64.9 | 64.1 |
| Aged for One Week at Room Temperature | | | | |
| 1st Determination | 65.1 | 64.8 | 60.5 | 65.2 |
| 2nd Determination | 64.5 | 64.2 | 63.4 | 65.6 |

Source: Econotech

PROCESSING

Pulping

There are two major factors related to pulping that are associated with wood quality and wood species: yield and pulp quality. Yield in this case is measured as bone dry wood input to bone dry pulp output. (Overall yield from a forestry and business viewpoint is often visualized from cubic metres harvested to pulp output.) Pulping yield is important from two economic aspects: cost of wood and production capacity of the pulp mill. A low yield means higher wood costs, and high loadings per ton pulp produced to the recovery boiler which is often the bottleneck in the chemical pulp mill.

The yield and required cooking chemical charge for the four trial wood samples are given in Table 6 (see also page 3 of Appendix).

Table 6. Comparative Kraft Pulping Factors

| | Sept. Lake Aspen | Meadow Crk. Aspen | Northwest Poplar | Walker Poplar | Mill Chips |
|--------------------|---------------------|-------------------------|---------------------|------------------|---------------|
| Active Alkali, % | 15.0 | 15.0 | 16.5 | 18.0 | 15.0 |
| Total Yield, % | 58.4 | 59.1 | 58.4 | 52.2 | 57.4 |
| Kappa | 15.2 | 16.6 | 16.6 | 17.7 | 15.1 |
| DCM Extractives, % | 0.95 | 0.66 | 0.86 | 0.76 | 0.80 |

All the aspen cooks, the two clones plus the mill sample were virtually identical in terms of results with the exception of the slightly lower yield for the mill sample which contained about 10% chips affected by rot. It is considered that the two tested aspen clones would essentially provide the same yield and same load to the recovery boiler as the presently mill run chips.

The only wood sample that was significantly different was the Walker poplar. This sample required 20% more cooking chemical and gave a 6% lower yield. It also had a slightly higher residual lignin left in the unbleached pulp in spite of the higher chemical charge. Certainly in terms of kraft pulping, this sample of Walker poplar would be considered inferior. However, it should be cautioned that it could be a factor of the geographical location (dry climate relative to other clones) rather than genetics. The Northwest poplar in terms of yield was comparable to the aspen clone, but did require 10% higher chemical loading.

The level of extractives in the unbleached pulp for all samples was comparable and is not an issue for further processing (bleaching) or pulp quality.

Bleaching

All unbleached pulp samples bleached were relatively easy to bleach. The final brightness and extractive (resin) content were essentially equivalent. There is a slight indication that the Walker poplar may require a marginally higher chemical loading for bleaching, but the results are not conclusive (Table 7 below and Table 4 of Appendix). However, there is nothing to indicate that bleaching of any of the four clones would give any operating problems.

Table 7. Chemical Requirements for Bleaching

| | Aspen | | Poplar | |
|---|------------|-------------|-----------|--------|
| | Sept. Lake | Meadow Crk. | Northwest | Walker |
| Kappa | 15.2 | 16.6 | 16.6 | 17.7 |
| O - Stage ¹ | | | | |
| NaOH % | 2.3 | 2.6 | 2.7 | 3.1 |
| Exit Kappa | 9.3 | 9.8 | 9.7 | 10.2 |
| D - Stage | | | | |
| ClO ₂ % (as Cl ₂) | 2.05 | 2.16 | 2.13 | 2.24 |
| Epo - Stage ¹ | | | | |
| NaOH % | 0.85 | 0.85 | 0.8 | 0.8 |
| H ₂ O ₂ % | 0.33 | 0.33 | 0.33 | 0.33 |
| Exit Kappa | 3.0 | 3.0 | 3.4 | 3.7 |
| D - Stage | | | | |
| ClO ₂ % | 0.1 | 0.1 | 0.1 | 0.1 |
| ISO Brightness | 90.9 | 90.6 | 91.3 | 91.2 |
| DCM Extractives | 0.55 | 0.53 | 0.66 | 0.65 |

¹ The oxygen initial pressure and final pressure was equivalent for bleaching of each species.

PULP QUALITY

Aspen BKP is a premium hardwood BKP and in this regard joins birch BKP and plantation eucalyptus BKP. These pulps are premium pulps for two reasons:

1. Consistency of quality.
2. Excellent absolute quality for some specific end use(s).

Aspen has a consistent fiber morphology that varies little with age of tree. In addition, it has excellent fiber morphology for coating base stock.

Two of the unbleached pulps of the trial wood samples (Meadow Creek aspen and Northwest poplar) were tested and compared with mill trembling aspen chips. The Northwest poplar gave the best results; the low energy requirement to reach 400 CSF for the mill trembling aspen is a confirmation of the presence of rot (Table 8). All pulps are within the ranges typical of aspen pulps (see Table 5 of Appendix).

Table 8. Comparative Unbleached Pulp Characteristics

| Unbleached Pulp Strength at 400 mls CSF | PFI Revs | Burst Factor | Tear Factor | Tensile km | Bulk cc/g |
|--|----------|-----------------|----------------|---------------|--------------|
| Meadow Creek Aspen | 4100 | 50 | 70 | 9.9 | 1.33 |
| Northwest Poplar | 2500 | 56 | 85 | 9.3 | 1.42 |
| Mill Aspen (Lab MCC) | 1000 | 50 | 71 | 8.7 | 1.28 |

However, since both aspen kraft pulp mills in Alberta (Peace River and Athabasca) market only BKP, the focus of the results was the bleached pulps.

The most common freeness for the use of hardwood BKP's for printing and specialty papers (the major end use(s) of aspen BKP) is about 400 CSF. Table 9 compares the results from the four trial wood samples with Al-Pac's average for aspen BKP (see also Table 6 of Appendix).

Table 9. Comparative BKP Characteristics of Selected Aspen/Poplar

| Bleached Pulp Strength at 400 mls CSF | PFI Revs | Burst Factor | Tear Factor | Tensile km | Bulk cc/g | Opacity % |
|---------------------------------------|----------|--------------|-------------|------------|-----------|-----------|
| September Lk. Aspen | 1500 | 35 | 62 | 7.1 | 1.44 | 68 |
| Meadow Crk. Aspen | 2000 | 39 | 69 | 6.9 | 1.43 | 66 |
| Northwest Poplar | 1300 | 47 | 83 | 7.2 | 1.34 | 67 |
| Walker Poplar | 300 | 43 | 73 | 7.6 | 1.38 | 72 |
| Mill Aspen (Lab Cook) | 1300 | 38 | 86 | 5.7 | 1.39 | 69 |
| Al-Pac Aspen Average | 900 | 28 | 66 | 6.5 | 1.39 | 75 |

These results are all reasonably comparable. Tear has the widest variation, but is also the measurement that is the least accurate. To get a good appreciation of the range of properties from the four trial wood samples, the results should be compared with the range of values from a commercial mill (Al-Pac) and from the properties of other hardwood BKP's. Table 10 compares aspen BKP with four other hardwood BKP's at 400 CSF. As with the unbleached results (Table 7), the Northwest poplar gave marginally better strength results for the bleached pulps.

Table 10. Comparison of Commercial Hardwood BKP's

| | Freeness | Tear | Tensile | Bulk | Opacity |
|------------------------|----------|-------|---------|-----------|---------|
| Aspen | 400 | 84 | 7.7 | 1.4 | 71 |
| Birch | 400 | 82 | 8.7 | 1.3 | 72 |
| Northern Hardwood | 400 | 74 | 6.6 | 1.5 | 73 |
| Plantation Eucalyptus | 400 | 94 | 6.4 | 1.6 | 78 |
| Southern Hardwood | 400 | 86 | 5.8 | 1.6 | 76 |
| Four Trial Wood Sample | 400 | 62-83 | 6.9-7.6 | 1.34-1.44 | 66-72 |
| Al-Pac Aspen Average | 400 | 66 | 6.5 | 1.39 | 75 |

Source: G.E. Styann & Associates Ltd., Econotech Services Ltd.

Birch and aspen BKP's are close in properties - they are also considered to be (along with maple BKP), the premium hardwood BKP's for coating base stock. The other hardwood BKP's (Table 10) are bulkier and have lower bonding strengths (tensile). However, a major property that does not show up in Table 10 is the proportion by weight of vessel elements; United States southern hardwood and eucalyptus are significantly higher in vessel elements.

Al-Pac's average test results for aspen BKP show slightly lower strength and higher opacity than would normally be anticipated. This could be an indication of decay in the wood chips.

COMMERCIAL SIGNIFICANCE

In evaluating aspen and poplar species or clones in terms of pulping and pulp quality there are a number of factors to consider:

- wood density,
- bark content,
- rot and other defect,
- yield through the digester,
- bleaching response,
- strength properties,
- optical properties, and
- proportion of vessel elements.

With the exception of the latter factor the remaining characteristics were determined for all samples with a good degree of certainty. However, it should be questioned whether the Walker poplar sample was representative in view of its growing site being considerably drier than the other test wood samples.

Economics of Wood Supply

The average wood density of the trembling aspen utilized by Alberta's pulp mills is 370 kg/m³. All the samples, with exception of Walker poplar were lower in wood density than the aspen pulp wood presently utilized. However, the aspen clones were only 5% less and the Northwest poplar was 8% less. This should only be considered a marginal factor regarding economics unless stumpage rates on a cubic meter basis become significant for pulpwood. The slightly lower density recorded on the mill chips (366 kg/m³) used for the lab cook could be due to the rot level (about 10% of the chips were affected by rot).

Overall the younger aspen clones (about 20 to 30 years younger than the 80 to 100 year old mature and overmature aspen used at present), and the young poplar samples (20 to 25 years old) should result in more positive overall yield. The freedom from rot means lower loss in the woods, higher conversion of roundwood to accept chips, and slightly higher yield through the pulp digester. For the two aspen clones (September Lake and Meadow Creek), a reasonable estimate of higher yield on a cubic metre of standing timber should be in the region of 5% in spite of the 5% lower density. Thus, the results indicate a positive contribution on overall yield for the aspen clones - even the poplar samples which either had an 8% (Northwest poplar) lower density or a 5 to 6% lower yield from the digester (Walker poplar) should do no worse than break even.

It should be noted that higher MAI's normally correlate with lower wood density, particularly within the same species or clones. However, the considerably higher estimated MAI for the aspen clones (4 m³/ha/yr to 8 m³/ha/yr) compared with the aspen stands presently harvested (2.5 m³/ha/yr) result in a significantly higher yield on a fiber weight basis.

Pulping and Bleaching

In terms of processing the two aspen clones and the Northwest poplar were positives - in particular, the marginally higher yield due to the lack of rot would result in a slightly lower solids load to the recovery boiler. In this regard, the only significant negative aspect of the entire evaluation was the lower yield and higher chemical charge required by the Walker poplar sample during kraft pulping. The additional load to the recovery boiler per ton pulp is estimated at about 8 to 10%. If this was the bottleneck, then pulp capacity would drop by 8 to 10% - a significant economic penalty.

The overall yield from the younger aspen clones (September Lake and Meadow Creek) is significantly superior to the mature and overmature aspen presently harvested as pulpwood in virtually every aspect.

1. The MAI is estimated to be 60% higher on a volume basis, and about 50% higher on a fiber weight basis.
2. The young aspen contains no rot and thus gives a higher pulp yield and higher pulp strength.
3. The lack of rot will also give a higher yield of accept chips from roundwood.

The overall estimate is that an increase of 55 to 60% in pulp yield per unit of land would result from the younger aspen clones from Meadow Creek and September Lake.

The younger poplar samples would provide an even more significant increase in pulp yield per hectare. The Northwest poplar and Walker poplar are estimated to provide about a threefold increase in pulp per unit of land.

The major negative aspect (the impact of the recovery boiler) of the Walker poplar needs to be confirmed since the growing conditions for this sample were considerably different than those of the other samples and the present supply of aspen pulpwood to the mills.

There appears to be no meaningful difference with respect to bleaching response.

The bleaching results for high yields pulps, such as BCTMP produced at Millar Western's Whitecourt mill, should be positive for the aspen clones when compared with the existing wood supply which suffers from some decay. There is some indication that the poplar samples could represent a disadvantage if the chips are not fresh - probably 2 weeks should be the maximum storage time. The remaining chemical and physical properties of the young poplar wood indicate that BCTMP quality should be comparable to that of trembling aspen.

Pulp Properties

The results strongly indicate that in terms of bulk properties, there is unlikely to be any significant commercial difference between the four tested aspen/poplar samples and the run-of-the-mill aspen. However, it is important to recognize that there is a very important non-bulk property that gives aspen BKP a premium position for coated papers - the low proportion of vessel elements. There is indirect evidence that the Walker poplar sample could be negative in this regard. The lower yield and the slightly more difficult bleaching response probably are due to a higher lignin content which could correlate with thicker, heavier vessel elements. If so, this would negate some of the premium position for coating base stock. As previously stated, this could be due to the drier growing conditions rather than genetics. However, prior to using Walker poplar in the Alberta BKP mills, samples grown in typical Alberta climatic conditions should be analyzed for lignin content and size of vessel elements.

CONCLUSIONS

This study demonstrates that the pulping of the aspen/poplar clones harvested at maturity and the poplar at slightly below maturity compare very favourably with the existing trembling aspen commercially harvested for BKP. In particular:

1. In spite of the lower wood density for the two tested aspen clones, there are positive overall yield benefits per cubic metre of harvested timber. The poplar samples are less positive in terms of overall yield per cubic metre.
2. The significantly higher estimated MAI's, coupled with the reduced rot content of the aspen clones and the poplar, would provide a much higher pulp yield per hectare of land utilized - about 60% higher for the aspen clones and 200% higher for the poplar.
3. The processing of the younger aspen clones and poplar in terms of wood handling, chipping and pulping should be easier in every respect with the exception of the pulping of Walker poplar.
4. The sample of poplar (Walker poplar) grown in a dry climate gave a significantly lower yield through the pulp digester. This and other results indicate a higher lignin content, and should be verified. This was the only meaningful negative result.
5. For both the aspen clones and the hybrid poplars, pulp quality is at least comparable and sufficiently close to the BKP produces from the existing aspen harvest as to represent no commercial problem. However, there were indications that brightness from poplar chips aged over 2 weeks could detract from use in BCTMP.
6. There is every indication that young aspen and poplar grown as shelterbelt or specifically on private woodlots for commercial harvest should be both a profitable business (as indicated by MAI) and a desirable source of fiber for Alberta's pulp mills.

GLOSSARY

| | |
|-----------------------|---|
| BKP | Bleached Kraft Pulp |
| BCTMP | Bleached Chemi-thermomechanical Pulp |
| OSB | Oriented Strand Board (Plywood Substitute for some uses) |
| DMI | Daishowa-Marubeni International Ltd. |
| MAI | Mean Annual Increment of Growth (usually measured as m ³ /ha/yr) |
| m ³ /ha/yr | cubic metres/hectare/year |
| Al-Pac | Alberta-Pacific Forest Industries Inc. |
| o.d. | oven dry |
| WAFL | Weighted Average Fiber Length |
| recovery boiler | A boiler for combustion of spent pulping liquor for recovering chemicals and energy values |
| Active Alkali | Measure of alkali available for pulping in cooking liquor |
| Kappa Number | Measure of lignin content left after chemical pulping |
| DCM extractives | Dichloromethane extraction of resins in wood or pulp |
| O - Stage | Oxygen delignification or bleaching stage |
| D - Stage | Chlorine dioxide bleaching stage |
| Epo - Stage | Alkaline peroxide extraction bleaching stage |
| ISO Brightness | European standard measurement of pulp brightness |
| CSF | Canadian Standard Freeness, an indirect measure of drainage |
| PFI revs | A measure of the energy needed to reduce freeness related to number of revolutions of a PFI mill |
| MCC | Extended Modified Cooking, a modern kraft pulping process that results in lower lignin content of unbleached pulp |
| opacity | A measure of the opaqueness of a pulp sheet (or paper sheet) |

APPENDIX I

Econotech Services Limited's Detailed Laboratory Trials

**REPORT TO ALBERTA-PACIFIC FOREST INDUSTRIES INC. AND
CANADIAN FOREST SERVICE
ON
PULPING AND BLEACHING PROPERTIES
OF ASPEN AND POPLAR CLONES**

BY

**ECONOTECH SERVICES LIMITED
852 DERWENT WAY
NEW WESTMINSTER, BRITISH COLUMBIA
V3M 5R1 CANADA
TEL: (604) 526-4221
FAX: (604) 526-1898**

**RANDY W. LOWE
SEPTEMBER 27, 1995
RWL:95:169
W.O. L50049 (LG)**

**REPORT TO ALBERTA-PACIFIC FOREST INDUSTRIES
CANADIAN FORESTRY SERVICE ON
PULPING AND BLEACHING PROPERTIES OF ASPEN AND POPLAR CLONES**

SUMMARY

Samples of September Lake aspen, Meadow Creek aspen, Northwest poplar and Walker poplar were shipped to Econotech in log form for evaluation of their pulping and bleaching properties. The logs were debarked and chipped. Bark content, wood density, DCM extractive content and wood brightness were measured for each chip sample. The chips were cooked with a kraft process to a 16 kappa target. The unbleached pulps were bleached using the Alpac sequence - ODEpoD to a 90+ ISO brightness. The pulp strengths were evaluated on two unbleached and the four bleached pulps. The results of this study indicated that the two aspen and two poplar samples had the same bleachability of mill aspen and had generally similar strength properties. The Walker poplar was not desirable since it had significantly lower pulp yield than the other three samples.

CONCLUSIONS

The following conclusions and observations were drawn from this study:

1. The aspen trees were at least twice as old as the poplar trees but the average log volume per unit length was 50 to 60% higher for the two poplar samples.
2. Bark content for the two aspen and two poplar samples ranged from 14.3 to 16.7% of total log weight.
3. The DCM wood extractives of the poplar samples were approximately 25% lower than those of the aspen samples.
4. Wood densities for the four samples ranged from 0.35 to 0.38 g/mL compared to 0.37 g/mL for the regular mill aspen.
5. The weighted average fiber lengths (WAFL) for the four samples were typical of hardwood pulps ranging from 0.92 to 1.07 mm compared to 0.96 for the mill aspen sample.
6. The September Lake aspen, Meadow Creek aspen and Northwest poplar gave pulp yield equivalent or slightly higher than regular mill chips with 57.4% yield. Walker poplar gave 5.2% on wood lower yield than the mill chips.
7. The poplar samples were slightly more difficult to cook than the aspen samples requiring approximately 1.5 to 3.0% more active alkali on wood.
8. All four brown stock samples bleached very easily to 90%+ ISO brightness using approximately the same chemical charges reported for the mill aspen.

9. The unbleached pulp strengths from the Meadow Creek aspen and Northwest poplar were in the range for aspen pulps. The unbleached Northwest poplar exhibited higher tear strength at lower freenesses.
10. All bleached pulps had strengths in the range expected for aspen pulps.

RESULTS AND DISCUSSION

Samples of September Lake aspen, Meadow Creek aspen, Northwest poplar and Walker poplar were delivered to Econotech on July 12, 1995. Each sample consisted of five logs approximately 1.5 m in length. Appendix Table 1 lists the diameter and length of each log received. The taper on the logs was fairly even. The logs were cut in half into two 0.75 m long pieces and one portion was retained from each log for debarking and chipping. Appendix Table 2 shows the green log weight with bark and the bark weights measured from each log sample. A sample of regular mill chips was also received in July 1995 for determination of basic wood density and fiber length.

Wood Properties

The average diameter and bark content for the four log samples are shown below:

| | Sept.Lake aspen | Meadow Crk. aspen | Northwest poplar | Walker poplar |
|--|--------------------|----------------------|---------------------|------------------|
| Tree age, yr | 58 | 62 | 18 | 27 |
| Average log diameter, cm | 19.8 | 20.1 | 25.2 | 24.8 |
| Log volume per m length, L | 30.8 | 31.7 | 49.9 | 48.3 |
| Average bark content on log, % o.d. basis | 14.3 | 15.5 | 14.3 | 16.7 |

Tree ages noted above were supplied by the Canadian Forestry Service. Although both poplar samples were less than half the age of the aspen samples, the poplars appear to be 5 cm thicker in diameter than the aspen samples. The poplar logs had approximately 50 to 60% more log volume per unit length. The bark content for the aspen and poplar samples ranged from 14.3 to 16.7%.

Table 1 summarizes the wood properties of the four chip samples.

| | Sept.Lake aspen | Meadow Crk. aspen | Northwest poplar | Walker poplar | Mill chips |
|--------------------|--------------------|----------------------|---------------------|------------------|---------------|
| DCM extractives, % | 2.11 | 2.14 | 1.44 | 1.68 | - |
| Density, g/mL | 0.351 | 0.352 | 0.339 | 0.379 | 0.366 |
| Wood brightness, % | 65.5 | 64.1 | 64.9 | 64.1 | - |
| WAFL, mm | 0.98 | 1.07 | 0.99 | 0.92 | 0.96 |

The DCM extractive content of the aspen chip samples appears to be higher than the poplar samples. Walker poplar had a slightly higher basic wood density than the other three samples. Wood brightness and fiber length from unbleached kraft pulp were fairly similar for both aspen and poplar samples. Wood brightness was determined on handsheets prepared from refining of chip samples in a laboratory Sprout-Waldron refiner. Fiber length measurements were determined on brown stock of cooks in Table 3 using modified TAPPI method T232 by projection. Graphs showing fiber length distribution are included in the Appendix.

Pulping Experiments

Table 2 shows some preliminary small (2.5 L) bomb cooks used to determine the pulping conditions. These trials showed that aspen chips pulped easier than the poplar samples. We had to increase the active alkali charge by 1.5 to 3.0% on wood for the two poplar samples and increase the H-factor by 8 to 10%. The pulping conditions are shown in Table 3.

| | Sept.Lake aspen | Meadow Crk. aspen | Northwest poplar | Walker poplar | Mill chips |
|------------------|--------------------|----------------------|---------------------|------------------|---------------|
| Active alkali, % | 15.0 | 15.0 | 16.5 | 18.0 | 15.0 |
| H-factor | 425 | 420 | 469 | 453 | 477 |
| Total yield, % | 58.4 | 59.1 | 58.4 | 52.2 | 57.4 |
| Kappa | 15.2 | 16.6 | 16.6 | 17.7 | 15.1 |
| DCM extract., % | 0.95 | 0.66 | 0.86 | 0.76 | 0.80 |

The two aspen samples cooked similarly to a recently pulped sample of mill aspen chips from the Alberta Pacific mill. The two poplar samples required 1.5 to 3.0% and appear to be slightly more difficult to cook resulting in slightly higher kappa numbers. Only the Walker poplar appear to have reduced yield. The Walker poplar with significantly lower yield and higher alkali demands

would reduce mill production by about 10% if used on a 100% basis. The other samples had yields approximately 58% compared to 57.4% for the mill aspen sample. DCM extractive levels were reduced to below 1% for all samples but there was no trend between extractive levels in wood chips and resultant extractive level in kraft pulp.

Bleaching

The Alpac O-D100-Epo-D sequence and bleaching conditions were used to bleach the four samples of screened brown stock. Table 4 summarizes the bleaching results and conditions. Appendix Table 3 shows the results of small trials used to determine the final D-stage chlorine dioxide dosages. All pulps were relatively easy to bleach. A 0.22 kappa factor was used in the D100-stage. Brightness after the Epo-stage ranged from 88.0 to 89.2% ISO. Application of 0.1% chlorine dioxide in the final D-stage raised final brightness to 90.6 to 91.3% ISO for all samples. The chemical charges required to attain the +90% ISO brightness were equivalent to dosages reported for normal mill operation. DCM (dichloromethane) extractives were measured on the four bleached pulps. The aspen pulps had marginally lower DCM extractives than the poplar pulps. The DCM extractive contents of the wood, brown stock and bleached pulp are summarized below:

| DCM extractives | Sept. Lake aspen | Meadow Creek aspen | Northwest poplar | Walker poplar |
|-----------------|------------------|--------------------|------------------|---------------|
| Wood | 2.11% | 2.14% | 1.44% | 1.68% |
| Brown stock | 0.95% | 0.66% | 0.86% | 0.76% |
| Bleached pulp | 0.55% | 0.53% | 0.66% | 0.65% |

Unbleached Pulp Strength

The Meadow Creek aspen and Northwest poplar brown stocks were selected for PFI strength evaluation. Standard CPPA test methods were used. The PFI strength development curves are attached to the Appendix. Table 5 tabulates the strength values for the pulps at initial freeness, 600, 500, 400 and 300 mLs CSF. The strength results of aspen brown stock from a lab MCC cook (B1458) used in the preliminary design of the mill in July 1990 has been added to Table 5. The chips used to prepare this MCC aspen mill pulp contained 10% rot. Tensile strengths are approximately 10% lower for MCC cooking procedure than from conventional cooking. The

strengths of the three brown stocks at 400 mLs CSF are compared below:

| Unbleached pulp strength at 400 mLs CSF | PFI revs | Burst factor | Tear factor | Tensile km | Bulk cc/g |
|---|----------|--------------|-------------|------------|-----------|
| Meadow Creek aspen | 4100 | 50 | 70 | 9.9 | 1.33 |
| Northwest poplar | 2500 | 56 | 85 | 9.3 | 1.42 |
| Mill aspen (Lab MCC) | 1000 | 50 | 71 | 8.7 | 1.28 |

All pulps are in ranges typical of aspen pulps. The following figures show the pulp strength plotted against the pulp freeness:

- Figure 1 Burst vs CSF
- Figure 2 Tear factor vs CSF
- Figure 3 Tensile vs CSF
- Figure 4 Bulk vs CSF

The behaviour of the three unbleached pulps with beating to lower freeness levels is shown in the above figures. The burst behaviour appears normal. The tear for the Northwest poplar appears to develop to reach higher levels than the Meadow Creek aspen or the 1990 mill aspen. Pulps with higher tear generally have lower tensile strengths. The Meadow Creek aspen had higher tensile strengths than the Northwest poplar. The plot of bulk against freeness (Fig. 4) shows that the Northwest poplar had higher bulk than the other two unbleached pulp samples.

In summary from the unbleached strength testing the properties of the Meadow Creek and Northwest poplar were in the range for aspen pulps. The Northwest poplar was marginally superior because of its higher tear and bulk properties.

Bleached Pulp Strength

CPPA PFI pulp strength evaluations were run on all four bleached pulps. The bleached pulp strengths at initial freeness, 500, 400 and 300 mLs CSF are shown in Table 6. A sample of bleached pulp (from aspen containing 10% rot) from the 1990 Alpac design study was used for a comparison. Alberta Pacific also provided a typical profile for their average strength of fully bleached aspen (see Appendix) for comparison.

The following figures show the pulp strength plotted against the pulp freeness:

- Figure 5 Burst vs CSF
- Figure 6 Tear factor vs CSF
- Figure 7 Tensile vs CSF

Figure 8 Bulk vs CSF
Figure 9 Opacity vs CSF

All bleached pulps have similar strength properties expected in the range for hardwood pulps. The Northwest poplar again showed higher tear strength than the September Lake aspen, Meadow Creek aspen and Walker poplar. Tear from the September Lake aspen appeared lowest of the four samples tested. The tensile behaviour of the four pulps were similar. High bulk reported for unbleached Northwest poplar was lost on bleaching.

The strength results from the average Alpac mill bleached pulp was generally lower than the lab bleached pulps. In comparing pulp strength results from mill and lab produced pulps, the mill results are generally 10 to 15% lower than the laboratory results. The MCC pulps will also have lower tensile strengths than the conventional kraft pulps. On this basis, the two aspen and two poplar samples studied were thought to be very similar in strength properties to the mill chips. The commercial bleached Alpac pulp did seem to exhibit higher opacity values but this may be the result of inter-laboratory testing variability. The bleached pulp strengths at 400 mLs CSF are shown below:

| Bleached pulp strength at 400 mLs CSF | PFI revs | Burst factor | Tear factor | Tensile km | Bulk cc/g | Opacity % |
|---------------------------------------|----------|--------------|-------------|------------|-----------|-----------|
| September Lake aspen | 1500 | 35 | 62 | 7.1 | 1.44 | 68 |
| Meadow Creek aspen | 2000 | 39 | 69 | 6.9 | 1.43 | 66 |
| Northwest poplar | 1300 | 47 | 83 | 7.2 | 1.34 | 67 |
| Walker poplar | 300 | 43 | 73 | 7.6 | 1.38 | 72 |
| Mill aspen (Lab cook) | 1300 | 38 | 86 | 5.7 | 1.39 | 69 |
| Alpac aspen (average) | 900 | 28 | 66 | 6.5 | 1.39 | 75 |

In summary, the bleached pulp strengths show that the two aspen and two poplar samples give strengths comparable to mill aspen currently in use after correcting for strength differences in mill versus lab comparisons. The tear on the September Lake aspen may be on the low side but this may not be important if the mill customers do not place specifications on tear.

Table 1
 Alberta-Pacific & CFS - L50049
Properties of Wood

| Sample | September Lake aspen | Meadow Creek aspen | Northwest poplar | Walker poplar | Control mill chips |
|--|----------------------------|--------------------------|---------------------|------------------|--------------------------|
| Bark, % on green weight | 14.5 | 14.6 | 14.5 | 17.0 | - |
| Bark, % o.d. solids | 61.2 | 61.8 | 49.6 | 50.1 | - |
| Wood, % o.d. solids | 62.3 | 57.8 | 50.6 | 51.2 | - |
| Bark, % on o.d. weight | 14.3 | 15.5 | 14.3 | 16.7 | - |
| DCM extractives, % | 2.11 | 2.14 | 1.44 | 1.68 | - |
| Basic density, g/mL | 0.351 | 0.352 | 0.339 | 0.379 | 0.366 |
| Wood brightness, % | 65.5 | 64.1 | 64.9 | 64.1 | - |
| <u>Wood brightness after ageing for one week at room temperature</u> | | | | | |
| 1st determination, % | 65.1 | 64.8 | 60.5 | 65.2 | - |
| 2nd determination, % | <u>64.5</u> | <u>64.2</u> | <u>63.4</u> | <u>65.6</u> | - |
| Average brightness, % | 64.8 | 64.5 | 62.0 | 65.4 | - |
| Pulp WAFL*, mm | 0.98 | 1.07 | 0.99 | 0.92 | 0.96 |

* WAFL = weighted average fiber length

Table 2
 Alberta-Pacific & CFS - L50049
Preliminary Bomb Cooks

| Cook number | K470-1 | K470-2 | K470-3 | K470-4 | K471-1 | K471-2 |
|------------------------------------|---------|--------|--------|--------|--------|--------|
| Simulation type | Batch | Batch | Batch | Batch | Batch | Batch |
| Lab digester type | S.Bomb | S.Bomb | S.Bomb | S.Bomb | S.Bomb | S.Bomb |
| <u>Furnish:</u> | | | | | | |
| Furnish | Aspen | Aspen | Poplar | Poplar | Poplar | Poplar |
| Location of supply | Sept L. | Meadow | N.West | Walker | N.West | Walker |
| Furnish, o.d. solids, % | 62.3 | 57.8 | 50.6 | 51.2 | 50.6 | 51.2 |
| O.D. charge wt, g | 150 | 150 | 150 | 150 | 150 | 150 |
| <u>Presteam:</u> | | | | | | |
| Temperature, °C | - | - | - | - | - | - |
| Time, min | - | - | - | - | - | - |
| <u>Cooking:</u> | | | | | | |
| Total time, min | 120 | 120 | 120 | 120 | 120 | 120 |
| Max temperature, °C | 160 | 160 | 160 | 160 | 160 | 160 |
| Time to max, min | 60 | 60 | 60 | 60 | 60 | 60 |
| Time at max, min | 60 | 60 | 60 | 60 | 60 | 60 |
| AA on wood, % Na ₂ O | 15 | 15 | 15.5 | 15.5 | 16.5 | 18 |
| L/W ratio (total liquid) | 4 | 4 | 4 | 4 | 4 | 4 |
| Sulfidity, % on AA | 30 | 30 | 30 | 30 | 30 | 30 |
| <u>End of cook:</u> | | | | | | |
| Residual EA, g/L Na ₂ O | - | 5.4 | 5.6 | 4.7 | 7.1 | 8.8 |
| Residual AA, g/L Na ₂ O | - | 10.6 | 10.9 | 10.4 | 12.9 | 15.4 |
| H - Factor | 460 | 462 | 464 | 466 | 460 | 462 |
| <u>Unbleached pulp:</u> | | | | | | |
| Total yield, % | - | 58.7 | 59.6 | 57.3 | 59.5 | 53.2 |
| Total rejects (+0.012"), % | - | - | - | - | - | - |
| Screened yield, % | - | - | - | - | - | - |
| Kappa, unscreened | 14.8 | 15.0 | 19.7 | 26.1 | 17.9 | 17.3 |

Table 3
 Alberta-Pacific & CFS - L50049
Pulping Conditions and Results

| Cook number | A3474 | A3475 | A3476 | A3477 |
|------------------------------------|------------|------------|------------|------------|
| Simulation type | Batch | Batch | Batch | Batch |
| Lab digester type | Circulated | Circulated | Circulated | Circulated |
| <u>Furnish:</u> | | | | |
| Furnish | Aspen | Aspen | Poplar | Poplar |
| Location of supply | Sept Lake | Meadow Ck | Northwest | Walker |
| Furnish, o.d. solids, % | 62.3 | 57.8 | 50.6 | 51.2 |
| O.D. charge wt, g | 3000 | 2800 | 3000 | 3000 |
| <u>Presteam:</u> | | | | |
| Temperature, °C | 100 | 100 | 100 | 100 |
| Time, min | 10 | 10 | 10 | 10 |
| <u>Cooking:</u> | | | | |
| Total time, min | 112 | 112 | 120 | 118 |
| Max temperature, °C | 160 | 160 | 160 | 160 |
| Time to max, min | 60 | 60 | 60 | 60 |
| Time at max, min | 52 | 52 | 60 | 58 |
| AA on wood, % Na ₂ O | 15 | 15 | 16.5 | 18 |
| L/W ratio (total liquid) | 4 | 4 | 4 | 4 |
| Sulfidity, % on AA | 30 | 30 | 30 | 30 |
| <u>End of cook:</u> | | | | |
| Residual EA, g/L Na ₂ O | 5.9 | 5.7 | 7.8 | 9.6 |
| Residual AA, g/L Na ₂ O | 11.0 | 10.9 | 13.8 | 16.1 |
| H - Factor | 425 | 420 | 469 | 453 |
| <u>Unbleached pulp:</u> | | | | |
| Total yield, % | 58.4 | 59.1 | 58.4 | 52.2 |
| Total rejects (+0.012"), % | 0.41 | 0.77 | 0.34 | 0.14 |
| Screened yield, % | 58.0 | 58.3 | 58.1 | 52.1 |
| Kappa, unscreened | 15.3 | 17.3 | 16.7 | 18.6 |
| Kappa, screened | 15.2 | 16.6 | 16.6 | 17.7 |
| Viscosity (0.5% CED), cp | 92.1 | 100.5 | 46.3 | 57.4 |
| DCM extractives, % | 0.95 | 0.66 | 0.86 | 0.76 |

Table 4

Alberta-Pacific & CFS - L50049 (LG)

Bleaching with ODEpoD Sequence

| Sample No. | A3474 | A3475 | A3476 | A3477 |
|--|----------------|--------------|-----------|----------|
| Wood furnish | Aspen | Aspen | Poplar | Poplar |
| Location of supply | September Lake | Meadow Creek | Northwest | Walker |
| Kappa | 15.2 | 16.6 | 16.6 | 17.7 |
| Viscosity, mPa.s | 92.1 | 100.5 | 46.3 | 57.4 |
| <u>O-Stage: 60 min, 100°C, 11% cons.</u> | | | | |
| NaOH, % | 2.3 | 2.6 | 2.7 | 3.1 |
| MgSO ₄ , % | 0.5 | 0.5 | 0.5 | 0.5 |
| O ₂ pressure, psig | 100-->58 | 100-->58 | 100-->58 | 100-->58 |
| O ₂ time, min | 60 | 60 | 60 | 60 |
| Final pH | 12.3 | 12.3 | 12.5 | 12.5 |
| Kappa No. | 9.3 | 9.8 | 9.7 | 10.2 |
| Viscosity, mPa.s | 40.9 | 45.3 | 36.3 | 31.6 |
| Stage yield, % | 98.1 | 96.8 | 97.0 | 95.5 |
| <u>D100-Stage: 60 min, 60°C, 10% cons.</u> | | | | |
| Kappa factor | 0.22 | 0.22 | 0.22 | 0.22 |
| ClO ₂ , as Cl ₂ , % | 2.05 | 2.16 | 2.13 | 2.24 |
| H ₂ SO ₄ , % | 0.65 | 0.65 | 0.7 | 0.7 |
| Final pH | 2.2 | 2.4 | 2.6 | 2.7 |
| Residual, g/L avail. Cl ₂ | <0.01 | <0.01 | <0.01 | <0.01 |
| <u>Epo-Stage: 90 min, 75°C, 10% cons.</u> | | | | |
| NaOH, % | 0.85 | 0.85 | 0.8 | 0.8 |
| H ₂ O ₂ , % | 0.33 | 0.33 | 0.33 | 0.33 |
| O ₂ pressure, psig | 46-->0 | 46-->0 | 46-->0 | 46-->0 |
| O ₂ time, min | 20 | 20 | 20 | 20 |
| Final pH | 10.7 | 10.8 | 10.7 | 10.7 |
| Residual H ₂ O ₂ , % | <0.01 | 0.01 | 0.02 | 0.03 |
| K No. (25 mL) | 2.2 | 2.2 | 2.7 | 3.0 |
| Kappa No. | 3.0 | 3.0 | 3.4 | 3.7 |
| Viscosity, mPa.s | 33.8 | 37.6 | 29.4 | 24.7 |
| ISO brightness, % | 88.0 | 88.4 | 88.9 | 89.2 |
| Stage yield, % | ~100 | 98.0 | 96.1 | 98.9 |
| Yield on brownstock, % | 98.1 | 94.9 | 93.2 | 94.4 |

Table 4

Alberta-Pacific & CFS - L50049 (LG)

Bleaching with ODEpoD Sequence

| Sample No. | A3474 | A3475 | A3476 | A3477 |
|--|-------------------|-----------------|-----------|--------|
| Wood furnish | Aspen | Aspen | Poplar | Poplar |
| Location of supply | September Lake | Meadow Creek | Northwest | Walker |
| <hr/> | | | | |
| <u>D-Stage: 160 min, 75°C, 10% cons.</u> | | | | |
| ClO ₂ , as ClO ₂ , % | 0.1 | 0.1 | 0.1 | 0.1 |
| H ₂ SO ₄ , % | 0.15 | 0.15 | 0.15 | 0.15 |
| Final pH | 4.4 | 4.4 | 4.5 | 4.5 |
| Residual ClO ₂ , % | trace | trace | trace | trace |
| Viscosity, mPa.s | 31.5 | 34.1 | 28.2 | 24.2 |
| ISO brightness, % | 90.9 | 90.6 | 91.3 | 91.2 |
| DCM extractives, % | 0.55 | 0.53 | 0.66 | 0.65 |

Table 5
 Alberta-Pacific & CFS - L50049
Unbleached Pulp Strength (CPPA Methods)

| <u>Sample</u> | <u>CSF mLs</u> | <u>Burst factor</u> | <u>Tear factor</u> | <u>Tensile km</u> | <u>Bulk cc/g</u> |
|--------------------------------------|----------------------|-------------------------|------------------------|-----------------------|----------------------|
| <u>Strength at 0 PFI revolutions</u> | | | | | |
| Meadow Creek aspen | 673 | 14 | 38 | 4.8 | 1.89 |
| Northwest poplar | 628 | 23 | 60 | 5.7 | 1.70 |
| Mill aspen (B1458) | 589 | 24 | 63 | 5.6 | 1.54 |
| <u>Sample</u> | <u>PFI rev's</u> | <u>Burst factor</u> | <u>Tear factor</u> | <u>Tensile km</u> | <u>Bulk cc/g</u> |
| <u>Strength at 600 mLs CSF</u> | | | | | |
| Meadow Creek aspen | 400 | 28 | 60 | 7.3 | 1.61 |
| Northwest poplar | 100 | 29 | 65 | 6.4 | 1.65 |
| <u>Strength at 500 mLs CSF</u> | | | | | |
| Meadow Creek aspen | 1800 | 42 | 68 | 9.3 | 1.41 |
| Northwest poplar | 800 | 46 | 79 | 8.3 | 1.48 |
| Mill aspen (B1458) | 300 | 36 | 72 | 7.0 | 1.45 |
| <u>Strength at 400 mLs CSF</u> | | | | | |
| Meadow Creek aspen | 4100 | 50 | 70 | 9.9 | 1.33 |
| Northwest poplar | 2500 | 56 | 85 | 9.3 | 1.42 |
| Mill aspen (B1458) | 1000 | 50 | 71 | 8.7 | 1.28 |
| <u>Strength at 300 mLs CSF</u> | | | | | |
| Meadow Creek aspen | 7100 | 53 | 71 | 10.1 | 1.30 |
| Northwest poplar | 5900 | 61 | 86 | 9.8 | 1.38 |
| Mill aspen (B1458) | 2000 | 59 | 70 | 9.5 | 1.25 |

Table 6
 Alberta-Pacific & CFS - L50049
Bleached Pulp Strength (CPPA Methods)

| Sample | CSF mLs | Burst factor | Tear factor | Tensile km | Bulk cc/g | Opacity % |
|--------------------------------------|--------------|-----------------|----------------|---------------|--------------|--------------|
| <u>Strength at 0 PFI revolutions</u> | | | | | | |
| September Lake aspen | 560 | 20 | 57 | 4.7 | 1.63 | 72 |
| Meadow Creek aspen | 568 | 20 | 53 | 4.6 | 1.64 | 71 |
| Northwest poplar | 556 | 24 | 59 | 4.7 | 1.59 | 75 |
| Walker poplar | 500 | 29 | 64 | 6.0 | 1.50 | 76 |
| Mill aspen (B1458-2) | 542 | 18 | 58 | 2.8 | 1.60 | 74 |
| Al-Pac average | 504 | 11 | 35 | 2.7 | 1.54 | 78 |
| Sample | PFI rev's | Burst factor | Tear factor | Tensile km | Bulk cc/g | Opacity % |
| <u>Strength at 500 mLs CSF</u> | | | | | | |
| September Lake aspen | 150 | 26 | 59 | 5.7 | 1.54 | 70 |
| Meadow Creek aspen | 200 | 29 | 58 | 5.4 | 1.54 | 69 |
| Northwest poplar | 150 | 32 | 71 | 5.6 | 1.48 | 71 |
| Walker poplar | 0 | 29 | 64 | 6.0 | 1.50 | 76 |
| Mill aspen (B1458-2) | 400 | 24 | 69 | 3.8 | 1.54 | 72 |
| Al-Pac average | 0 | 11 | 35 | 2.7 | 1.54 | 78 |
| <u>Strength at 400 mLs CSF</u> | | | | | | |
| September Lake aspen | 1500 | 35 | 62 | 7.1 | 1.44 | 68 |
| Meadow Creek aspen | 2000 | 39 | 69 | 6.9 | 1.43 | 66 |
| Northwest poplar | 1300 | 47 | 83 | 7.2 | 1.34 | 67 |
| Walker poplar | 300 | 43 | 73 | 7.6 | 1.38 | 72 |
| Mill aspen (B1458-2) | 1300 | 38 | 86 | 5.7 | 1.39 | 69 |
| Al-Pac average | 900 | 28 | 66 | 6.5 | 1.39 | 75 |
| <u>Strength at 300 mLs CSF</u> | | | | | | |
| September Lake aspen | 3300 | 43 | 64 | 7.9 | 1.39 | 67 |
| Meadow Creek aspen | 4200 | 48 | 80 | 8.3 | 1.34 | 64 |
| Northwest poplar | 3000 | 58 | 88 | 8.8 | 1.27 | 66 |
| Walker poplar | 2000 | 58 | 75 | 9.6 | 1.34 | 71 |
| Mill aspen (B1458-2) | 2300 | 52 | 84 | 7.0 | 1.28 | 66 |
| Al-Pac average | 2450 | 41 | 75 | 7.0 | 1.28 | 72 |

Burst vs CSF

Unbleached Pulps

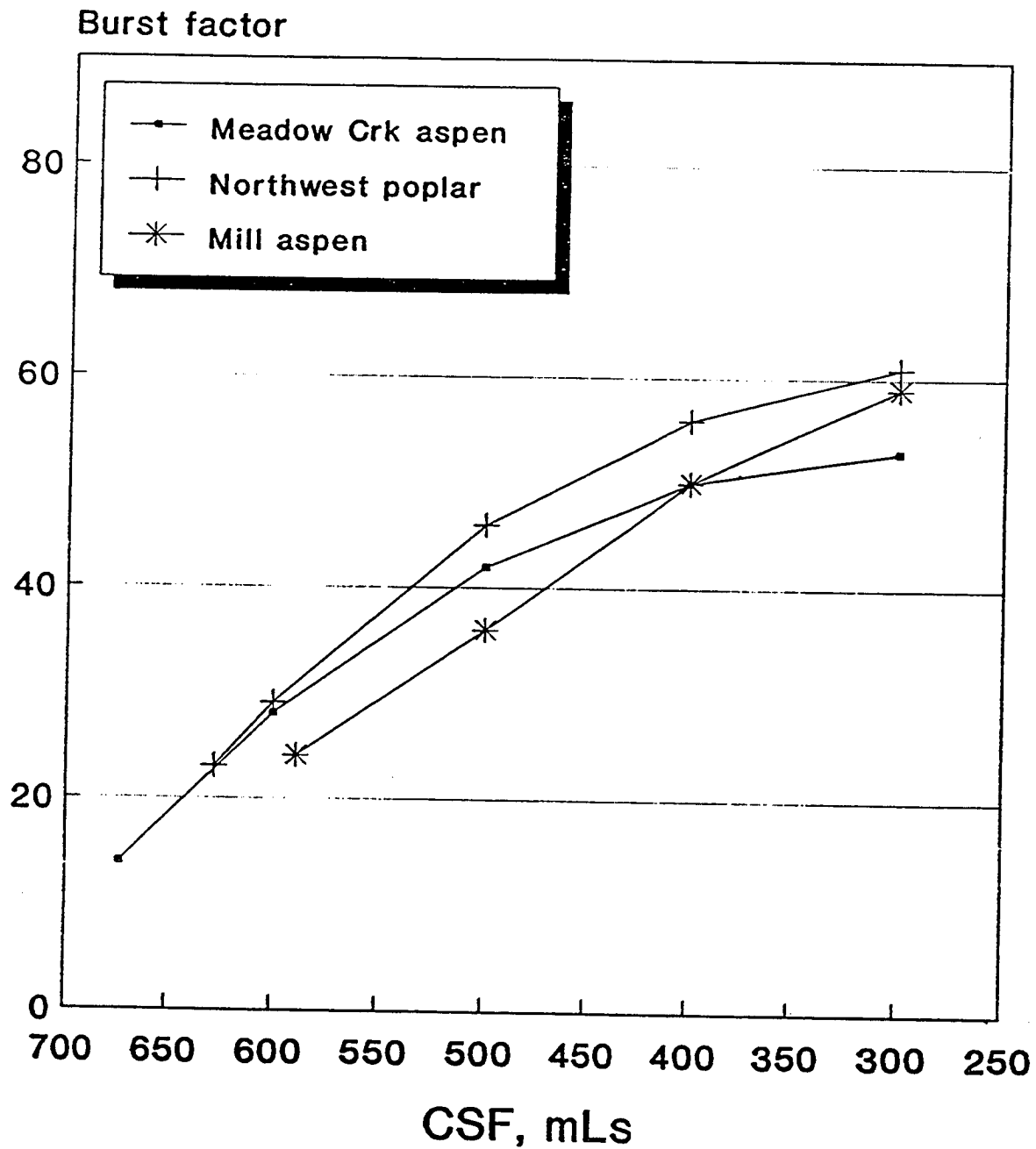


Figure 1

Tear vs CSF Unbleached Pulps

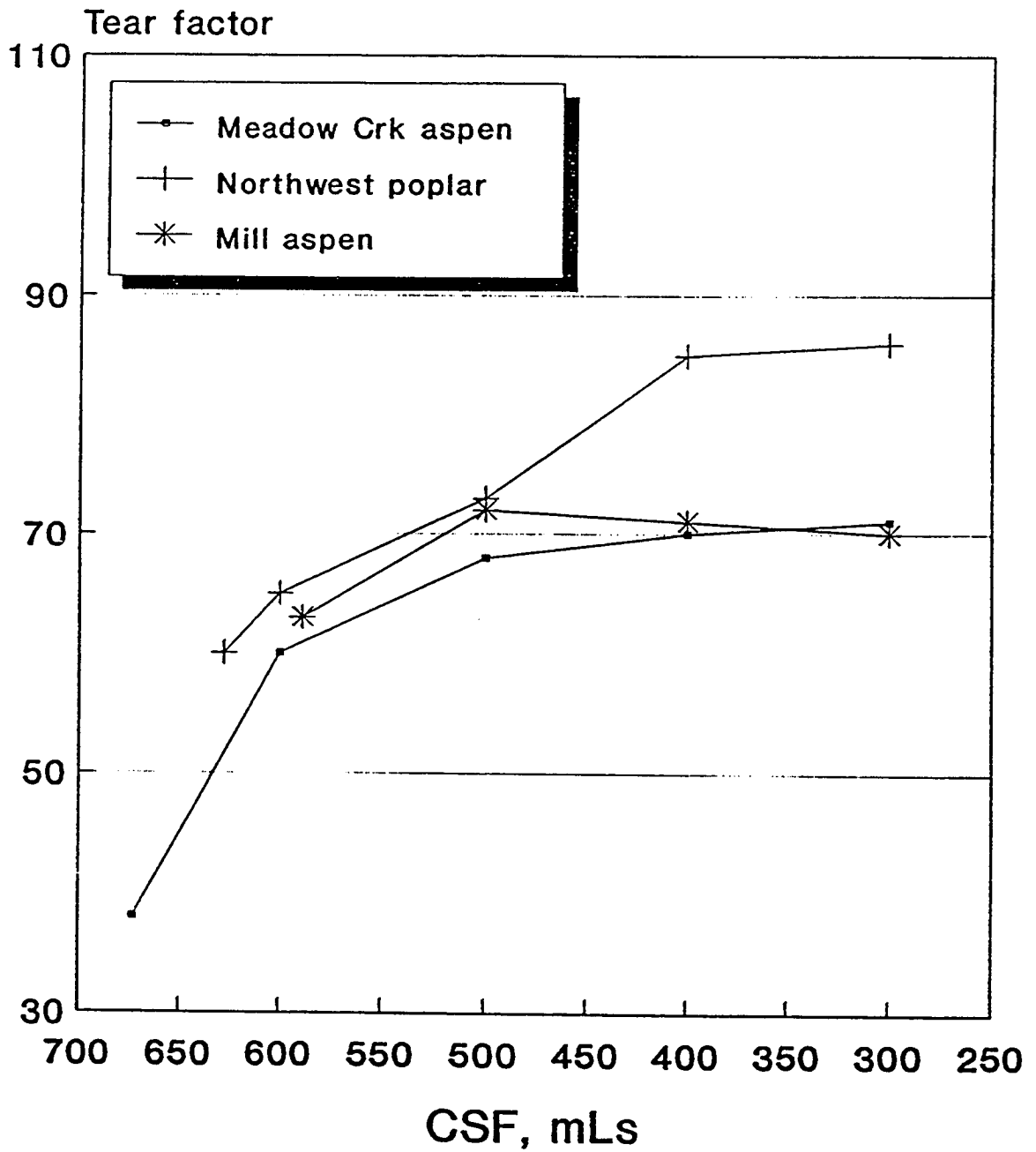


Figure 2

Tensile vs CSF Unbleached Pulps

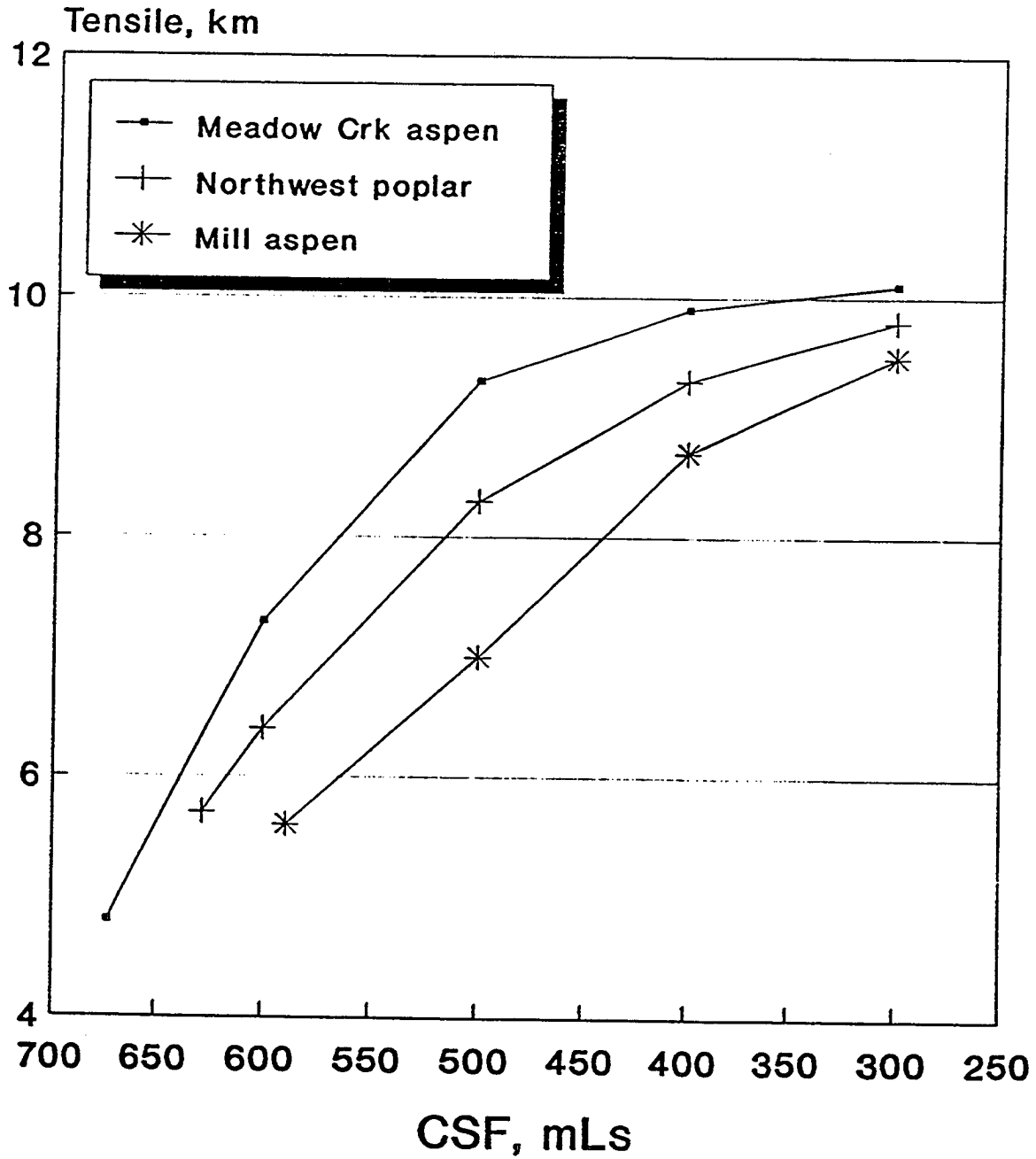


Figure 3

Bulk vs CSF Unbleached Pulps

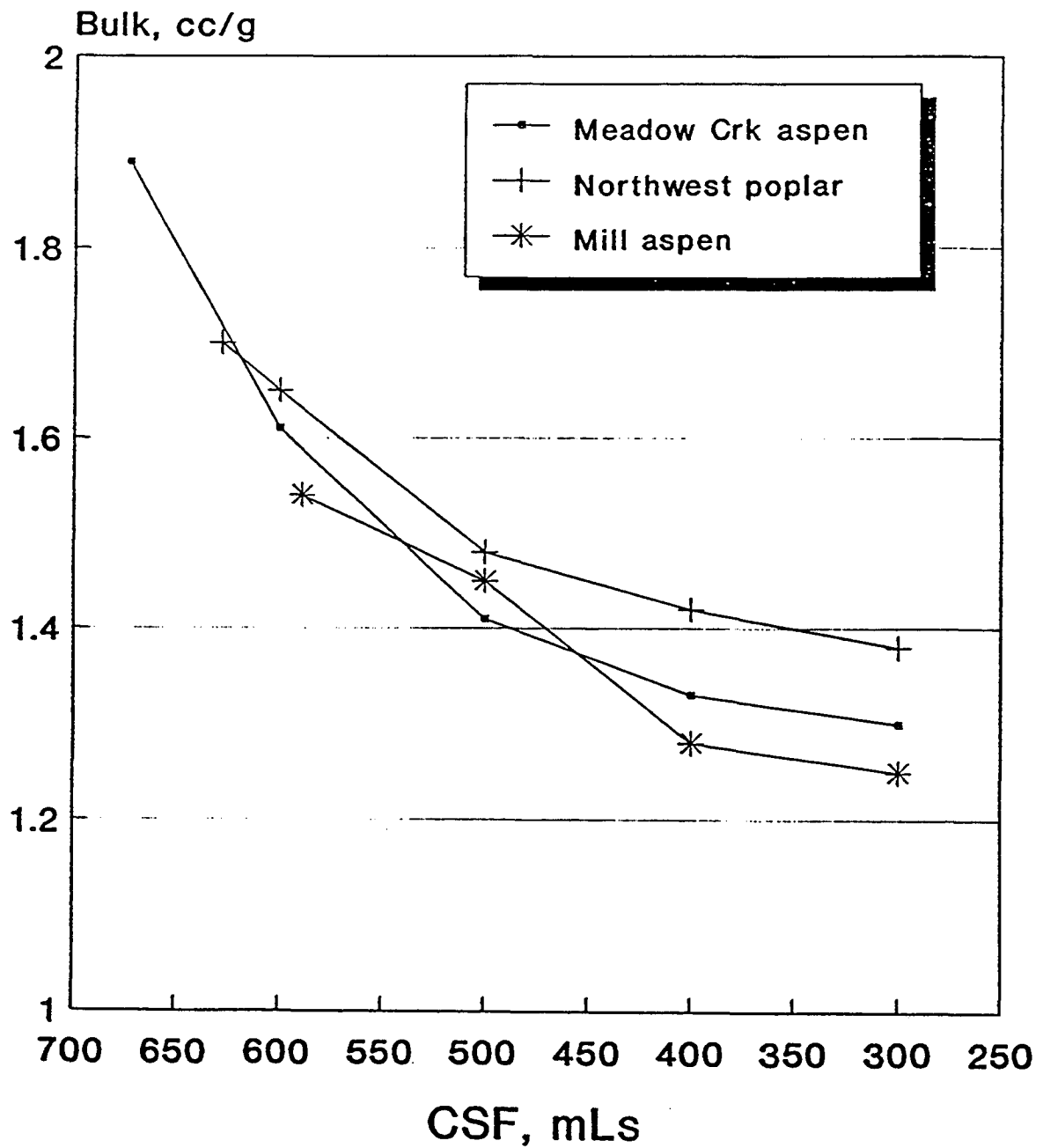


Figure 4

Burst vs CSF Bleached Pulps

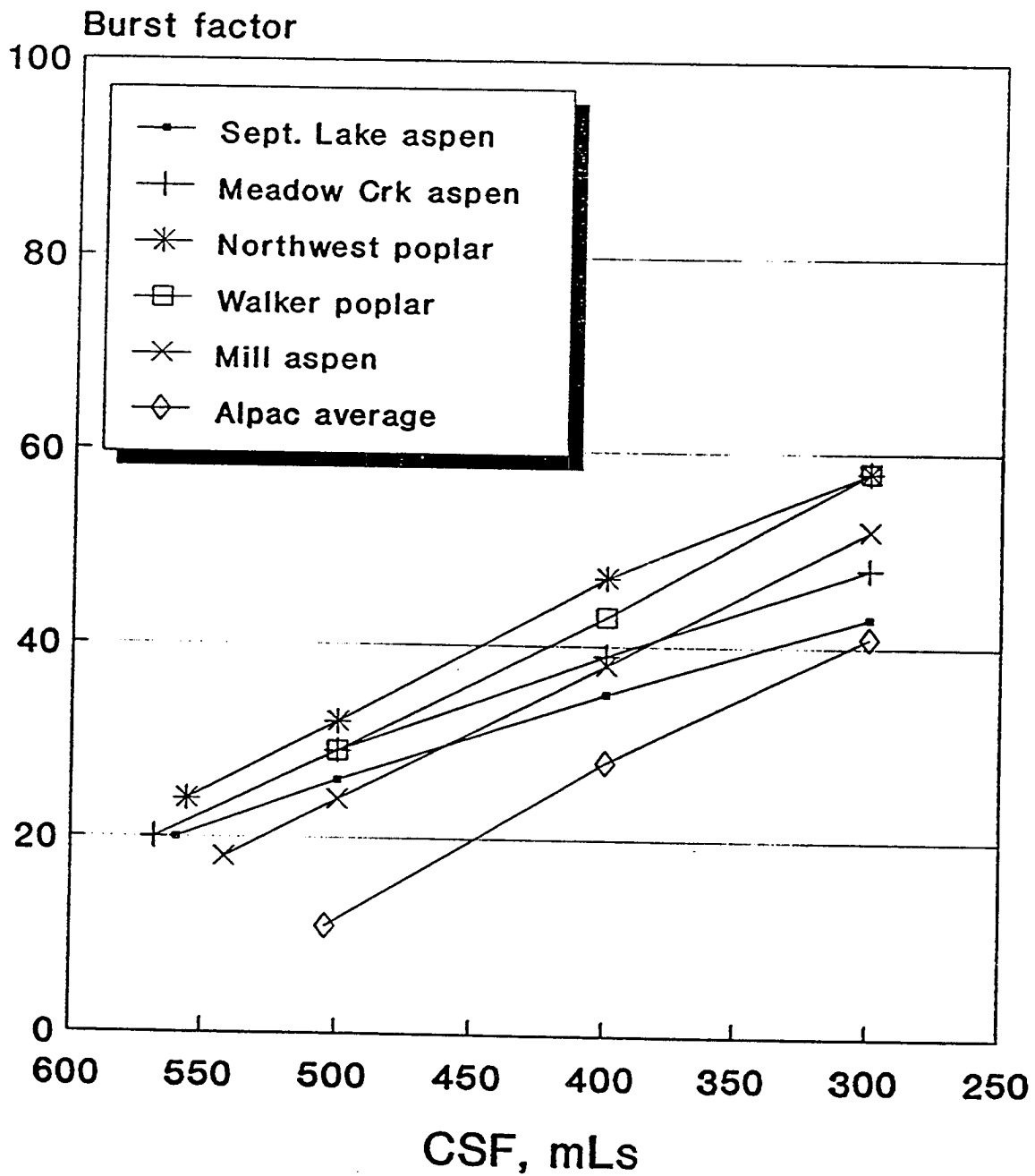


Figure 5

Tear vs CSF Bleached Pulps

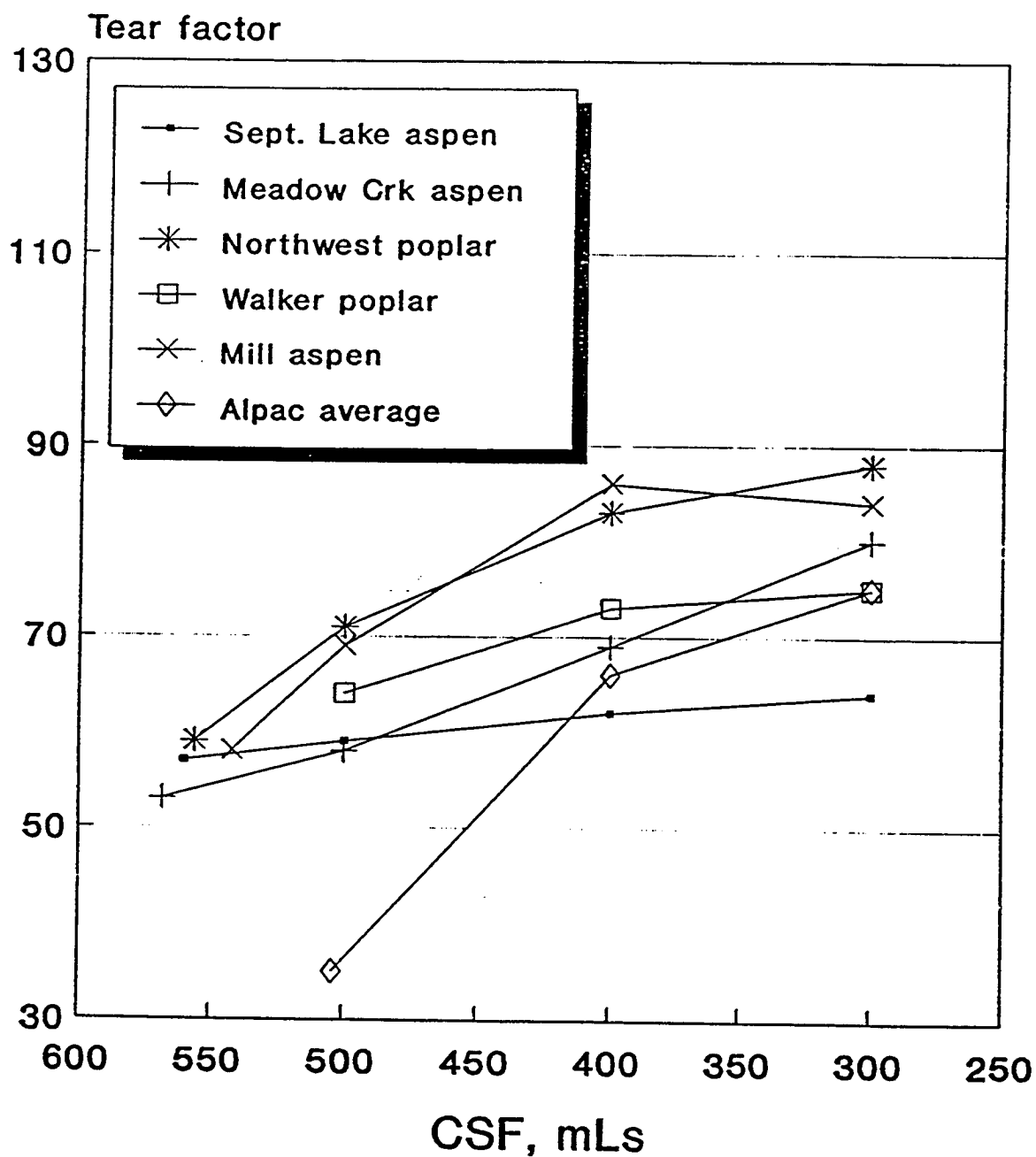


Figure 6

Tensile vs CSF Bleached Pulps

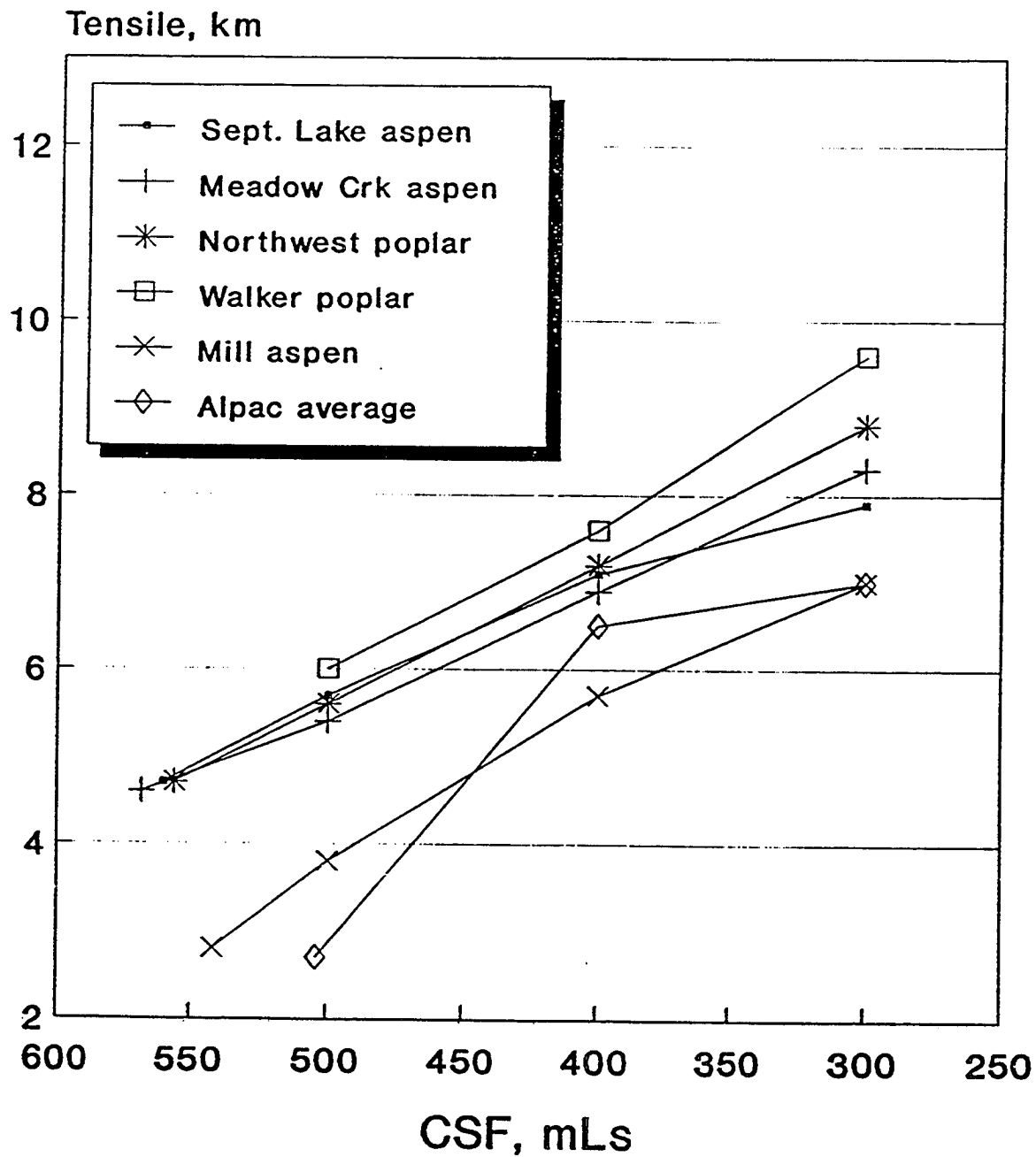


Figure 7

Bulk vs CSF Bleached Pulps

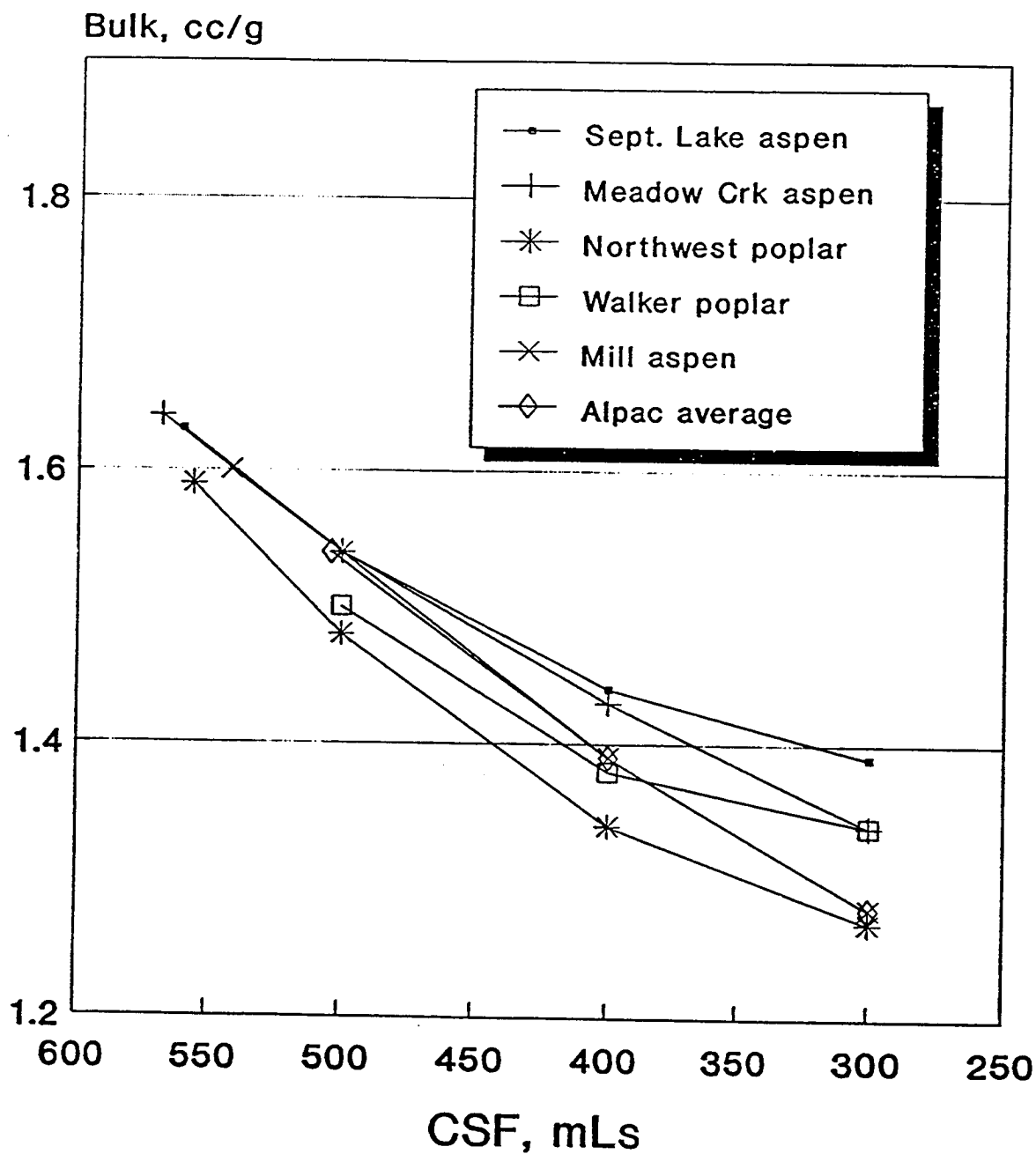


Figure 8

Opacity vs CSF

Bleached Pulps

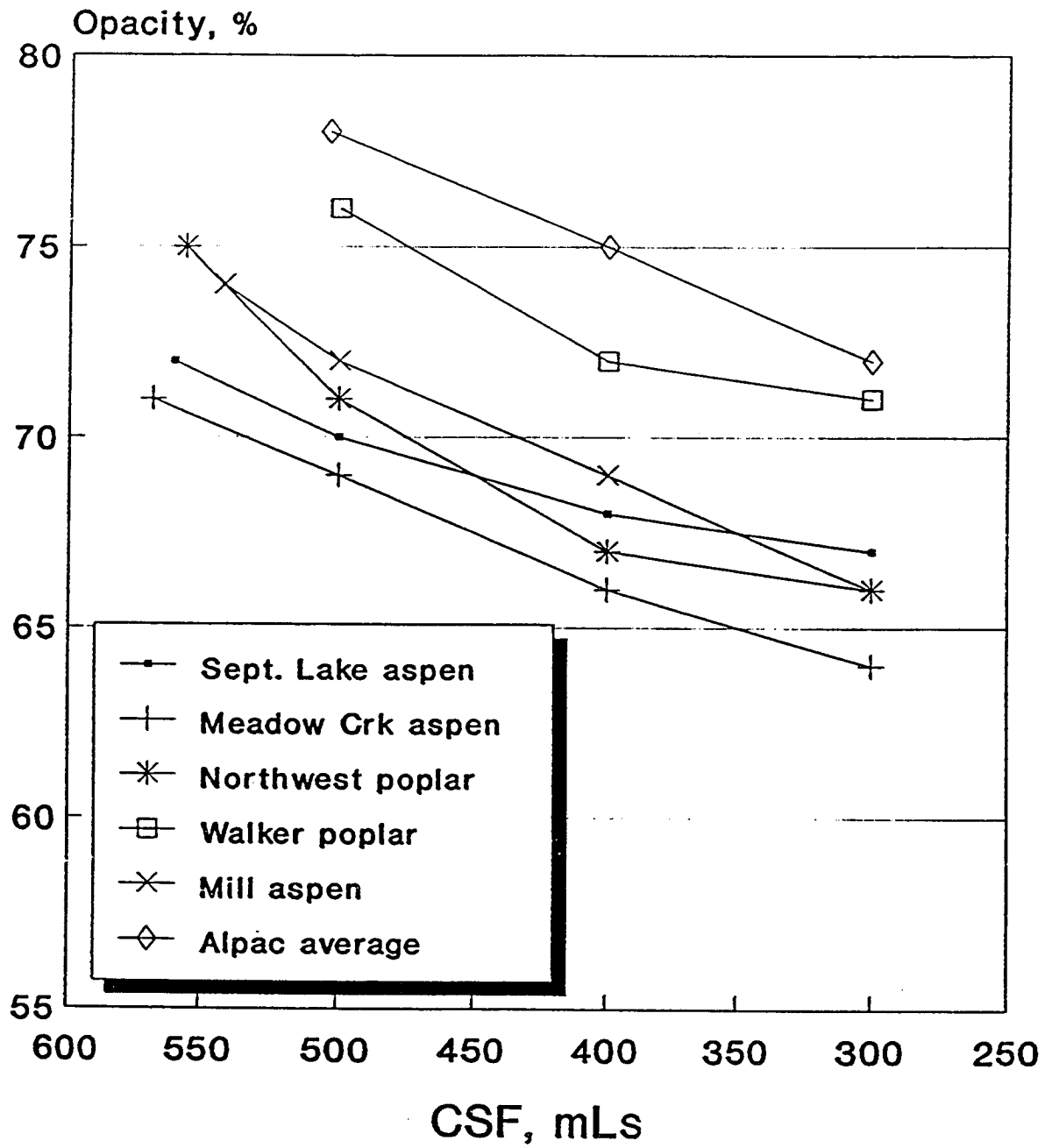


Figure 9

APPENDIX

Appendix Table 1
 Alberta-Pacific & CFS - L50049
Log Dimensions

September Lake Aspen

| Log # | Length, cm | <u>Diameter, cm</u> |
|---------|------------|---------------------|
| | | With bark |
| 1 | 152 | 21.0 |
| 2 | 145 | 19.2 |
| 3 | 141 | 19.0 |
| 4 | 152 | 21.2 |
| 5 | <u>156</u> | <u>18.8</u> |
| Average | 149 | 19.8 |

Meadow Creek Aspen

| Log # | Length, cm | <u>Diameter, cm</u> |
|---------|------------|---------------------|
| | | With bark |
| 1 | 147 | 21.6 |
| 2 | 136 | 19.8 |
| 3 | 143 | 19.4 |
| 4 | 151 | 18.8 |
| 5 | <u>148</u> | <u>20.8</u> |
| Average | 145 | 20.1 |

Northwest Poplar

| Log # | Length, cm | <u>Diameter, cm</u> |
|---------|------------|---------------------|
| | | With bark |
| 1 | 154 | 18.2 |
| 2 | 137 | 36.0 |
| 3 | 152 | 25.5 |
| 4 | 147 | 24.2 |
| 5 | <u>141</u> | <u>22.0</u> |
| Average | 146 | 25.2 |

Walker Poplar

| Log # | Length, cm | <u>Diameter, cm</u> |
|---------|------------|---------------------|
| | | With bark |
| 1 | 144 | 18.6 |
| 2 | 140 | 22.2 |
| 3 | 137 | 27.1 |
| 4 | 149 | 23.6 |
| 5 | <u>144</u> | <u>32.5</u> |
| Average | 143 | 24.8 |

Appendix Table 2
 Alberta-Pacific & CFS - L50049
Green Bark Content

September Lake Aspen

| Log # | Green Weight (kg) | | | |
|-------|-------------------|------------|-----------------|------|
| | Log + Bark | Bark | | |
| 1 | 33.0 | 3.7 | | |
| 2 | 28.6 | 5.5 | | |
| 3 | 24.3 | 3.2 | | |
| 4 | 31.5 | 3.8 | | |
| 5 | <u>26.3</u> | <u>4.6</u> | Average Green | |
| Total | 143.7 | 20.8 | Bark Content, % | 14.5 |

Meadow Creek Aspen

| Log # | Green Weight (kg) | | | |
|-------|-------------------|------------|-----------------|------|
| | Log + Bark | Bark | | |
| 1 | 34.6 | 4.6 | | |
| 2 | 25.9 | 3.8 | | |
| 3 | 30.4 | 4.5 | | |
| 4 | 26.8 | 4.5 | | |
| 5 | <u>33.5</u> | <u>4.6</u> | Average Green | |
| Total | 151.2 | 22.0 | Bark Content, % | 14.6 |

Northwest Poplar

| Log # | Green Weight (kg) | | | |
|-------|-------------------|------------|-----------------|------|
| | Log + Bark | Bark | | |
| 1 | 33.5 | 5.3 | | |
| 2 | 56.3 | 7.2 | | |
| 3 | 49.0 | 7.3 | | |
| 4 | 42.5 | 6.8 | | |
| 5 | <u>43.7</u> | <u>6.0</u> | Average Green | |
| Total | 225.0 | 32.6 | Bark Content, % | 14.5 |

Walker Poplar

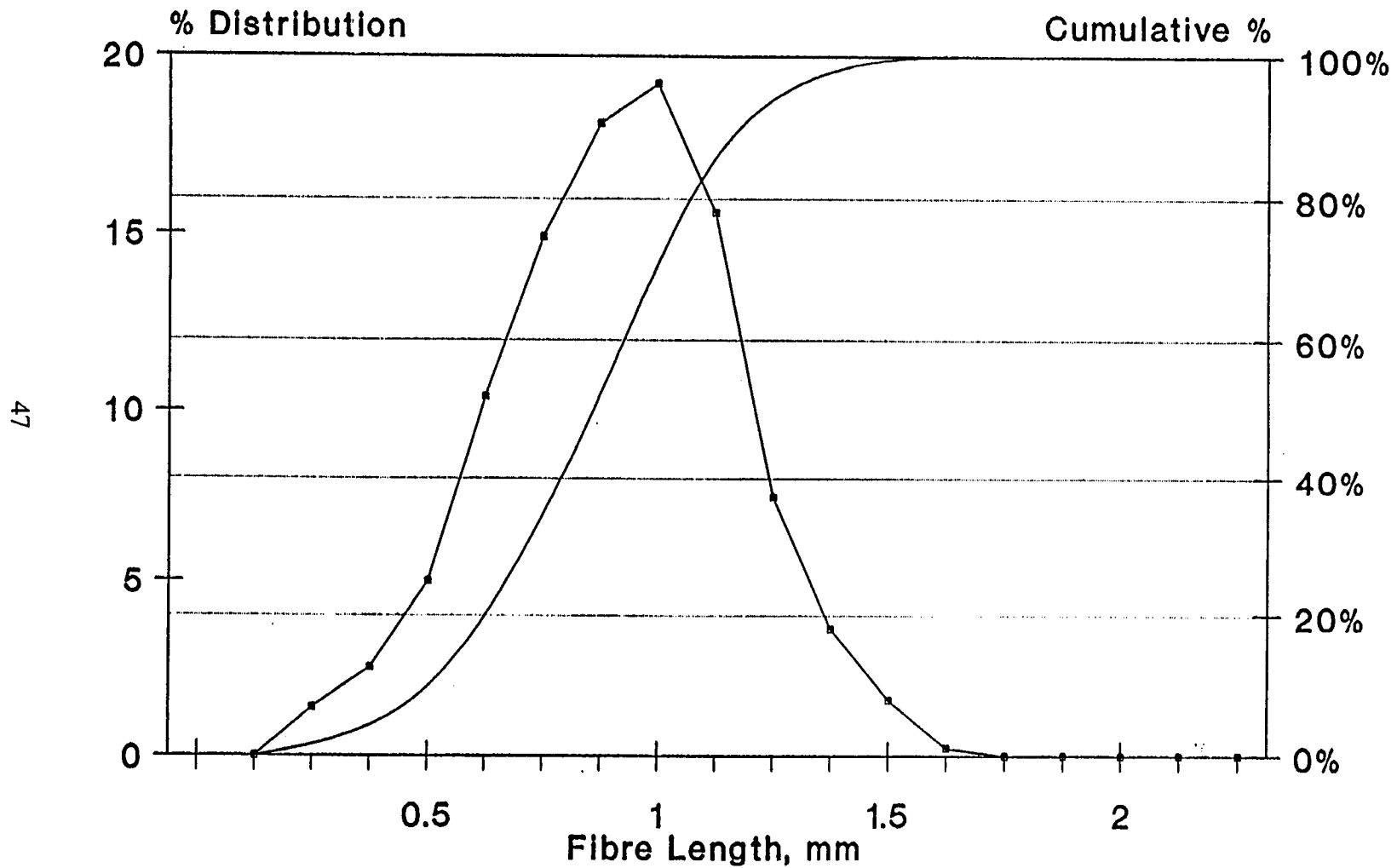
| Log # | Green Weight (kg) | | | |
|-------|-------------------|-------------|-----------------|------|
| | Log + Bark | Bark | | |
| 1 | 27.7 | 5.7 | | |
| 2 | 35.5 | 6.4 | | |
| 3 | 57.9 | 9.8 | | |
| 4 | 44.6 | 7.8 | | |
| 5 | <u>77.5</u> | <u>11.6</u> | Average Green | |
| Total | 243.2 | 41.3 | Bark Content, % | 17.0 |

Appendix Table 3
 Alberta-Pacific & CFS - L50049 (LG)
Small D1-Stage Trials on Epo-Pulps from Table 4

| | | | | | | |
|---|----------------|--------------|-----------|-------|-------|-------|
| Sample No. | A3474 | A3475 | A3476 | | | |
| Wood furnish | Aspen | Aspen | Poplar | | | |
| Location of supply | September Lake | Meadow Creek | Northwest | | | |
| Kappa | 15.2 | 16.6 | 16.6 | | | |
| Viscosity, mPa.s | 92.1 | 100.5 | 46.3 | | | |
| <u>Epo-Stage: 90 min, 75°C, 10% cons.</u> | | | | | | |
| K No. (25 mL) | 2.2 | 2.2 | 2.7 | | | |
| Kappa No. | 3.0 | 3.0 | 3.4 | | | |
| ISO brightness, % | 88.0 | 88.4 | 88.9 | | | |
| <u>D-Stage: 160 min, 75°C, 10% cons.</u> | | | | | | |
| Sample No. | a | b | a | b | a | b |
| ClO2, as ClO2, % | 0.1 | 0.3 | 0.1 | 0.3 | 0.1 | 0.3 |
| H2SO4, % | 0.1 | 0.04 | 0.1 | 0.04 | 0.15 | 0.05 |
| Final pH | 4.7 | 4.3 | 4.6 | 4.2 | 4.4 | 4.3 |
| Residual ClO2, % | <0.01 | trace | <0.01 | trace | trace | trace |
| Viscosity, mPa.s | - | - | - | - | - | - |
| ISO brightness, % | 90.8 | 91.1 | 90.8 | 91.2 | 91.0 | 91.4 |

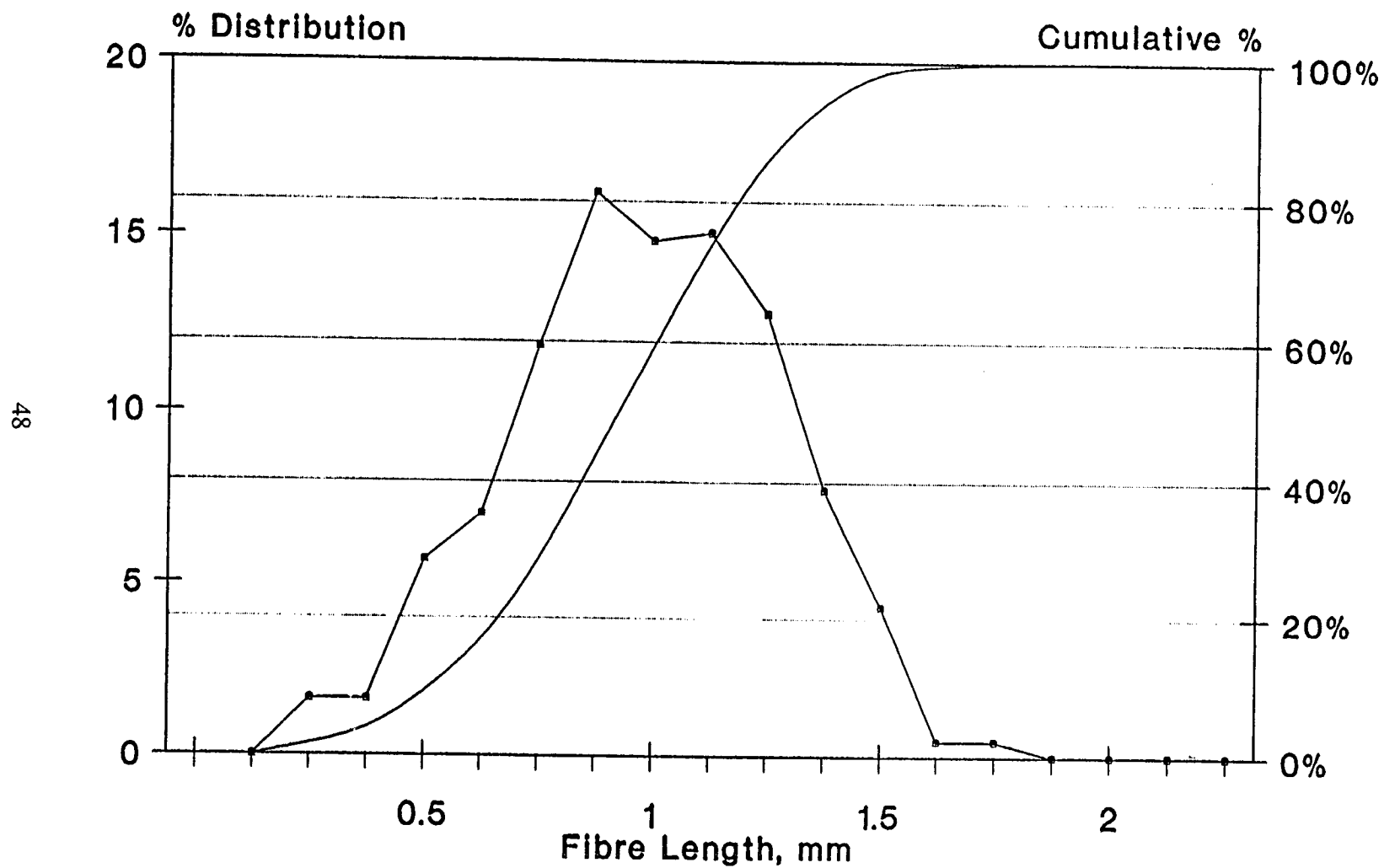
Cook A3474 - September Lake Aspen

Length weighted average = 0.98 mm



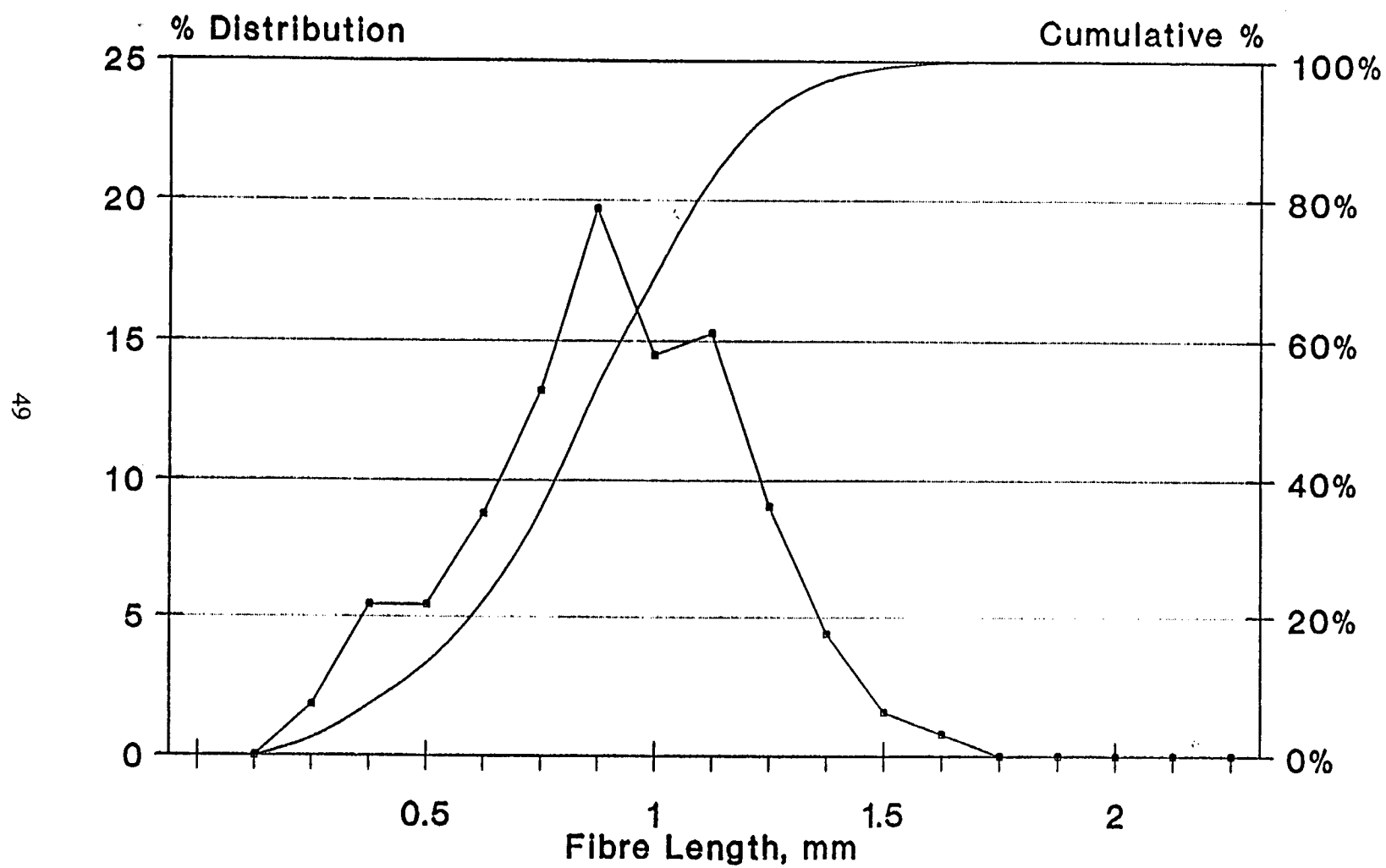
Cook A3475 - Meadow Creek Aspen

Length weighted average = 1.07 mm



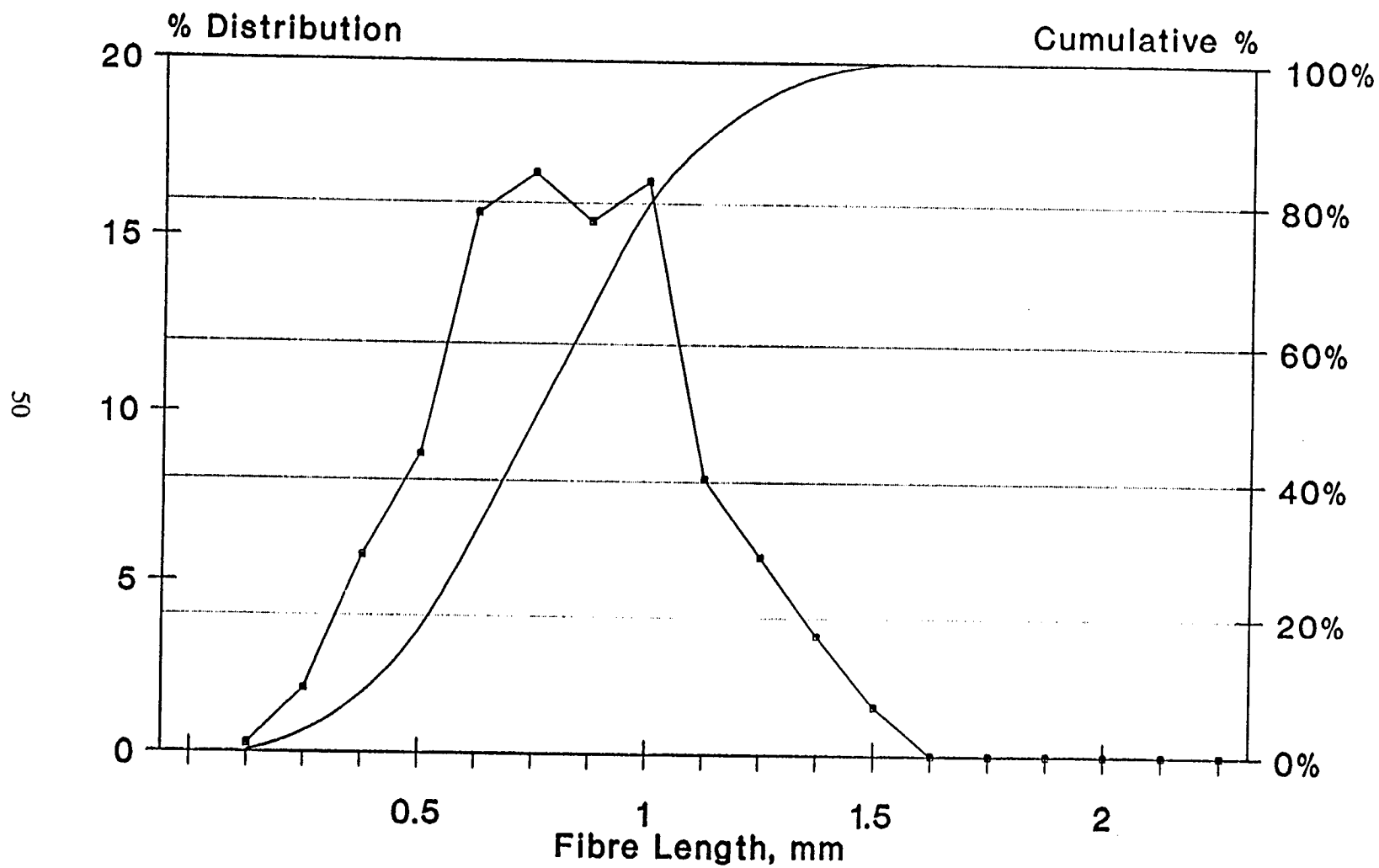
Cook A3476 - Northwest Poplar

Length weighted average = 0.99 mm



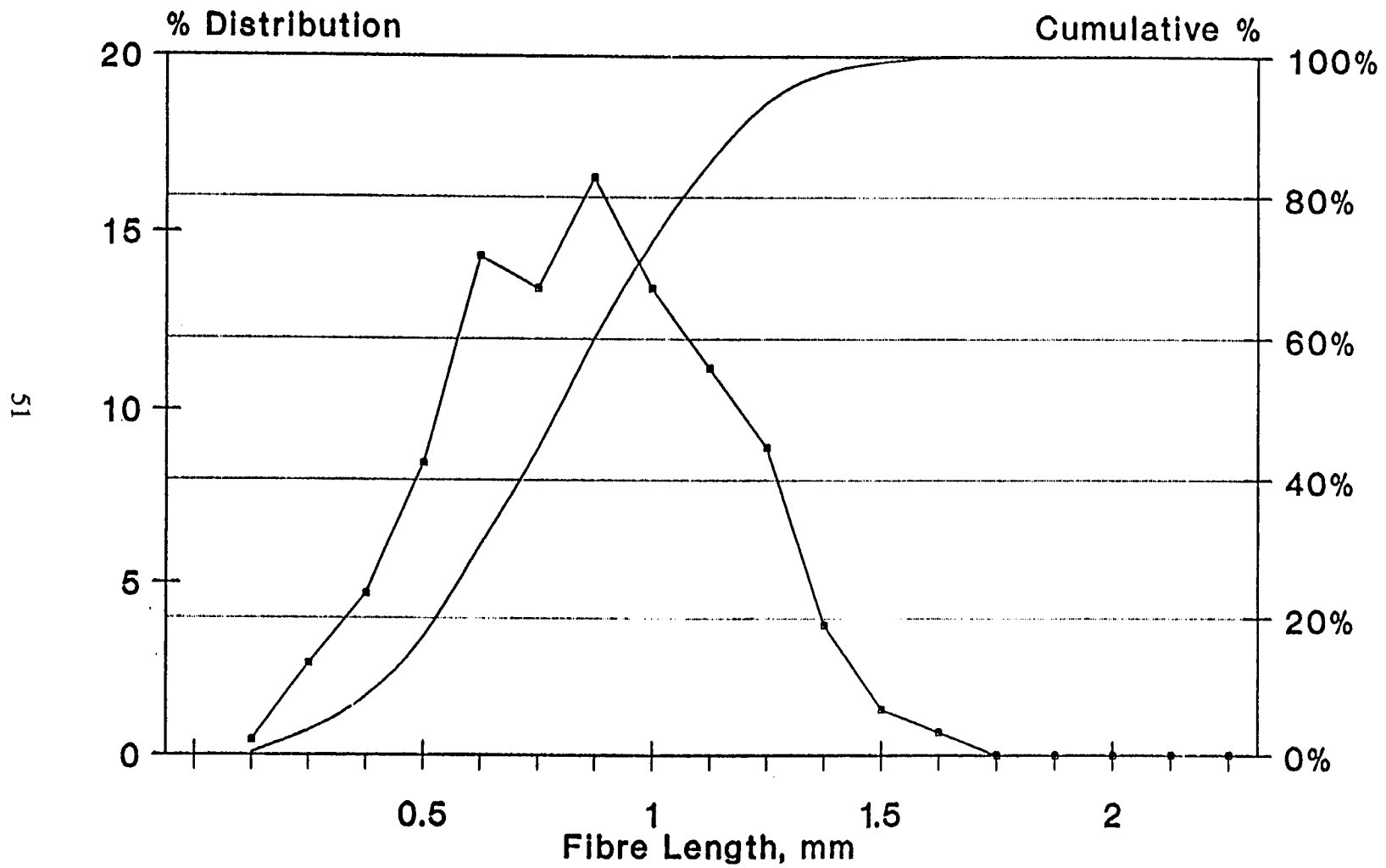
Cook A3477 - Walker Poplar

Length weighted average = 0.92 mm



Cook A3482 - Mill chips

Length weighted average = 0.96 mm



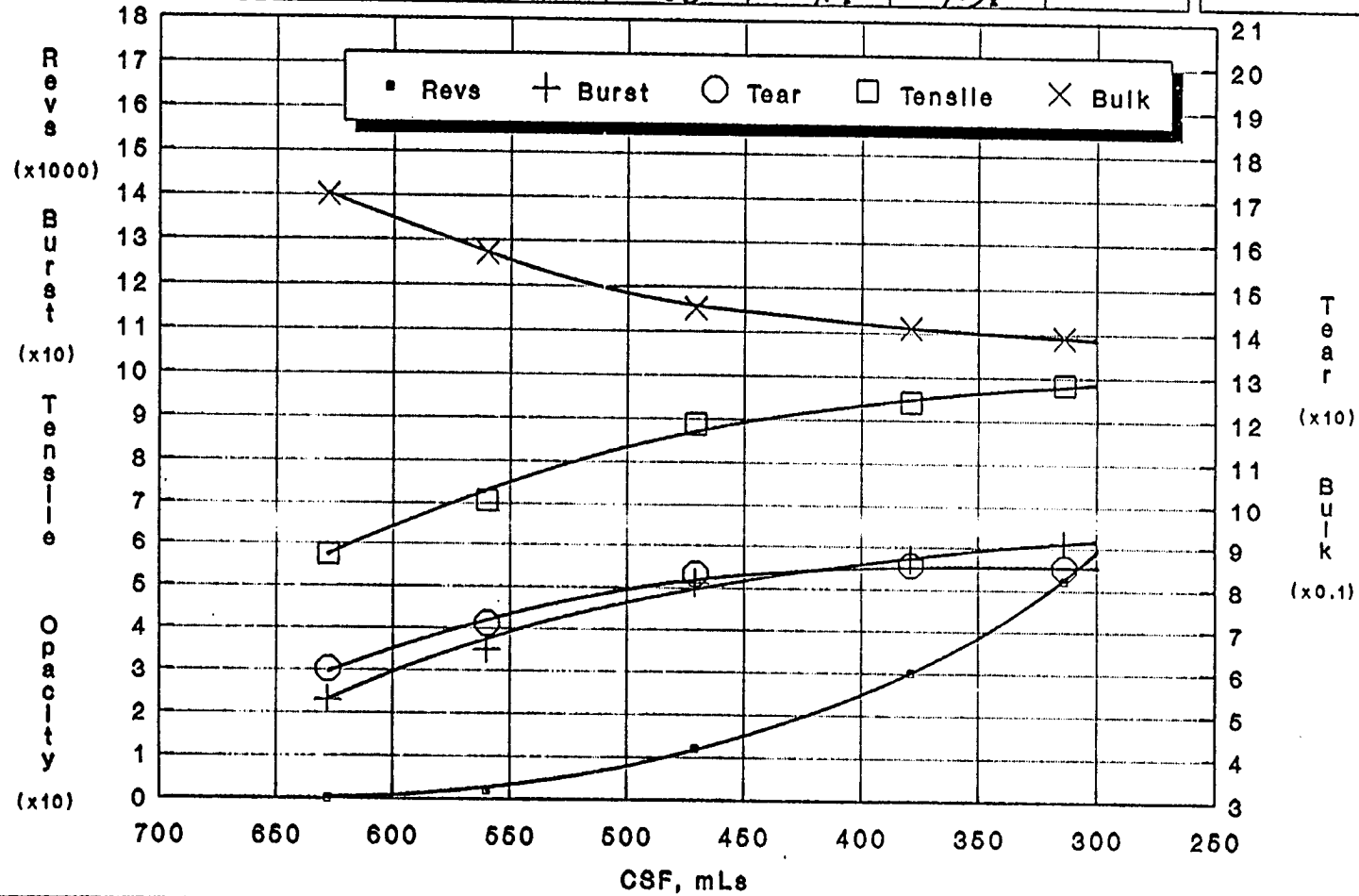
UNBL. POPLAR ALBERTA-PACIFIC FOREST INDUSTRIES W.O.#L50049

CPPA

A3476
UNBL. NORTHWEST
22/AUG/96 EP

| CSF mLs | PFI revs | BURST factor | TEAR factor | TENSILE km | BULK cc/g | OPACITY % |
|------------|-------------|-----------------|----------------|---------------|--------------|--------------|
| 628 | 0 | 23 | 60 | 5.7 | 1.70 | |
| 600 | 100 | 29 | 65 | 6.4 | 1.65 | |
| 600 | 800 | 46 | 79 | 8.3 | 1.48 | |
| 400 | 2500 | 56 | 85 | 9.3 | 1.42 | |
| 300 | 5900 | 61 | 86 | 9.8 | 1.38 | |

KAPPA NO.: 18.6
VISCOSITY: 46.3



UNBL. ASPEN

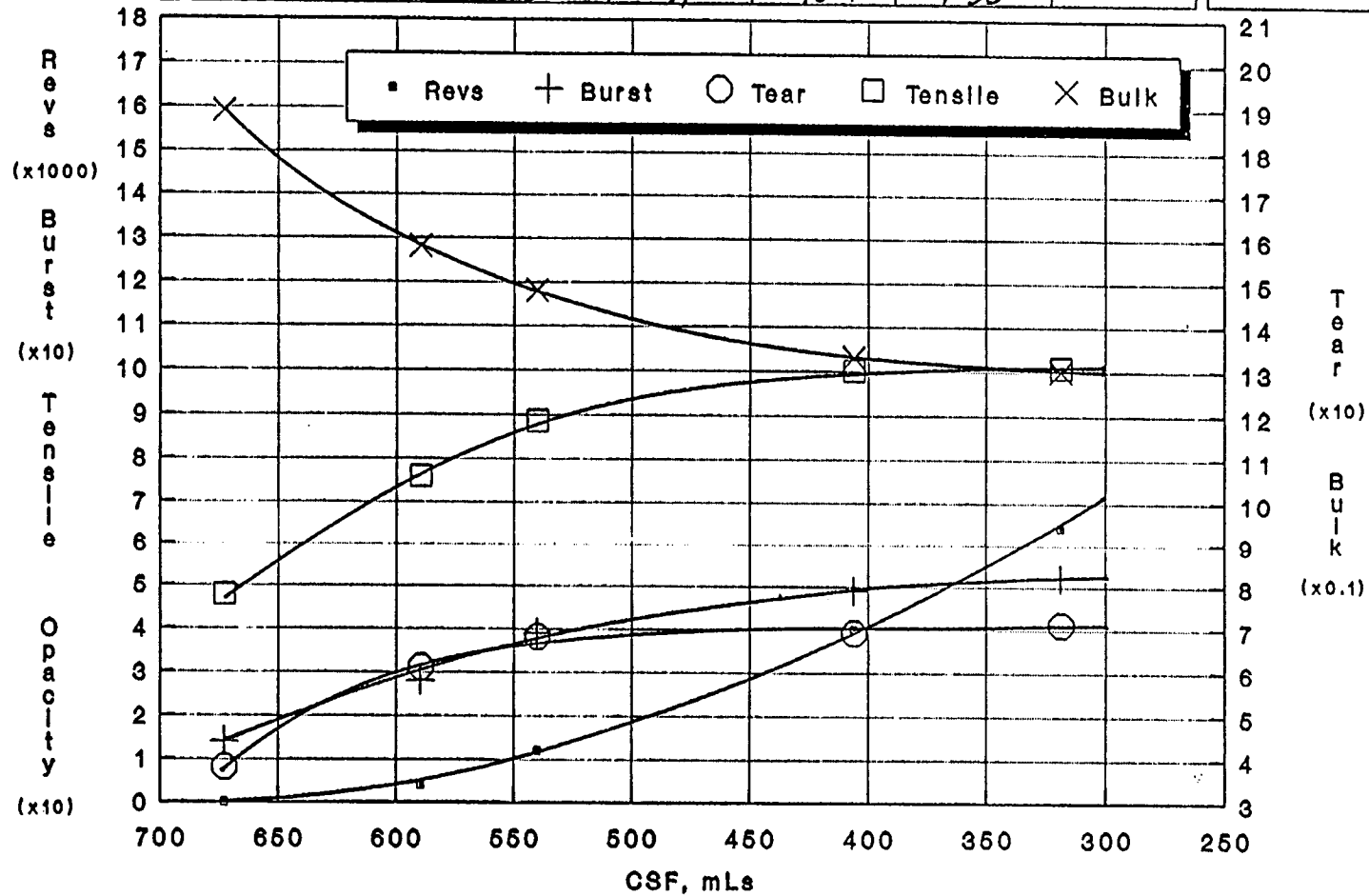
ALBERTA-PACIFIC FOREST INDUSTRIES W.O.#L50049

CPPA

A3475
UNBL. MEADOW
CREEK
22/AUG/95 EP

| CSF mLs | PFI revs | BURST factor | TEAR factor | TENSILE km | BULK oo/g | OPACITY % |
|------------|-------------|-----------------|----------------|---------------|--------------|--------------|
| 873 | 0 | 14 | 38 | 4.8 | 1.89 | |
| 800 | 400 | 28 | 60 | 7.3 | 1.61 | |
| 600 | 1800 | 42 | 68 | 9.3 | 1.41 | |
| 400 | 4100 | 50 | 70 | 9.9 | 1.33 | |
| 300 | 7100 | 53 | 71 | 10.1 | 1.30 | |

KAPPA NO.: 16.6
VISCOSITY: 100.6



BLEACHED

ALBERTA-PACIFIC FOREST INDUSTRIES W.O.#L50049

CPPA

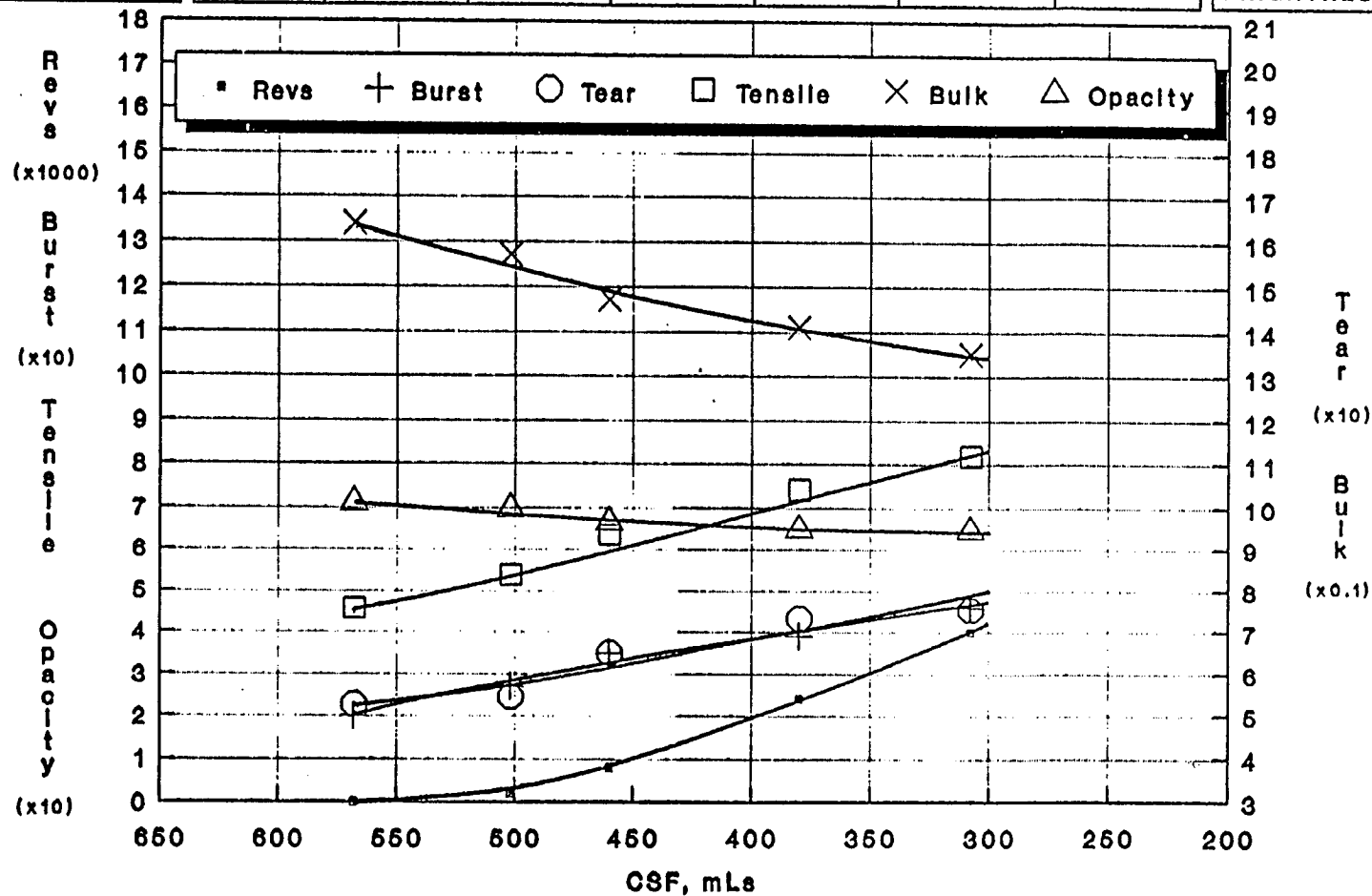
A3475-2-D1

MEADOW CREEK ASPEN

11/SEPT/96 VK

| OSF mLa | PFI revs | BURST factor | TEAR factor | TENSILE km | BULK cc/g | OPAQITY % |
|------------|-------------|-----------------|----------------|---------------|--------------|--------------|
| 668 | 0 | 20 | 53 | 4.6 | 1.64 | 71 |
| 600 | 200 | 29 | 58 | 5.4 | 1.54 | 69 |
| 400 | 2000 | 39 | 69 | 6.9 | 1.43 | 66 |
| 300 | 4200 | 48 | 80 | 8.3 | 1.34 | 64 |

VISCOSITY: 34.1
BRIGHTNESS: 90.6



BLEACHED

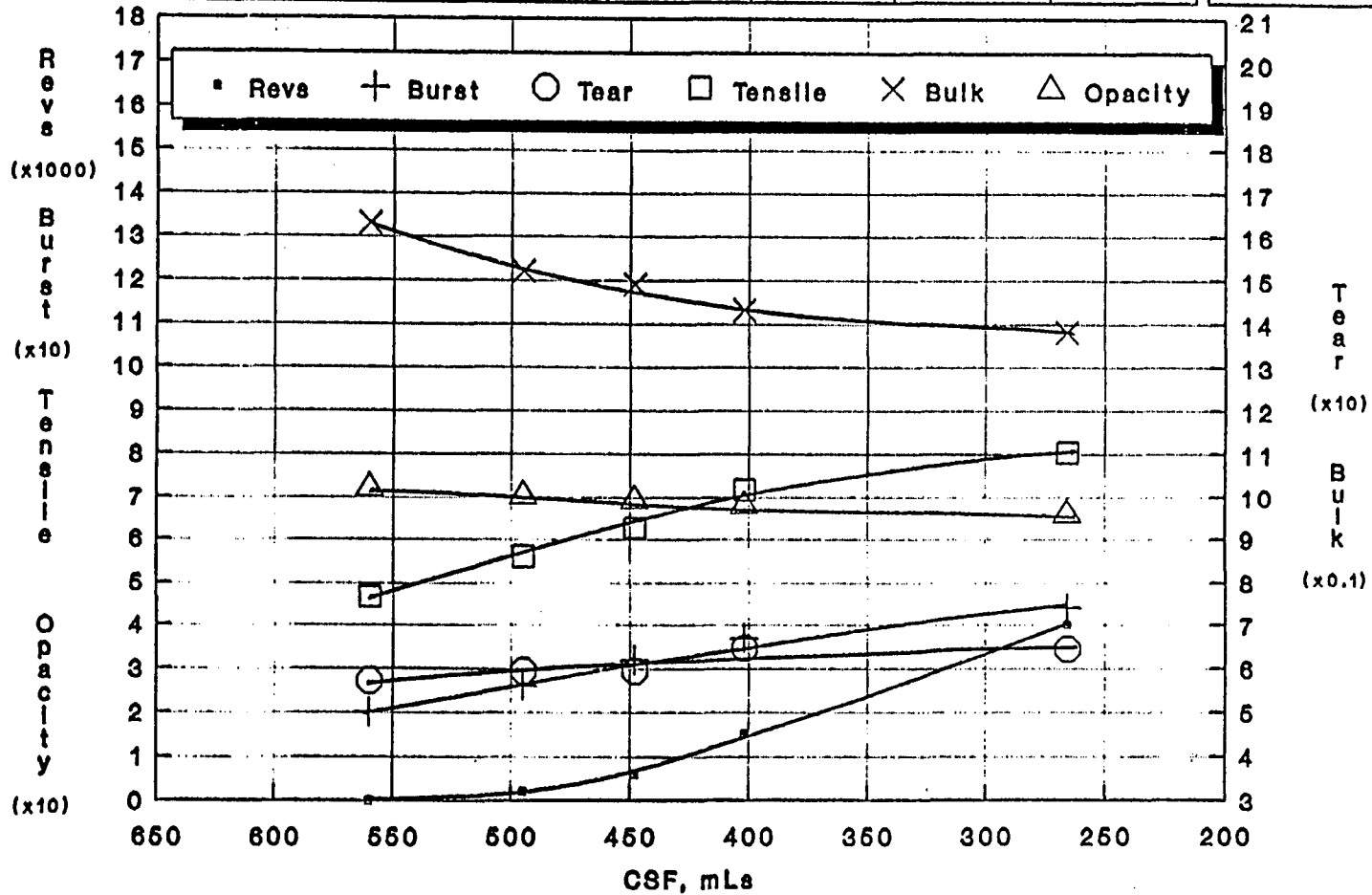
ALBERTA-PACIFIC FOREST INDUSTRIES W.O.#L50049

CPPA

A3474-1-D1
SEPT. LAKE ASPEN
11/8EPT/95 VK

| CSF mLs | PFI reva | BURST factor | TEAR factor | TENSILE km | BULK cc/g | OPAQITY % |
|------------|-------------|-----------------|----------------|---------------|--------------|--------------|
| 580 | 0 | 20 | 57 | 4.7 | 1.63 | 72 |
| 500 | 150 | 26 | 59 | 5.7 | 1.54 | 70 |
| 400 | 1500 | 35 | 62 | 7.1 | 1.44 | 68 |
| 300 | 3300 | 43 | 64 | 7.9 | 1.39 | 67 |

VISCOSITY: 31.6
BRIGHTNESS: 90.9



BLEACHED

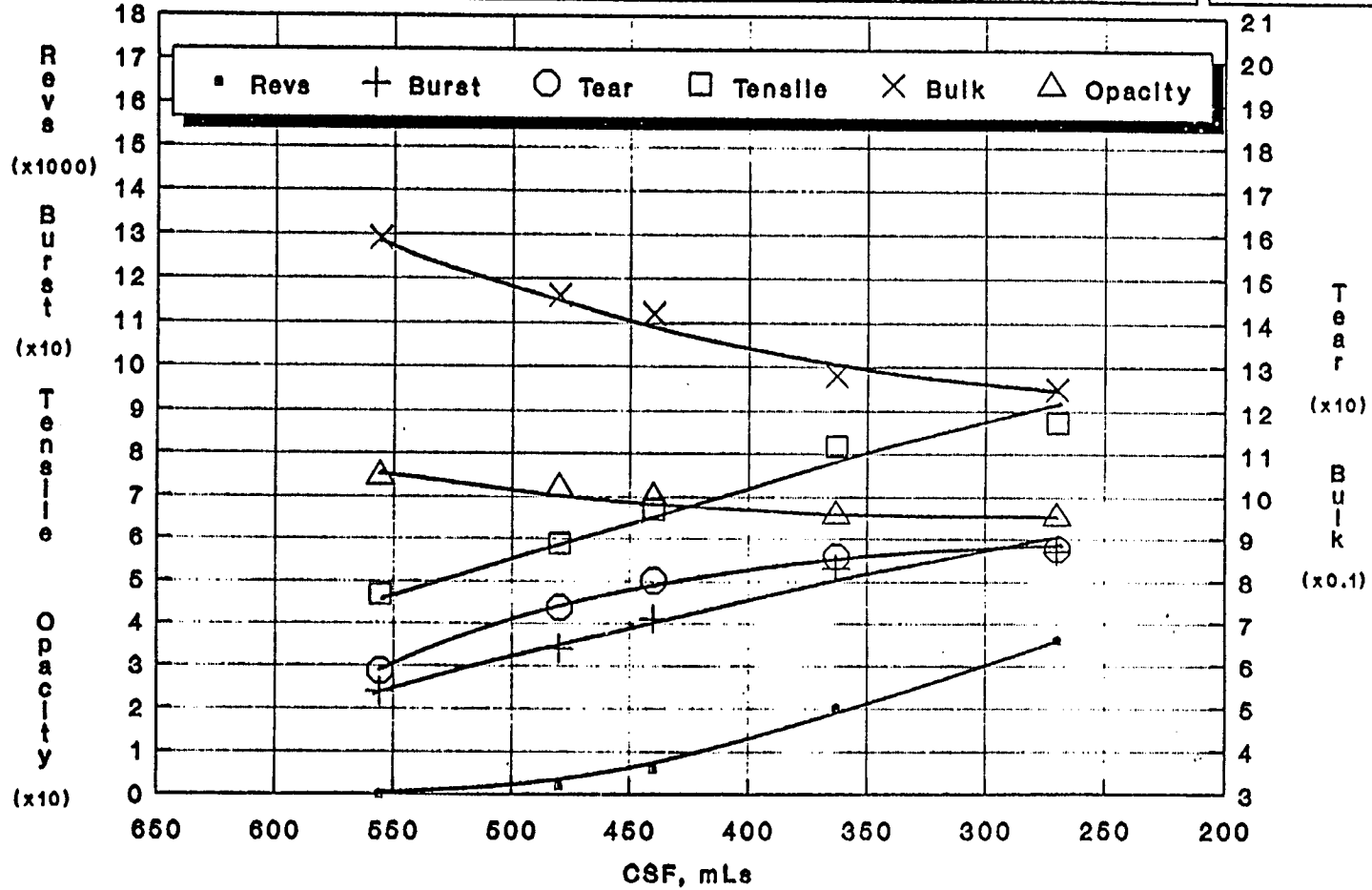
ALBERTA-PACIFIC FOREST INDUSTRIES W.O.#L60049

CPPA

A3476-2-D1
NORTHWEST PAPER
11/SEPT/96 VK

| OSF mLs | PFI revs | BURST factor | TEAR factor | TENSILE km | BULK cc/g | OPACITY % |
|------------|-------------|-----------------|----------------|---------------|--------------|--------------|
| 556 | 0 | 24 | 59 | 4.7 | 1.59 | 75 |
| 500 | 150 | 32 | 71 | 5.6 | 1.48 | 71 |
| 400 | 1300 | 47 | 83 | 7.2 | 1.34 | 67 |
| 300 | 3000 | 58 | 88 | 8.8 | 1.27 | 66 |

VISCOSITY: 28.2
BRIGHTNESS: 91.3



BLEACHED

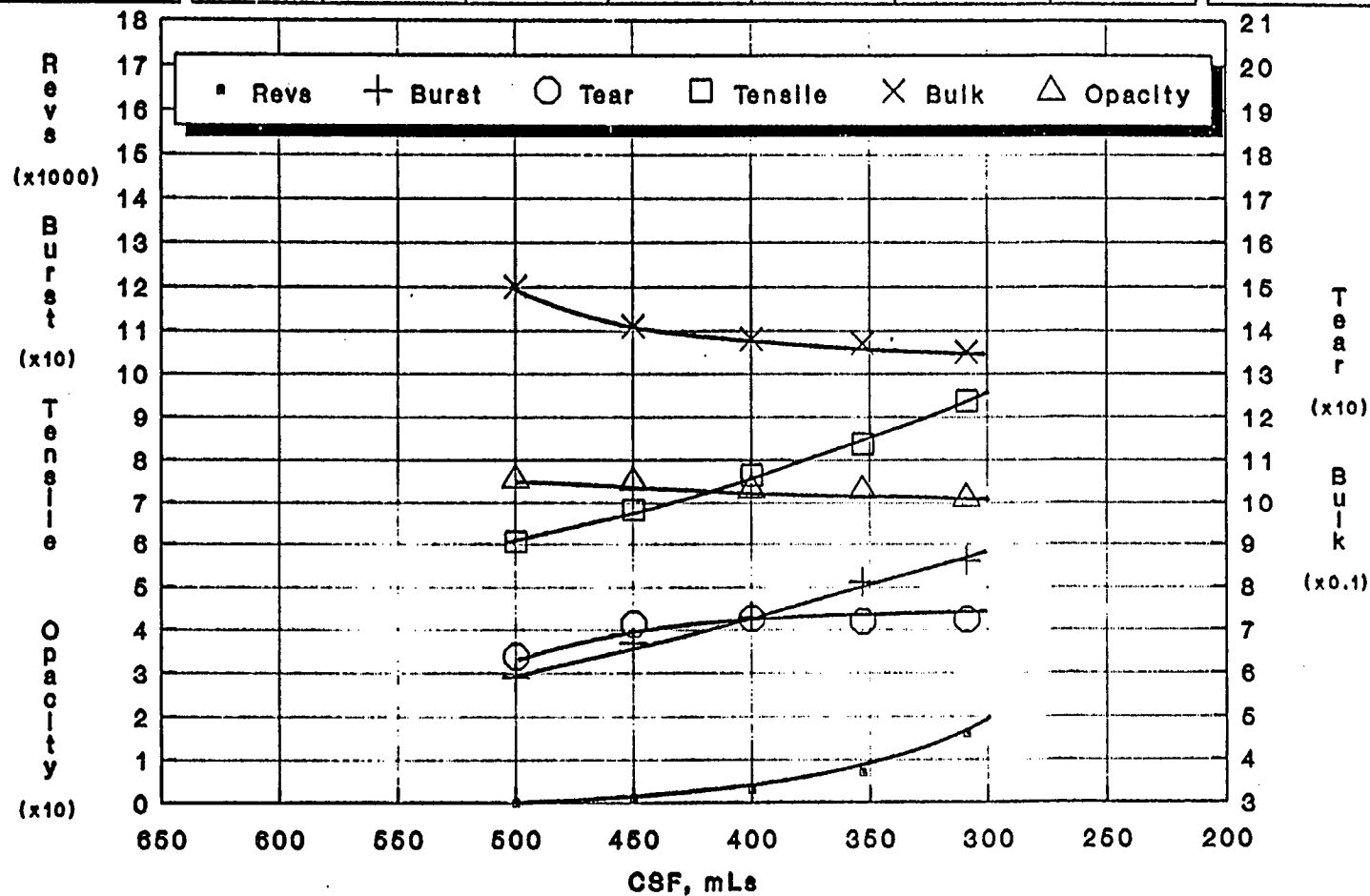
ALBERTA-PACIFIC FOREST INDUSTRIES W.O.#L60049

CPPA

A3477-2-D1
WALKER POPLAR
11/SEPT/95 VK

| OSF mLs | PFI revs | BURST factor | TEAR factor | TENSILE km | BULK cc/g | OPACITY % |
|------------|-------------|-----------------|----------------|---------------|--------------|--------------|
| 500 | 0 | 29 | 64 | 6.0 | 1.50 | 76 |
| 400 | 300 | 43 | 73 | 7.6 | 1.38 | 72 |
| 300 | 2000 | 58 | 75 | 9.6 | 1.34 | 71 |
| | | | | | | |

VISCOSITY: 24.2
BRIGHTNESS: 91.2



ALPAC ASPEN

TYPICAL GRADE PROFILE



| | | | | | |
|-------------------------|----------------------|------|------|------|------|
| PFI | Revolutions | 0 | 400 | 2000 | 5000 |
| Breaking Length | km | 2.7 | 4.2 | 6.6 | 8.3 |
| Tear Index (1 ply) | mN•m ² /g | 2.9 | 4.4 | 6.4 | 7.4 |
| Tear Index (4 ply) | mN•m ² /g | 3.4 | 5.9 | 7.4 | 7.5 |
| Burst | kN/g | 1.05 | 1.99 | 3.65 | 4.97 |
| Stretch | % | 1.39 | 2.22 | 3.04 | 3.56 |
| Porosity | sec/100 ml | 4 | 8 | 29 | 137 |
| Bulk | cm ³ /g | 1.54 | 1.43 | 1.30 | 1.21 |
| Density | g/cm ³ | 0.65 | 0.70 | 0.77 | 0.83 |
| Opacity | % | 78 | 76 | 73 | 69 |
| Light Scattering Coeff. | m ² /kg | 39 | 35 | 28 | 24 |
| Freeness - CSF | ml | 504 | 428 | 326 | 198 |
| Freeness - SR | *SR | 22 | 27 | 38 | 57 |

Pulp Sheet

| | |
|----------------------|--------------------------------------|
| Sheet Brightness | 90.8 % |
| Oven-Aged Brightness | 90.3 % |
| ISO Dirt | 0.90 mm ² /m ² |

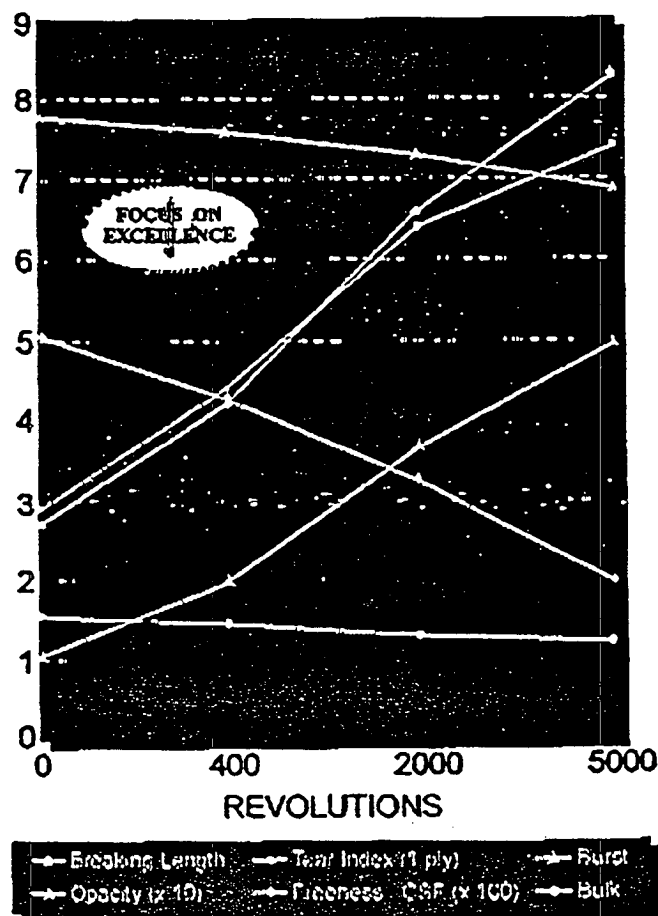
Chemical

| | |
|----------------------|------------|
| Viscosity, 0.5 m CED | 24.7 mPa•s |
| DCM Extractives | 0.35 % |
| Ash | 0.60 % |

Fibre

| | |
|-----------------|-------------|
| Species | Aspen |
| Average Length | 0.73 mm |
| Fibres Per Gram | 14 million |
| Coarseness | 11 mg/100 m |

| | Inches & lb | cm & kg |
|--------|-------------|---------|
| Length | 32 | 81.3 |
| Width | 32 | 81.3 |
| Height | 16 | 40.6 |
| Weight | 550 | 250 |



GLOSSARY

| | |
|------------------|---|
| active alkali | Active alkali (AA) in kraft pulping refers to the weight of sodium hydroxide and sodium sulfide expressed as sodium oxide equivalents. The active alkali charge is the ratio of active alkali charged per kg of o.d. wood expressed as a percentage. |
| brown stock | Unbleached pulp coming from the digester. |
| bulk | The compactness property of a sheet in relation to its weight. Bulk decreases as a pulp is beaten. |
| burst factor | The strength of a sheet, determined by dividing its bursting strength by its basis weight. |
| burst strength | The maximum uniformly distributed pressure applied at right angles to its surface that a test piece of paper will stand before it breaks under specific test conditions. |
| CPPA | Canadian Pulp and Paper Association |
| CSF | Canadian Standard Freeness, the drainage properties of the pulp as measured on a CSF tester. |
| DCM extractives | The per cent of materials present in wood which can be extracted using dichloromethane, an organic solvent. |
| effective alkali | Effective alkali (EA) in kraft pulping refers to the weight of sodium hydroxide and one-half of the sodium sulfide expressed as sodium oxide equivalents. |
| H-factor | Units which are used to express the degree or level of energy used in cooking. H-factor integrates the relative rate of cooking over the cooking cycle to obtain a single number that can be used to determine the degree of cooking that has taken place. The cooking rate is determined by the cooking temperature. |
| handsheet | A single sheet of paper made by draining water from a pulp suspension on a screen covered sheet mold. It is used in testing the properties of pulp and paper. |
| Kappa factor | The ratio of chlorine dioxide expressed as % chlorine equivalents over the kappa number of the pulp entering the D100-stage (i.e. pulp kappa number multiplied by the kappa factor indicates the % chlorine dioxide as chlorine applied to the pulp). |

| | |
|-----------------------|--|
| Kappa number | The amount of permanganate consumed by pulp under standard conditions. This number indicates indirectly the lignin content of the pulp. Higher numbers indicate higher lignin contents. |
| MCC | Modified Continuous Cooking, a continuous digester cooking process patented by Ahlstrom Kamyr Inc. |
| o.d. basis | Oven-dried basis, percentages or weights expressed on the wood solids without accounting for water present. |
| O-D100-Epo-D | A four stage bleaching sequence consisting of treating pulp sequentially with an oxygen delignification (O) stage, then a 100% chlorine dioxide (D100) stage, followed by a oxidative extraction stage (Epo) with hydrogen peroxide and completed with a final chlorine dioxide (D) stage. |
| PFI development curve | A graph plotting the strength values of pulp against the freeness which drops with increased beating. |
| PFI evaluation | A pulp strength evaluation performed using a PFI mill (beater). |
| PFI revs | The number of revolutions of the beater in the PFI mill used to develop the pulp strength. |
| refiner | Equipment which can be used to mechanically convert wood chips to pulp. |
| sulfidity | The ratio of sodium sulfide expressed as equivalent sodium oxide to the active alkali concentration. |
| tear factor | An expression of tear strength equal to the force in grams required to tear a strip of paper under specific conditions divided by the basis weight in grams per square meter multiplied by 100. |
| tensile | Also known as tensile breaking length, the calculated limiting length of a strip of paper of any uniform width beyond which, if such a strip were suspended by one end, it would break by its own weight. |
| wood density | The oven dried weight of a wood sample expressed over its green (water saturated) volume. |