12-1-1973

TB65: The Commercial Use of Puckerbrush Pulp

Andrew J. Chase

Fay Hyland

Harold E. Young

December 1973

The Commercial Use of Puckerbrush Pulp

Andrew J. Chase
Fay Hyland
Harold E. Young

Technical Bulletin 65
Life Sciences and Agriculture Experiment Station
University of Maine at Orono

TABLE OF CONTENTS

Abstract 3

Introduction 4

Experimental Procedures

a. Chip Preparation 7

b. Cooking Procedure 7

c. Bleaching Procedure 9

d. Liquor Preparation 9

e. Test Procedures 9

Results and Discussion

a. Sulfate Pulping of Puckerbrush Mixtures and Puckerbrush-Commercial Hardwood Mixtures 10

b. Magnesium Bisulfite Pulping of Gray Birch Puckerbrush 16

c. Neutral Sulfite Semichemical (NSSC) Pulping of Puckerbrush Mixtures. 18

d. Variables in Puckerbrush Pulping 20

e. Consumption and Characteristics of Chemicals Used in Sulfate Pulping of Puckerbrush 25

f. A Chemical Characteristic of Pulp from Puckerbrush 30

g. Other Results 31

Conclusions 31

Literature Cited 32

Appendix 35

ACKNOWLEDGMENTS

The authors wish to acknowledge the support of the Maine Transportation Department, The Seven Islands Land Company, the J. D. Irving family of New Brunswick and the Life Sciences and Agriculture Experiment Station (McIntire-Stennis funds). This support made it possible for John Ribe, Peter Hamilton, John Trafford and Michael Young to harvest and prepare the tree and shrub material and for Richard Orcutt and A. Krishnagopalan to conduct the pulping studies.

The contribution of the Chemical Engineering Department of the University of Maine at Orono is gratefully acknowledged for the use of its facilities and equipment.

The Commercial Potential of Puckerbrush Pulp

Andrew J. Chase[1], Fay Hyland[2] and Harold E. Young[3]

Abstract

A study was made to investigate the potential of several local puckerbrush or weed trees and shrubs as sources of fiber for papermaking. It is an extension of previous studies which were reported in Technical Bulletin 49 of the Life Sciences and Agriculture Experiment Station, University of Maine at Orono.

Pulping experiments were conducted in the pulp and paper laboratories of the Chemical Engineering Department of UMO. Four different pulping processes were used. They were the sulfate, the magnesium bisulfite, the neutral sulfite semichemical, and the cold caustic. Six puckerbrush species, alder, gray birch, red maple, pin cherry, aspen, and willow were used. In most cases only the branch and stemwood portions, with bark intact, were pulped.

Mixtures of puckerbrush species, and commercial chip-puckerbrush species mixtures were pulped by the sulfate process with the objective of producing a pulp that would be suitable for fine grade papers. The results indicated that weed, or "puckerbrush" species need not be segregated in the sulfate process. A good grade of bleachable pulp, in the yield range of 40 to 45 percent, was produced. This is 5 percentage points lower than the yield realized from commercial hardwoods, because of the bark in the puckerbrush species. The pulp has adequate physical characteristics for most fine paper grades.

The other three pulping processes were used to produce higher yield pulps suitable for coarse grades of paper and paperboard. Mixtures of species, and gray birch alone, were used. The magnesium bisulfite process produced a pulp in the 50 percent yield category but this, being an acidic process, did not adequately pulp the bark. The neutral sulfite semichemical process gave a relatively high yield, 65 to 75 percent, of a pulp which compared favorably in appearance and strength properties with commercial pulps used in the manufacture of corrugating board. The cold caustic pulping process resulted in high yields, 70 to 80 percent of a pulp that had many of the characteristics of that produced from commercial hardwood chips.

---

[1] Professor of Chemical Engineering, University of Maine at Orono.
[2] Professor emeritus of Botany, University of Maine at Orono.
[3] Professor of Forest Resources, University of Maine at Orono.

Brief studies of pulping of bark from several puckerbrush species, and of the needles from several types of conifers, showed the undesirable aspects of these materials as sources of papermaking fiber. Yields were very low, ranging from zero to 30 percent, and the fiber was generally very weak and very difficult to handle in a sheet-making operation.

The consumption of chemicals and the characteristics of the spent liquor in the sulfate process were investigated and compared with the results from pulping commercial chips. It was found that the puckerbrush does "consume" more chemical per cook. However, this process is cyclical, i.e., the chemical is recovered and reused. Therefore a greater "consumption" of chemical indicates a higher load of chemical circulating within the system, but does not necessarily mean higher chemical costs. The spent liquor from puckerbrush does have a slightly different composition, mainly as a result of dissolved bark materials, which might necessitate changes in the chemical recovery operations.

Brief studies were made of the properties of pulp from various height locations of the tree, and on the effect of different methods of puckerbrush chip preparation. In general, pulp produced from the top portion is weakest and method of chip preparation for puckerbrush has no significant effect on pulp strength.

It was concluded from these results, as well as from previous studies, that the puckerbrush species represent a source of fiber that is competiive, in physical caraceristics and papemaking properties, wih commercal grades of hardwood pulps.

Moderate-to-high yield production of pulps for use in coarse grades of paper and paperboard, e.g., corrugating medium, appears to be a particularly promising use for puckerbrush.

Introduction

The main objective of this study was to investigate the potential of small tree or bush "weed" species as a source of fiber for the paper and paper board industries. This is an extension of the work reported in Technical Bulletin 49 of the LSA Experiment Station, University of Maine (1).

The rationale for the study and for similar work preceding it is not simply academic. Instead, it is hoped that the results obtained and the conclusions drawn will eventually lead to some practical applications by industry tending toward the efficient use of fibrous raw materials that are potentially useful and are now being wasted.

The use of our forest materials for wood and paper products expands at an ever-increasing rate and it is a demonstrated, though largely ignored, fact that this usage rate can exceed the growth rate at a time in the not-too-distant future.

F. P. Doane, Jr., writing a review article in American Paper Industry (2), presents some interesting figures on the potential of heretofore unrecognized or ignored sources of fibers, and points up the several possibilities for augmenting the fiber supply obtained by the present conventional methods.

The general theme of a technical program sponsored by the Forest Products Division of The American Institute of Chemical Engineers at the 1973 meeting in New Orleans, La. was "Combating Impending Shortages of Pulp Fiber." Some solutions discussed in the papers presented were: improvements in growing and harvesting methods of forest crops, more complete and efficient use of present fiber sources, reuse of wastes, i.e., recycling, and supplementing of natural fibers with man-produced fibers. Some of the papers presented at this meeting are being published in 1974 as a symposium series. Publication will be done by The American Institute of Chemical Engineers.

The research on development of new fiber crops and on different techniques for the growing and harvesting of established fiber sources has been quite extensive. Studies along these lines have been conducted and are continuing at the USDA Northern Utilization Research and Development Division. This work has been concerned mainly with the potential of various grasses and other non-woody plants as fiber sources. Short rotation growing of woody fiber sources is being studied by foresters in the United States as well as in other areas of the world (3-9).

The use of small trees and plants normally considered to be a nuisance and of negligible commercial value as a source of fiber has been the subject of studies by University of Maine investigators, and is the main subject of this report (1, 10-13). This work has resulted in a quantity of information concerning the chemical and physical characteristics of fiber from several species of noncommercial trees and shrubs and the potential of such fiber as a component of various types of paper and paperboard. A biomass study using plots of these species is being conducted by Professor H. E. Young, University of Maine, Orono at the present time.

More efficient and complete utilization of presently commercial fiber sources has been the subject of a great number of research studies both in North America and abroad. The "complete tree" concept, which developed at the University of Maine and which was studied in many laboratories over a period of almost two decades, has expanded to other countries and is now being applied commercially, in varying degrees of completeness, by a sizeable and growing number of paper industry companies in the United States and Canada. The basic premise of this concept is that parts of the tree, such as the top, branches, stump, and even the roots, that are typically left to waste do contain valuable fiber. Studies have confirmed this and many mills are now pulping these tree components as an integral part of their raw material supply, and with good results. Some of the pioneering studies of the complete tree concept were made at the University of Maine (14-16). A most comprehensive survey of the literature on complete-tree utilization has been conducted by J. L. Keays and co-workers (17).

The use of such tree components as bark, branches, top, and stump, by the paper industry has required some innovative developments in harvesting and handling methods and equipment. There are at present several makes of equipment which can sever the tree at the ground level, remove the top and branches and slash into the desired lengths all in one sequential operation. There are also portable chippers that can be transported to the logging site where chipping of the logs is accomplished. One of these chippers can handle whole trees, chipping stem, branches, top, bark and foliage simultaneously (18).

The presence of bark, foliage, and wood from tree components other than the stem naturally have affected, in varying degrees, the pulping and paper making operations and the properties of the paper and paperboard products of those operations. Examples are lower pulping yields, particularly in the manufacture of fine bleaching grade pulps, higher pulping and bleaching chemical demands, more pulp screening and cleaning required, and in some cases slightly inferior strength characteristics. However, it is gradually becoming recognized that these problems are possible of solutions and are insignificant in many cases. Some of the innovations common to complete tree and "puckerbrush" pulping may in fact solve more problems than are created. For example, environmental considerations, rules, and regulations have created a nearly impossible situation in some areas in the handling of bushes and small trees cut from highway rights-of-way. They must be removed periodically but can't be burned or sprayed. Research has shown that many species are excellent sources of fiber for paper. The cost of lower yields and higher chemical usage in whole tree pulping may be more than compensated for by the reduction in equipment and operations used in present day wood handling, debarking and chip screening.

The trend in the paper industry is in the direction of high yield pulping, for several reasons: the impending shortage of raw material, pollution regulations, and the economic fact that cost of raw material per unit of product is lower. The concepts of complete tree utilization and high yield pulping are compatible.

Experimental Procedure

The six puckerbrush species used in this study were speckled alder (*Alnus rugosa* (Du Roi) Spreng.), gray birch (*Betula populifolia* Marsh.), red maple (*Acer rubrum* L.), pin cherry (*Prunus pennsylvanica* L.f.) quaking aspen (*Populus tremuloides* Michx.) and slender willow (*Salix gracilis* Anderss.).

The commercial hardwood consisted of chips obtained from Penobscot Company, Division of Diamond International, Old Town, Maine. Their exact composition is unknown but they were probably primarily birch and maple.

(a) Chip preparation.

The only portions of puckerbrush used were the stemwood and branches. The exact proportions of each, and whether debarked or not, is explained in the Results and Discussion section.

The Klockner chipper was used for most of the work and a description of it can be found in the Appendix, Part 3. In one phase of the study, that having to do with the effect of method of chipping on pulping results, the Carthage 4-knife disk chipper was also used.

The Williams chip classifier was used to screen the chips prior to cooking and the screening was done according to TAPPI Standard Method T-16.

Chips were spread on screens and allowed to reach moisture equilibrium at ambient conditions before cooking.

(b) Cooking procedure.

Two digesters were used, the choice depending on how many different samples were to be cooked simultaneously and how large a pulp sample was needed for subsequent tests.

The larger of the two digesters was a high pressure stainless steel vessel having a capacity of 15 to 20 pounds of chips (dry basis). It was heated by continuous circulation of the cooking liquor through an external heat exchanger. Cooking conditions of time and temperature were controlled by means of a Honeywell Data Trak Programmer-Vutronik indicating control station set-up. Chips were contained within a stainless steel basket having eight compartments. Thus, several different kinds of chips could be cooked simultaneously. The cylindrical basket and cover, made of 316 stainless steel, were perforated with 1/8 inch holes on 3/16 inch centers to allow adequate circulation of liquor without mixing of different chip types.

The basket was easily loaded and inserted into the digester. It was constructed to conform to the inside dimensions of the digester with only enough clearance to allow easy insertion and removal.

The other digester, also constructed of stainless steel and having an external heat exchanger, had a capacity of two to three pounds of chips and contained a two-compartment basket.

When a cook was completed, steam flow to the heat exchanger was stopped and digester pressure was reduced. Spent liquor was sewered, the cover removed from the digester, and the basket removed. When the larger digester was used, cold water was circulated through the basket of chips for a few minutes before it was removed. The cooked chips were dumped into a box with a screened bottom where they were washed until the washings contained no discernable spent liquor. They were then transferred to a Morden Slushmaker where they were vigorously agitated and defibered for five minutes. Conditions of time and consistency for the defibering operations were the same for all pulps because this particular treatment can affect the percent rejects realized from a cook. The defibered pulp was transferred to a container that served as a supply tank for the vibratory pulp screen. Dilution water was added, consistency measurements made and *unscreened pulp yields* determined. After screening, the accepted pulp was again diluted, consistency measurements made and *screened pulp yields* determined. The difference between the unscreened and screened yields was the reject material. Where appropriate, samples of the screened pulp were saved for physical and chemical tests.

The preceding description of cooking procedures applies to the pulping studies using the sulfate, magnesium bisulfite, and neutral sodium semichemical processes.

The cooking procedure for the cold caustic treatments consisted of soaking the chips in a sodium hydroxide solution in an open steel vessel for a given time and at a given temperature. Temperature was controlled by immersing the vessel containing the chips in a water bath and initial caustic concentration was controlled by adjusting caustic-to-wood ratio and amount of dilution water.

At the end of the soaking period, the chips were treated in a Bauer single rotating disk refiner with the main objective being to break down the softwood chips into fibers and fiber bundles. The refined material was then screened and yields determined as described previously. In the case of this pulp the amount of rejects was determined by drying and weighing *all* the reject material from the screening.

(c) Bleaching procedure.

The bleaching requirement of the pulp was determined from the Kappa number-bleach demand relationship, TAPPI Standard Method T-214.

A standard 4-stage bleaching sequence was used. This consisted of chlorination, caustic extraction, hypochlorite, and chlorine dioxide, with water washing of the pulp after each stage. Sixty percent of the total chlorine demand, as determined from the Kappa number, was added in the chlorination and the remaining 40 percent divided equally between the hypochlorite and chlorine dioxide stages.

(d) Liquor preparation.

Cooking liquor for the sulfate cooks was made by weighing out the required amounts of chemically pure sodium hydroxide and sodium sulfite to give the desired sulfidity and active alkali-to-wood ratio. The chemicals were then dissolved and the solutions diluted to a volume sufficient to just cover the chips in the digester. There was usually some variation in the amount of dilution water used because of differences in chip packing density and amount of chips cooked. Thus, the liquor-to-wood ratio and cooking liquor concentration varied slightly from cook to cook but the sulfidity and alkali-to-wood ratio were the same for all cooks (Table 1).

Magnesium bisulfite liquor was made by bubbling sulfur dioxide gas into a suspension of magnesium hydroxide until the proper concentration of bisulfite, as determined by titration, was reached. Cold caustic liquor was prepared by dissolving a measured amount of flake sodium hydroxide in water.

All bleach liquors, i.e., chlorine water, hypochlorite solution, and chlorine dioxide solution were obtained from Penobscot Company, Division of Diamond International, Old Town, Maine.

(e) Test procedures.

Most of the tests made on pulp, handsheets and cooking liquors were standard procedures as described in the TAPPI Standards and Suggested Methods, published by the Technical Association of the Pulp and Paper Industry. Some of these tests are referred to in other parts of this paper. For the convenience of those who may be interested in the details of the tests, all those that were used in this study are listed below according to their title and TAPPI number.

Sieve Analysis of Pulpwood Chips	T-16
Kappa Number of Pulp	T-236
Analysis of Soda and Sulfate White and Green Liquors	T-624
Analysis of Soda and Sulfate Black Liquor	T-625
One Percent Caustic Solubility of Pulp	T-212
Analysis of Bleach Liquor	T-611
Freeness of Pulp	T-227
Laboratory Processing of Pulp (Beater Method)	T-200
Forming Handsheets for Physical Tests of Pulp	T-205
Physical Testing of Pulp Handsheets	T-220

Results and Discussion

(A) Sulfate Pulping of Puckerbrush Mixtures and Puckerbrush-Commercial Hardwood Mixtures.

The economics and mechanics of the harvesting of puckerbrush for use as paper pulp would undoubtedly dictate a non-selective operation as far as species is concerned. Therefore, the raw material supplied to a pulping operation would in most cases be a mixture of species, particularly if it came from natural or wild stands such as road or powerline rights-of-way. Furthermore, separation of the material into its several component parts, i.e., stem, branches, top and stump, prior to pulping would not be feasible.

The most probable manner of using puckerbrush would be as a supplement to standard commercial pulpwood wherein it would be chipped at the harvesting site, with no attempt at species or component classification, and would then be pulped in mixture with chips from commercial pulpwood at the mill.

Several sulfate cooks were made to obtain information on the properties of pulps that could be produced from such mixtures.

(a) Puckerbrush mixtures.

Two mixtures of puckerbrush representative of those that might normally grow on highway rights-of-way were used in this study. Their compositions, in weight percent, were 45% alder and 55% willow for one mixture, and 50% aspen 35% gray birch, and 15% red maple for the other. For each mixture the components used were the stem and branches with bark intact. The pulping and bleaching conditions are shown in Table I and the results in Table II.

The conditions were the same as those that were established as optimum in previous studies (1). Yields were very satisfactory, considering that the cooks were made on wood that was not debarked. Under normal commercial conditions of pulp washing, defibering and screening,

Table I

Pulping and Bleaching Conditions

Type of Cook	Sulfate (Kraft)
Active Alkali-to-Wood Ratio	$0.2 \frac{\#\text{Alkali (as } Na_2O)}{\#\text{Dry Wood}}$
Sulfidity	25%
Temperature (Max.)	345°F
Time at Max. Temperature	1 hour
Liquor-to-Wood Ratio	$7 \text{ to } 9 \frac{\#\text{Liquor}}{\#\text{Wood}}$
Cooking Liquor Concentration (approx.)	2.3 $\#/ft.^3$ (as Na_2O)
Type of Bleach	4-Stage
Stage 1	Chlorination (60% of demand)
Stage 2	Caustic Extraction
Stage 3	Hypochlorite (20% of demand)
Stage 4	Chlorine Dioxide (20% of demand)

Table II

Pulping and Bleaching Results
(Puckerbrush Mixtures)

Parameter	Willow-Alder (WAL)	Maple-Aspen-Birch (MAB)
Acceptable Pulp Yield (%)	41.4	42.3
Rejects Yield (%)	2.8	6.0
Total Yield (%)	44.2	48.3
Kappa Number	29	30
G. E. Brightness	81.9	85.3

some of the reject material that resulted would eventually be converted to accepted fiber. Thus, it is apparent that yields of 40 to 45 percent of unbleached pulp from pulping of these typical puckerbrush mixtures are possible. The Kappa numbers 29 and 30, indicate a good degree of delignification and a pulp which, if it were from commercial chips, would bleach easily but still possess adequate strength potential. The 4-stage bleaching treatment produced medium brightness which could probably be improved to some extent by additional stages. However, it has been established previously (1) that puckerbrush pulp is more difficult to bleach than commercial pulp. One reason, undoubtedly, is the presence of bark residue.

Samples of the unbleached pulp from each puckerbrush mixture were mechanically refined in the standard beater. Hand sheets were made and tested for strength characteristics using the TAPPI Standard Methods. The results of these tests are shown in Tables III and IV. There was little difference between the physical properties of the two mixtures. The response to mechanical treatment for the alder-willow mixture was somewhat different than that of the aspen-birch-maple. After 20 minutes of refining, there was sufficient deterioration of the fibers that freeness measurements could not be made because a large percentage of the fiber fragments were passing through the screen of the freeness tester. However, burst and tensile strength were still increasing at this point (Table III). Previous work had shown that the pulp from willow was very sensitive to mechanical treatment and present results corroborate this.

In general, the pulps obtained from these two mixtures of puckerbrush species were slightly lower in physical strength than would normally be expected of pulp similarly produced from standard hardwood chips. The yield, and brightness potential are in excellent agreement with the results of previous studies.

(b) Puckerbrush-Commercial Hardwood mixtures.

The pulping characteristics and physical properties of pulp from puckerbrush-commercial hardwood mixtures were examined. One exploratory cook was made on a 50/50 mixture of gray birch puckerbrush-commercial hardwood chips. This was followed by a series of cooks on mixtures that differed with respect to the puckerbrush species and the weight ratios of puckerbrush to commercial hardwood. The sulfate process was used for all cooks with the same conditions as those shown in Table I.

The pulp from the exploratory cook was well pulped, having a Kappa number of 22. The yield of screened pulp was 44.5%, with 1.9% reject material. A standard beater test was made on the pulp and the re-

Table III

Properties of Sulfate Pulp from Puckerbrush Mixture
(45% Alder, 55% Willow)

Beating Time (Minutes)	C. S. Freeness	Bulk (cc/gm.)	Burst Factor	Tear Factor	Breaking Length (Meters)
0	378	1.62	49	62	8,590
5	308	1.54	64	65	9,080
10	277	1.44	72	65	9,750
20	263	1.40	78	55	10,880

Table IV

Properties of Sulfate Pulp from Puckerbrush Mixture
(50% Aspen, 35% Gray Birch, 15% Red Maple)

Beating time (Minutes)	C. S. Freeness	Bulk (cc/gm.)	Burst Factor	Tear Factor	Breaking Length (Meters)
0	477	2.29	42	73	8,070
10	373	2.08	57	73	9,600
20	268	2.07	66	67	10,410
30	187	2.07	66	60	10,820
40	100	1.96	65	56	10,130

sults are shown in Table V. Included in the table for comparison are results obtained in previous work on 100% commercial chips and 100% gray birch stemwood-branch mixture. The strength properties of the puckerbrush-commercial mixture are intermediate between those of the comparison pulps. In the absence of synergistic or opposite effects, these are the expected results.

Two puckerbrush mixtures were used in the series of cooks made on puckerbrush-commercial chip blends. They were willow-alder (WAL) and maple-aspen-gray birch (MAB). The mixtures were chipped and screened exactly as they were harvested and delivered, i.e., no effort was made to prepare mixtures containing specific proportions of different species. After chipping and screening, the mixtures were blended in definite proportions, by weight, with the commercial chips. Thus, for each puckerbrush mixture, there were three different blends of puckerbrush mixture-commercial chips: 75/25, 50/50, and 25/75. In addition, 100% commercial chips and 100% puckerbrush cooks were made as standards for comparison.

Table V

Properties of Sulfate Pulp from Gray Birch Puckerbrush Commercial Hardwood Mixtures*

Pulp Type	Beating Time (Minutes)	Burst Factor	Tear Factor	Breaking Length (Meters)
Gray Birch	0	45	76	10,620
Commercial Hardwood	0	30	66	6,560
50/50 Mixture	0	46	74	9,500
Gray Birch	10	79	92	13,730
Commercial Hardwood	10	56	86	9,650
50/50 Mixture	10	77	102	12,110
Gray Birch	20	82	89	14,170
Commercial Hardwood	20	69	86	11,400
50/50 Mixture	20	75	92	13,270

*Puckerbrush portion: gray birch stem and branches with bark intact
Commercial Hardwood: primarily debarked birch and maple

Standard beater tests were made on all pulps from this series of cooks. Table VI shows the results of tests made on handsheets, as well as the yield and Kappa number for each pulp. It should be noted that the physical test values shown are *maximum* values. The reader is referred to Tables 1A-4A in the Appendix for the complete results of the beater tests.

The differences in burst, tear, and tensile strength between the puckerbrush-commercial mixture and the 100% commercial pulp are not sufficiently large to be significant. It can be concluded that the *maximum* values of these properties, as well as the Kappa number are essentially

Table VI

Sulfate Pulp from Puckerbrush-Commercial Hardwood Mixtures

Mixture	Acceptable Pulp Yield (%)	Rejects (%)	Kappa Number	Bulk (cc/gm.)	Burst Factor	Tear Factor	Breaking Length (meters)
100% CH	47.2	5.5	27.0	1.87	78	83	12,500
100% WAL	43.2	2.8	27.0	1.70	82	75	12,100
100% MAB	43.1	5.0	27.8	1.78	80	78	11,770
25 WAL/75 CH	47.4	5.3	27.3	1.80	81	83	12,140
25 MAB/75 CH	47.2	4.2	25.5	1.86	81	83	12,660
50 WAL/50 CH	43.1	4.2	29.0	1.81	77	81	12,140
50 MAB/50 CH	45.8	4.4	26.0	—	82	79	12,070
75 WAL/25 CH	44.1	3.1	29.0	1.74	79	75	12,430
75 MAB/25 CH	44.7	4.6	27.5	1.82	80	79	12,190

CH: Commercial hardwood, primarily debarked birch and maple.

WAL: Willow-alder, stemwood and branches, with bark.

MAB: Red maple-aspen-gray birch, stemwood and branches, with bark.

the same for all pulps. However, real differences are indicated for pulp yield. Lower yields of puckerbrush pulp resulted from the presence of bark in the material pulped.

The defibering treatment following the cook is not as severe as that used in commercial pulping and this accounts for the relatively high percent of rejects. Much of this material is acceptable fiber and would be recovered under more typical defibering and screening procedures.

These results present good evidence that certain puckerbrush species can be pulped successfully in mixture with commercial hardwood chips. Strength properties may not be materially different from those of pulp made from commercial chips. Unbleached pulp yields will be approximately 5 percent lower and the pulp may require additional mechanical cleaning and a higher bleach demand because of bark residue.

Study of the beater test results (Tables 1A-4A) indicates that the response to mechanical treatment is quite similar for the 100% pulps and the mixtures, i.e., strength properties are developed at about the same rate for all pulps.

(B) Magnesium Bisulfite Pulping of Gray Birch Puckerbrush.

A brief study was made of the response of puckerbrush to pulping with an acidic cooking liquor. The main reason for this phase of the pulping study was an attempt to produce a good grade of bleachable pulp from puckerbrush material at a higher yield than had been realized from the sulfate process.

Gray birch stemwood with bark removed was pulped with a magnesium bisulfite liquor. Several cooks were made to determine suitable cooking conditions. Once these were established, they were used in several cooks on a gray birch stemwood-branch mixture with bark intact. The resulting pulps were refined in the standard beater; handsheets were made and tested for strength properties. The results are shown in Table VII with those for a sulfate pulp of the same puckerbrush material included for comparison. Table VIII contains the pulping conditions, Table IX the pulping and bleaching results.

It is shown that gray birch stemwood with bark removed can be treated by an acid process to produce a pulp that will bleach to a high brightness level with an overall yield of approximately 50 percent. Compared with the yields and bleachability of puckerbrush pulps from the sulfate process, this represents significant improvement. However, the bisulfite pulp is somewhat inferior in bursting and tearing strength (Table VII).

Table VII

Properties of Magnesium Bisulfite Puckerbrush Pulps

Pulp Type	Beating Time (min.)	Burst Factor	Tear Factor	Breaking Length (meters)
GB, S-B, mg base	0	39	50	9,450
GB, S, mg base	0	38	63	9,890
GB, S-B, Sulfate	0	45	76	10,620
GB, S-B, mg base	10	49	51	10,580
GB, S, mg base	10	66	54	13,900
GB, S-B, Sulfate	10	79	92	13,730
GB, S-B mg base	20	47	44	10,770
GB, S, mg base	20	71	51	14,120
GB, S-B, Sulfate	20	82	89	14,170

GB, S-B, mg base = Magnesium bisulfite pulp from Gray Birch stemwood-branch mixture with bark intact.
GB, S, mg base = Magnesium bisulfite pulp from Gray Birch stemwood (debarked).
GB, S-B, Sulfate = Sulfate pulp from Gray Birch stemwood-branch mixture

Bisulfite pulping of a gray birch stemwood-branch mixture containing the bark produced a material which, compared with the pulp from debarked stemwood, had a much higher Kappa number, a lower yield, and was difficult to bleach to a high brightness. It was also inferior in strength. This pulp appeared to be well cooked despite the high bleach demand and high Kappa number. Most of the reject material was bark residue and the screened pulp also contained uncooked bark particles which undoubtedly was the main factor causing the high Kappa number and the inferior physical properties.

Table VIII

Conditions for Magnesium Bisulfite Cooks

Chemical to Wood Ratio	$\frac{\#\ SO_2}{\#\ \text{Dry Chip}}$	0.16
Time to Maximum Temperature		1.0 hr.
Time at Maximum Temperature		2.5 hr.
Maximum Cooking Temperature		330°F
pH of Cooking Liquor (initial)		4.7
(final)		3.7

Table IX

Results of Magnesium Bisulfite Cooks

Pulped Material	Number Kappa	Pulp Unbleached Yield %	Pulp Bleached Yield %	Rejects %	Brightness G.E.
Gray Birch Stemwood (debarked)	25.4	56	50	2.5	84-89
Gray Birch Stemwood-Branch Mixture (bark intact)	42.0	46.4	—	5.9	82
Standard. Sulfate Pulp from Gray Birch Stemwood-Branch (bark intact)	29.6	39.9	—	1.5-2.0	80

Based on these few results it may be concluded that gray birch puckerbrush with bark intact can be pulped by the bisulfite process. The material so produced should have potential for use in some grades of unbleached paper and paperboard. However, it is inferior in strength and brightness potential to the pulp produced from debarked chips. Two reasons are advanced. First, the bark of the gray birch species is not chemically attacked and dissolved by the acidic bisulfate liquor to the same degree that it is by the alkaline sulfate liquor. Second, the acidic liquor does not penetrate the bark-covered stem and branches as rapidly or as uniformly as does the alkaline liquor of the sulfate process.

(C) Neutral Sulfite Semichemical (NSSC) Pulping of Puckerbrush Mixtures.

These are the results of some exploratory work on the potential of puckerbrush as a source of pulp for corrugating paperboard material commonly used in the packaging industry.

Several semichemical cooks were made on puckerbrush *mixtures* using a sodium-base neutral sulfite cooking liquor. The liquor composition and cooking conditions are shown in Table X.

The partially cooked chips were mechanically treated in a Bauer laboratory refiner for the sole purpose of defibering. The resulting pulp was washed and yield determinations were made. Samples of the pulp were treated in the TAPPI standard beater and handsheets were made and tested.

Three puckerbrush mixtures, all with bark intact, were used in this study. They were the stemwood and branch portions of gray birch—red maple—aspen, alder—willow, and gray birch only. No attempt was made to determine the proportion of each species in a mixture. They were chipped and pulped "as received" from the forest.

Table X

Conditions for NSSC Cooks

Pretreatment of Chips	Steamed at 100 psi for 5 minutes.
Chemical Charge to digester:	
Sodium sulfite (Na_2SO_3)	12% (Based on bone dry chips)
Sodium carbonate (Na_2CO_3)	6% (Based on bone dry chips)
pH of cooking liquor:	
Initial	11.0
Final (at end of cook)	8.9-9.2
Cooking temperature	340°F
Time at cooking temperature	1 hour

The yield and handsheet test results are shown in Table XI as ratios of the magnitude of the property of the puckerbrush handsheet to that of a sample of commercial corrugating board. It should be noted that maximum values obtained in tests on the puckerbrush sheets were used in calculating the ratios.

Yields ranged from 60 to 70 percent not including losses incurred in the refining operation. These would not be tolerated in a commercial operation and if accounted for, would increase the yield by 2 to 5 percentage points. The yields obtained here are lower than normal for industrial production of corrugating pulp but they could doubtlessly be increased by a more thorough study of the cooking and refining conditions.

The puckerbrush pulp generally produced a bulkier (less dense) sheet than the commercial pulp as indicated by the bulk ratio. The strength properties of the puckerbrush were superior, with the exception of tearing strength. Burst strength was at least 30 percent greater, tensile was at least 20 percent greater, and the crush strength, which is a critical property for corrugating board, was from 10 to 25 percent greater.

The physical appearance of the puckerbrush sheets was not as good as that of the commercial sample because of the higher content of bark particles. This may not be a serious deficiency in most cases where corrugating medium is used. With respect to fiber bundles (small particles having the appearance of uncooked wood) there was no significant difference between the puckerbrush and commercial sheets. These characteristics are controlled mainly by the pulp refining and cleaning operations.

The results of this abbreviated study indicate that puckerbrush pulp shows promise as a material for corrugating board. The cook yield may be somewhat lower than that reaiized from pulping of normal size wood but the physical characteristics of the pulp may be superior.

Table XI

Properties of NSSC Puckerbrush Pulp

Pulp Source	Pulping Yield (%)	Bulk Ratio	Burst Ratio	Tear Ratio	Tensile Ratio	Crush Ratio
Gray Birch	66.5	1.25	1.58	1.04	1.30	1.16
Gray Birch, Red Maple, Aspen mixture	65.8	1.10	1.32	0.98	1.21	1.27
Alder-Willow	60.4	0.97	1.54	0.98	1.34	1.13

$$\text{Ratio} = \frac{\text{Property Value for Puckerbrush Sheet}}{\text{Property Value for Commercial Sheet.}}$$

(D) Variables in Puckerbrush Pulping.

There are potentially many variables that can affect the results obtained in a pulping study. The degree to which they can be controlled varies greatly from reasonably good control of the cooking variables to very little control of the chemical and physical characteristics of the material that is being pulped.

Once the cooking conditions have been optimized, as they have for the work presented in this paper, the process is then more or less at the mercy of a raw material whose natural properties vary with internal location, geography, and even the seasons.

The study reported here was made to determine the magnitude of the effects of "wood preparation variables" and "inherent variables" on the results obtained from the pulping of puckerbrush.

(a) Inherent variables.

The stem of a single aspen tree was divided into four sections, designated as stump, above stump, below top, and top, having approximate ages of 60, 45, 16, and 8 years, respectively. Each section was chipped and then pulped, with bark intact, using the sulfate process and cooking conditions shown in Table I. The resulting pulps were then tested for yield and physical properties. Table XII shows the yield, Kappa number and percent reject material, and the *maximum* value for each strength property. The complete results of the beater tests for the pulp from all four sections are presented in the Appendix, Tables 5A - 8A.

Inspection of the results in Table XII shows clearly the definite effects that vertical location within a tree has on pulping yield and pulp properties. The top section of the tree contains a higher ratio of bark-to-wood and also a higher percentage of juvenile wood (19). Both contributed to the lower yield.

Pulp strength decreases with increasing height in the tree mainly because of decreasing fiber length. There is probably some over-cooking of the top section in this case with subsequent weakening of the intrinsic strength of the fibers.

The wood from the stem section, at the stump, of three gray birch trees (ages 10, 20, and 30 years) was pulped with the bark intact. The sulfate process was used. This was done for the purpose of studying the effect of tree age on pulping results. Table XIII shows the yields, Kappa numbers, percent rejects and maximum strengths that were realized. The complete results of beater tests made on the three samples are shown in Tables 9A-12A of the Appendix.

The differences in strength properties and yield among these three samples are not particularly significant so it must be concluded that age of the tree, over the 10 to 30 year span, has no effect on the quality of pulp from the stump portion. Admittedly, these conclusions are based on a very brief study and few data.

(b) "Wood preparation variables"

A considerable amount of research has been performed in the pulping industry to determine the effect of variables in the wood preparation phase of pulping on properties of the pulp. It has been shown that there is an optimum size range for chips which will produce the best grade of pulp. Shape of the chip, which is determined largely by the type of chipping equipment, can also be an effective variable, particularly in the acid pulping processes. Such research has, of course, concentrated on chips from normal size trees, i.e., those that are harvested commercially for pulpwood.

In the case of puckerbrush pulping, it was thought that screening of the chips might not be necessary because of the small size of most of the material and its relatively low density. Particularly in sulfate pulping of this material, the penetration of cooking liquor throughout the chips

Table XII

Effect of Location of Wood in Tree on Pulping Results

Location (Approx. Age)	Acceptable Pulp Yield (%)	Rejects (%)	Kappa Number	Bulk (cc/gm)	Burst Factor	Tear Factor	Breaking Length (meters)
Stump (60 years)	48.3	5.0	19.2	2.08	77	80	—
Above Stump (45 years)	44.9	5.1	19.3	2.14	75	88	12,170
Below Top (16 years)	39.3	4.1	19.9	2.19	58	81	11,010
Top (8 years)	37.3	3.5	21.4	2.21	47	45	10,200

Note: Sulfate cook. Sections pulped were from a single aspen tree with bark intact.

Table XIII

Effect of Tree Age (at Stump) on Pulping Results

Age (years)	Acceptable Pulp Yield (%)	Rejects (%)	Kappa Number	Burst Factor	Tear Factor	Breaking Length (Meters)
10	42.8	2.2	18.1	89	88	10,420
20	43.1	1.2	17.3	100	106	12,470
30	43.9	1.7	17.7	88	92	10,920

Sulfate cook. Wood from stem sections of 3 birch tree with bark intact.
Only *maximum* strength characteristics are shown.

should be rapid and uniform. The short cooking times which were found to be optimum for puckerbrush pulping seem to substantiate this assumption.

Gray birch stemwood with bark intact was chipped and the chips were classified by screening into three fractions, the material retained on 7/8, 5/8, and 3/8 inch mesh screens. Samples of each fraction were cooked by the sulfate process. The resulting pulps were tested for yield and strength properties and the results are shown in Table XIV.

Unscreened yields ranged from 55 percent for the 7/8 inch material to 47 percent for the 3/8 inch. During the chip screening operation it was noted that the loose bark fragments tend to classify and concentrate on the 3/8 inch screen. Thus, it should be correct to expect that the 3/8 inch chip fraction would have the lowest pulping yield. It is reasonable

Table XIV

Effect of Chip Size on Handsheet Properties

Beating Time (min.)	Strength Property and Three Chip Sizes											
	Bulk			Burst Factor			Tear Factor			Breaking Length (Meters)		
	(3/8	5/8	7/8)	(3/8	5/8	7/8)	(3/8	5/8	7/8)	(3/8	5/8	7/8)
0	2.25	2.18	2.23	30	36	32	76	82	85	7,830	8,230	7,140
10	2.18	1.92	2.13	75	81	77	83	86	84	11,970	12,140	12,200
20	2.05	1.82	2.09	86	93	81	80	76	75	12,290	11,910	11,350
30	1.98	1.74	1.93	87	95	82	76	74	69	10,170	9,750	10,830

Sulfate cook. Chips from gray birch stem with bark intact to conclude that chip size *per se*, within the size range investigated, has no significant effect on pulp yield from a sulfate cook. The results of strength tests on the three fractions indicate no significant differences as a result of chip size.

Two types of chippers were used in the puckerbrush studies. A Carthage disc-type chipper was used for all the work reported in Technical Bulletin 49, Life Sciences and Agriculture Experiment Station, University of Maine. The Klockner chipper was used in the study reported in this paper. A complete discussion of the rationale for using the Klockner rather than the Carthage chipper, a brief description of it, and a comparison of the performances of the two chippers is included in the Appendix (Part 3).

It will suffice at this point to explain that the Klockner is designed to handle just such material as puckerbrush, whereas the Carthage is the standard chipper for normal size pulpwood sticks or logs. The Klockner knives make a cut that is more nearly perpendicular to the wood surface than is the shearing cut of the Carthage. Such a cutting action has a compressing and crushing effect which might produce fiber damage and which might also retard penetration of cooking liquor in the longitudinal or fiber direction of the chip. This could have an effect on pulp quality. To ascertain the extent of such an effect, if in fact it did exist, gray birch stemwood, both debarked and with bark intact, and gray birch branches, were prepared in the two chippers, pulped by the sulfate process, and the resulting pulps compared.

Table XV shows the yields resulting from all the cooks and Table XVI shows the results of beater tests on the debarked stemwood pulp only.

Table XV

Effect of Chipper Type on Pulp Yield

Type of Wood	Acceptable Pulp Yield %		% Rejects		Kappa Number	
	C	K	C	K	C	K
Gray Birch stem, debarked	51.6	48.6	1.0	7.6	25.0	22.2
Gray Birch stem, bark intact	47.6	49.2	1.4	5.2	22.4	24.4
Gray Birch branches, bark intact	34.6	35.8	1.2	1.9	30.9	30.2

Sulfate Cook.
C = Carthage Chipper
K = Klockner Chipper

Table XVI

Effect of Chipper Type on Pulping Results

Beating Time (min.)	Property and Two Types of Chippers													
	Acceptable Pulp Yield (%)		% Rejects		Kappa Number		Bulk (cc/gm)		Burst Factor		Tear Factor		Breaking Length (Meters)	
	(C	K)	(C	K)	(C	K)	(C	K)	(C	K)	(C	K)	(C	K)
0	51.6	48.6	1.0	7.6	25.0	22.2	1.63	1.72	46	35	88	87	8,520	8,000
10							1.39	1.43	81	77	97	107	10,390	10,480
20							1.35	1.31	95	90	87	99	10,980	10,510
30							1.27	1.29	97	96	76	94	11,080	12,370
40							—	1.24	96	100	58	81	8,880	8,970

Sulfate Cook. Gray Birch stemwood, debarked.
C = Carthage Chipper
K = Klockner Chipper

The Carthage chips gave a slightly higher yield of screened pulp than did the Klockner chips, 51.5 compared with 48.5 percent. The pulp from Klockner chips contained a much higher percentage of rejects than did that from the Carthage chips. This indicates that the Klockner cutting action may hinder subsequent cooking liquor penetration. It should be noted, however, that the Klockner reject pulp was "soft" and under commercial fiber handling operations it would, in large part, be defibered and recovered as acceptable fiber.

The strength properties of the pulp were not affected significantly by the type of chipper used. One exception is a higher tearing strength for the pulp from Klockner chips. No explanation is advanced for this.

It appears that the type of chipper creates no important difference in either the yield or strength properties of puckerbrush pulp produced by the sulfate process. Therefore that chipper, in this case the Klockner, which is more adaptable in processing small size materials such as puckerbrush presents an advantage.

(E) Consumption and Characteristics of Chemicals Used in Sulfate Pulping of Puckerbrush.

The consumption of chemicals per unit of pulp produced should be greater in puckerbrush pulping than in the case of pulp from normal size trees. Two reasons for the higher consumption are the bark which uses chemical with very low return of fiber (see Appendix, Table 20A), and the relatively young carbohydrate portion of the puckerbrush which is more susceptible to chemical degradation than is that of more mature trees. Thus, for puckerbrush, a lower yield is realized and a higher chemical consumption might be expected.

The spent liquor remaining at the conclusion of a puckerbrush cook might also be expected to have a different composition than that resulting from pulping normal size wood. For example, if essentially the same chemical-to-wood ratio is used for puckerbrush and for normal chips, the spent liquor from the puckerbrush would carry a higher ratio of organic-to-inorganic solids. However, if a higher chemical-to-wood ratio were used for the puckerbrush, the spent liquor might have an organic-to-inorganic ratio approximately the same as or even lower than that from the normal chip pulping.

"Chemical consumption" is something of a misnomer because most of the active chemicals in the cooking liquor are recovered from the spent liquors and reused in what is essentially a cyclical closed system. However, the term does give an indication of what percentage of the active chemical in the fresh cooking liquor has combined with wood and bark components during the cook.

In the sulfate pulping process, energy is recovered from the organic portion of the spent liquor by burning the solids in a recovery furnace and producing steam. The inorganic solids then pass through the recovery process and are reused in the cooking liquor. Generally the higher the organic/inorganic ratio of the spent liquor, the greater its heating value.

For the purpose of determining the "chemical consumption" and the spent liquor composition in puckerbrush pulping, cooks were made on six species. They were red maple, gray birch, aspen, alder, willow, and pin cherry. The stems and branches, both with bark intact, were pulped separately. A sample of commercial hardwood chips, debarked, was pulped as an internal standard for comparison. Pulping conditions were those described in Table I.

Kappa number and total yield of unscreened pulp were determined for each sample. The spent liquors were analyzed for active alkali, sulfidity, and for the ratio of organic-to-inorganic materials. The results are shown in Table XVII.

For each species the yield is less for the branches than for the stemwood, in agreement with previous results. The yield differences appear not to be as large as has previously been shown and this is because total unscreened yield is shown here and this includes reject material which normally is higher for the branch portions.

Kappa numbers are comparable to those from previous work with the branch pulp having the higher values for all species.

The figures for chemical consumption show that more chemical is "consumed" by all puckerbrush species than by the commercial chips. Also, for each puckerbrush species, the branch portion shows a higher consumption than the stemwood. These results are in agreement with the ideas postulated in the preceding discussion, i.e., yield decreases and chemical consumption increases with increasing proportions of bark-to-wood.

It is noted that the chemical consumption never exceeded 85 percent which means that sufficient chemical was charged to the digester for every cook and there was always a residual of unused active alkali in the spent liquor. Commercial pulping practice usually results in an 80 to 85 percent consumption of chemical.

The ratio of organic-to-inorganic solids in the spent (black) liquor is higher for branches than for stemwood with one exception, aspen. Again, this results from the higher proportion of bark-to-wood in the branches and approximately 80 to 90 percent of the bark appears as dissolved organic material in the spent liquor.

Table XVII

Chemical Consumption in Puckerbrush Pulping
(Sulfate Process)

Species and Section Pulped	Total Pulp Yield (%)	Kappa Number	Percent of Total Chemical Consumed	White Liquor Sulfidity / Black Liquor Sulfidity	Ratio in Black Liquor Organic Solids / Inorganic Solids
Commercial Hwd Chips	50.5	30.1	66	0.39	1.66
Red Maple Stem	51.8	23.8	72	0.39	1.83
Red Maple Branches	45.2	37.0	80	0.36	1.98
Gray Birch Stem	47.7	19.0	77	0.52	1.65
Gray Birch Branches	39.8	37.1	81	1.03	2.13
Aspen Stem	48.3	22.7	78	0.55	1.97
Aspen Branches	40.9	34.2	82	0.99	1.64

Alder Stem	48.8	32.3	78	0.56	1.99
Alder Branches	39.8	39.8	85	0.99	2.16
Willow Stem	50.1	29.4	73	0.59	1.70
Willow Branches	47.0	36.7	76	0.73	2.24
Cherry Stem	49.9	22.9	73	0.72	1.69
Cherry Branches	45.4	29.9	79	1.30	1.93

The ratio of sulfidities of the fresh and spent liquors shows, with one exception, higher values for the branchwood than for the stemwood. A value less than unity for this ratio indicates that of the two active chemicals, sodium hydroxide and sodium sulfide, in the cooking liquor the former is "consumed" in the pulping reactions to a greater degree than is the latter. The fact that the ratio is higher in the case of branch pulping may indicate more nearly equal consumption of the two chemicals. Thus, the composition of the inorganic part of black liquor is affected by the bark and small branch wood. Further study of this would be required before definite conclusions could be made.

It is apparent that puckerbrush pulping would have some effect on the chemical recovery operations of sulfate pulping. Compared with the conditions existing in pulping of normal chips, the spent liquor will have a higher organic content and possibly a different heating value; the charge of chemical to the digester may need to be higher, and the sodium-sulfur ratio in the recovery cycle will be different.

(F) A Chemical Characteristic of Pulp from Puckerbrush.

A chemical analysis was made on the pulps previously described in Section E to determine their alkali solubility. This analysis gives quanti-

Table XVIII

Alkali Solubility of Puckerbrush Pulps

Species and Section		Total Pulp Yield (%)	Kappa Number	Alkali Solubility (%)
Commercial Hwd		50.5	30.1	5.41
Red Maple	Stem	51.8	23.8	7.38
Red Maple	Branches	45.2	37.0	8.51
Gray Birch	Stem	47.7	19.0	9.37
Gray Birch	Branches	39.8	37.1	8.43
Aspen	Stem	48.3	22.7	8.68
Aspen	Branches	40.9	34.2	6.89
Alder	Stem	48.8	32.3	11.70
Alder	Branches	39.8	39.8	9.90
Willow	Stem	50.1	29.4	8.93
Willow	Branches	47.0	36.7	8.10
Cherry	Stem	49.9	22.9	7.49
Cherry	Branches	45.4	29.9	7.13

tative information concerning the hemicellulosic content of the pulp. This is the carbohydrate portion that is composed of shorter chain length and more reactive molecules than the alpha-cellulose. If present in the proper proportion with the longer chain, less reactive alpha-cellulose, it can add to the physical strength of paper made from the pulp. Reference to Table XVIII shows that all puckerbrush pulps exceed the commercial pulp in alkali solubility, indicating a higher content of hemicellulosic material for the puckerbrush. This accounts, in part, for the fact that some of the puckerbrush pulps are stronger than the commercial pulp.

(G) Other Results.

Several other subjects that would be of importance in a general examination of the potential sources of fibrous raw material were investigated. This work and the results and conclusions obtained were limited in scope. They are discussed in the Appendix.

Conclusions

The results observed in this study lead to the following conclusions concerning the use of puckerbrush as a source of fiber for the paper industry:

(1) Mixtures of puckerbrush species can be satisfactorily pulped by the sulfate process to produce a pulp slightly lower in yield but comparable in strength characteristics to commercial hardwood sulfate pulps.

(2) The same is true for mixtures of puckerbrush and commercial hardwood chips.

(3) Puckerbrush cannot be pulped as well by an acidic process (magnesium bisulfite) as by the sulfate process. However, higher yields are realized and a lower grade of pulp, suitable for some unbleached papers and paperboard, can be produced.

(4) The neutral sulfite semichemical process will pulp puckerbrush in the yield range 65 to 75 percent, producing a pulp which generally is quite suitable for corrugating medium.

(5) Pulp properties, particularly strength, will vary with height location of wood in the tree. Generally there is a decrease in strength from stump to top, the most drastic decrease occurring at the top section. Age of the tree at the stump, within the range 10 to 30 years, has no material effect on strength of pulp produced from that section.

(6) Chip size and type of chipping action of the two chippers used in this work have no significant effect on the quality of puckerbrush pulp.

(7) In sulfate pulping of puckerbrush the chemical "consumed" per cook increases as the proportion of bark-to-wood increases, e.g., it is greater for the branch component than for the stemwood. The spent liquor has a higher ratio of organic-to-inorganic materials than does that from commercial hardwoods because of the dissolved bark components. This probably gives the spent liquor solids a higher heating value and would necessitate some changes in the chemical recovery system. It does *not* mean that sulfate pulping of puckerbrush would require more pulping chemical per unit of pulp produced.

(8) Puckerbrush sulfate pulp contains a greater percentage of hemicellulosic material than does pulp from commercial woods.

Literature Cited

1. Chase, A. J., F. Hyland, and H. E. Young. 1971. Puckerbrush Pulping Studies. Life Sciences and Agriculture Experiment Station, Univ. of Maine, Tech. Bulletin 49.
2. Doane, F. P. Jr., December 1972. Our Fiber Supplies. American Paper Industry: 33-34.
3. McAlpine, R. G., C. L. Brown, A. M. Herrick and H. E. Ruark. 1966. "Silage" Sycamore Forest Farmer: 26:6
4. Steinbeck, K and J. T. May. 1971. Misc. Rept. 132, Life Sciences and Agriculture Experiment Station, University of Maine.
5. Dawson, D.H. and J. B. Crist. 1972. 6th TAPPI Forest Biology Conference, IPC, Appleton, Wisconsin.
6. Brodie, J. D. and A. R. Ek. *Ibid.*
7. Young, H. E. 1971. Forest Biomass Studies Misc. Rept. 132, Life Sciences and Agriculture Experiment Station.
8. McKnight, V. J. 1972. Innovations in Silvicultures: Are They Necessary? Forest Farmer 31(10): 12.
9. Zobel, B. J. and R. C. Kellison. 1972. Short-Rotation Forestry in the Southeast. TAPPI, Vol. 55, No. 8 (Aug.) pp. 1205-08.
10. Dyer, R. F., A. J. Chase and H. E. Young. Potential Pulp from Presently Non-Commercial Woody Perennials. Pulp & Paper Magazine of Canada, Jan. 5, 1968.
11. Young H. E. 1972. Puckerbrush Utilization for Paper Products. TAPPI. Vol. 55, No. 8. (Aug.) pp 1202-04.
12. Young, H. E. Woody Fiber Farming. A paper presented at a meeting of the Highway Research Board, Washington, D.C. Jan. 1972.
13. Hyland, F. In process of publication by LSA Experiment Station. Univ. of Maine.
14. Kurrle, F. L. 1973. Nitric Acid Digestion of Logging Residues of Red Spruce. TAPPI. Vol. 46, No. 4. pp. 267-272.
15. Young, H. E. and A. J. Chase. 1965. Fiber Weight and Pulping Characteristics of the logging Residue of Seven Tree Species in Maine. Maine Agricultural Experiment Station, Univ. of Maine, Tech. Bulletin 17.
16. Unpublished Masters theses, Univ. of Maine. Keniston. W. W. 1964. Physical and Chemical Characteristics of Pulp from Various Parts of the Tree.

Michaud, C. . and D. W. Smith. 1964. Chemical and Physical Properties of Sulfate Pulp from Various Parts of Deciduous Trees.
Martin, R. W. and N. W. Hanson. 1965. Whole Tree Pulping—Sulfate Pulping of Red Maple.

17. Complete—Tree Utilization. An Analysis of the Literature. J. L. Keays.
Part I: Unmerchantable Top of Bole. 1970.
Part II: Foliage. 1971.
Part III: Branches. 1971. Report VP-X-71.
Part IV: Crown and Slash. 1971. Report VP-X-77.
Part V: Stump, Roots and Stump-Root System. 1971. Report VP-X-79.
All published by the Department of Fisheries and Forestry, Canadian Forestry Service.
18. ——————— Whole Tree chips produced for test. Forest Ind. 98(7):67 (1971).
19. Eskilsson, S. Whole tree pulping. Part I Fibre properties. Sevensk Papperstidning 75, p. 3970402, (1972)
20. Rydholm, S. A. Pulping Processes, Intersciences Publishers, Page 412.
21. Hakkila, P. 1971. Personal correspondence.

APPENDIX

Tables of Results of Beater Tests

Tables 1A- 4A Puckerbrush—Commercial Hardwood Mixtures

Tables 5A- 8A Pulps from Various Locations in a Single Tree

Tables 9A-12A Pulps from Stem Section of Trees of Different Ages.

Cold Caustic Pulping of Puckerbrush

Chipping Puckerbrush

Bark Component of Puckerbrush

Pulping Puckerbrush Bark

Dimensions of Puckerbrush Bark Fibers

Sulfate Pulping of Conifer Needles

Table 1A
Effect of Beating on Handsheet Bulk
(Puckerbrush-Commercial Hardwood Mixtures)

		25/75		50/50		75/25		100%	
Beating Time (minutes)	100% CH	WAL	MAB	WAL	MAB	WAL	MAB	WAL	MAB
0	1.87	1.81	1.87	1.81	2.08	1.71	1.79	1.75	1.82
10	1.61	1.60	1.62	1.60	1.79	1.61	1.63	1.57	1.62
20	1.48	1.50	1.53	1.51	1.51	1.54	1.54	1.52	1.52
30	1.40	1.44	1.42	1.45	1.44	1.47	1.48	1.46	1.46
40	1.33	1.37	1.34	1.37	1.36	1.43	1.40	1.42	1.40

Table 2A
Effect of Beating on Handsheet Burst Factor

		25/75		50/50		75/25		100%	
Beating Time (minutes)	100% CH	WAL	MAB	WAL	MAB	WAL	MAB	WAL	MAB
0	21	27	25	32	20	36	33	42	32
10	47	53	53	55	47	61	57	64	55
20	68	69	73	70	70	72	70	70	70
30	78	75	80	77	77	79	77	78	74
40	78	81	81	75	82	77	80	82	75

Table 3A
Effect of Beating on Handsheet Tear Factor

		25/75		50/50		75/25		100%	
Beating Time (minutes)	100% CH	WAL	MAB	WAL	MAB	WAL	MAB	WAL	MAB
0	72	76	70	76	68	69	77	72	75
10	83	82	82	81	78	75	79	69	78
20	83	77	83	74	79	73	74	75	70
30	82	77	76	71	76	68	68	67	71
40	72	83	71	71	68	68	65	69	65

Table 4A
Effect of Beating on Handsheet Tensile Strength
(Breaking Length in Meters)

		25/75		50/50		75/25		100%	
Beating Time (minutes)	100% CH	WAL	MAB	WAL	MAB	WAL	MAB	WAL	MAB
0	5600	6070	6200	7510	—	6270	6890	9400	7450
10	9200	9920	9960	10460	8810	10450	9580	11360	10130
20	10970	11600	11240	10990	9990	11970	11460	12090	10830
30	12500	11910	12660	11570	11670	12430	11300	12110	11770
40	11930	12140	12070	12240	12070	11640	12190	10770	11080

Table 5A

Effect of Location of Wood in Tree on Handsheet Bulk
(Bulk in cc/gm)

	Location and Ages in Years			
Beating Time (min.)	Stump (60)	Above Stump (45)	Below Top (16)	Top (8)
0	2.08	2.14	2.19	2.21
10	2.00	2.06	1.99	1.99
20	1.78	1.94	1.82	1.80
30	1.70	1.82	1.76	1.61
40	1.59	1.76	—	—

Sulfate cook. Wood from single aspen tree with bark intact.

Table 6A

Effect of Location of Wood in Tree on Handsheet Burst Factor

	Location and Ages in Years			
Beating Time (min.)	Stump (60)	Above Stump (45)	Below Top (16)	Top (8)
0	33	32	32	31
10	58	50	46	39
20	72	70	49	46
30	77	75	58	47
40	72	72	—	—

Sulfate cook. Wood from single aspen tree with bark intact.

Table 7A

Effect of Location of Wood in Tree on Handsheet Tear Factor

	Location and Ages in Years			
Beating Time (min.)	Stump (60)	Above Stump (45)	Below Top (16)	Top (8)
0	69	62	63	45
10	80	80	76	42
20	76	88	81	42
30	73	78	57	45
40	64	67	—	—

Sulfate cook. Wood from single aspen tree with bark intact.

Table 8A

Effect of Location of Wood in Tree on Tensile Strength
(Breaking Length in Meters)

	Location and Ages in Years			
Beating Time (min.)	Stump (60)	Above Stump (45)	Below Top (16)	Top (8)
0	9450	8830	6230	7200
10	11630	10860	8790	7530
20	—	11600	9850	9360
30	—	12170	11010	10200
40	—	10440	—	—

Sulfate cook. Wood from stem sections of 3 gray birch trees with bark intact.

Table 9A

Effect of Tree Age on Handsheet Bulk
(Bulk in cc/gm)

	Ages in Years		
Beating Time (min.)	10	20	30
0	1.66	1.66	1.84
10	1.66	1.56	1.76
20	1.47	1.44	1.51
30	1.35	1.26	1.46

Sulfate cook. Wood from stem sections of 3 gray birch trees with bark intact.

Table 10A

Effect of Tree Age on Handsheet Burst Factor

	Ages in Years		
Beating Time (min.)	10	20	30
0	50	71	50
10	82	100	85
20	89	96	88
30	88	94	87

Sulfate cook. Wood from stem sections of 3 birch tree with bark intact.

Table 11A

Effect of Tree Age on Handsheet Tear Factor

Beating Time (min.)	Ages in Years		
	10	20	30
0	88	106	82
10	86	90	92
20	77	85	85
30	71	75	77

Sulfate cook. Wood from stem sections of 3 gray birch trees with bark intact.

Table 12A

Effect of Tree Age on Handsheet Tensile Strength
(Breaking Length in Meters)

Beating Time (min.)	Ages in Years		
	10	20	30
0	9280	10510	9940
10	10420	12470	10920
20	9220	11180	10370
30	8580	9420	8900

Sulfate cook. Wood from stem sections of 3 gray birch trees with bark intact.

(2) Cold Caustic Pulping of Puckerbrush.

The "cold caustic" pulping process is so-named because it consists of treating wood chips with a sodium hydroxide solution at relatively low temperatures and essentially atmospheric pressure. It is a soaking process in which the chemical reaction is mild but sufficient to permit subsequent fiber separation using a mechanical treatment. The yield of pulp is very high, the quality and strength relatively low. However, the pulp is used extensively in corrugating board, newsprint and other cheaper grades of paper (20).

A few cold caustic treatments were made on gray birch stemwood with bark intact. The variables of temperature, time, and sodium hydroxide concentration were studied.

The chemical treatment was followed by a mechanical defibering treatment of the swollen and softened chips in a laboratory Bauer disk refiner. In the refining treatment the variables investigated were number of passes through the refiner, type of refiner plate, and plate clearance.

Table 13A

Summary of Results of Cold Caustic Cooks

Cook #	% NaOH based on Dry Chip Wgt.	Time of Treatment (hr.)	Temperature (°F)	Yield Acceptable Fiber (%)	% Rejects	Refiner Treatment
5	3.5	2	70	67.4	10.4	1 pass. Fine Fiberizing plates
6	3.5	4	70	67.9	8.1	1 pass. Fine Fiberizing plates
3	5.0	2	85	38.1	33.5	1 pass. Open defibering plates
4	10.0	2	100	33.6	33.6	1 pass. Open defibering plates
2	10.0	2	150	49.2	7.2	1 pass. Fiberizing plates
1	10.0	1	150	51.3	11.4	1 pass. Fiberizing plates
7	3.5	2	70	72.7	3.5	3 passes. Coarse, medium, then fine
8	3.5	2	70	77.6	5.3	plates 2 passes. Fine plates for both.

Initial conc. of caustic liquor = 2.0% by weight.

Table 14A

Comparison of Cold Caustic and Sulfate Puckerbrush Pulps

Beating Time (min.)	C.S. Freeness		Bulk (cc/gm)		Burst Factor		Tear Factor		Breaking Length (meters)	
	CC	S	CC	S	CC	S	CC	S	CC	S
0	626	468	2.93	1.63	24	60	60	108	5910	9870
5	571	395	2.85	1.62	27	75	62	96	6410	11550
10	484	352	2.59	1.56	35	84	60	95	7790	12540
20	382	234	2.58	1.38	38	90	60	93	8410	12820
30	279	122	2.63	1.36	41	91	62	82	8910	12510
40	179	—	2.77	—	44	—	62	—	9400	—
50	110	—	2.71	—	40	—	61	—	9310	—

CC = cold caustic pulp from cook 8.
S = sulfate

The product from each treatment was then tested for yield and percent reject material. The results are shown in Table 13A.

Total yields (acceptable fiber plus rejects) were generally in the 70 to 80 percent range. Yield of acceptable fiber generally increased with decreasing caustic-to-wood ratio and temperature of treatment. The refiner plates referred to as coarse, medium, and fine serve the following functions. The coarse plate simply breaks down the swollen chips into smaller pieces or fiber bundles, the medium plate continues the defibering or fiber separation process, and the fine plate actually does some refining or fiberizing of the individual fibers.

Cooks, 5, 6, 7, and 8 were all made under the same conditions of percent caustic and temperature. Cook 6 differed from the others only in the time of treatment. The results indicate that nothing is gained by continuing the chemical soak beyond two hours. Comparison of Cooks 5, 7, and 8 shows the effect of different mechanical treatment. First it is apparent that the chips from these cooks did not require mechanical treatment with a series of different refiner plates, e.g., the yield from Cook 7 was not as high as that from Cook 8 for which only the fine plates were used. The effect of multiple passes is shown by comparing Cooks 5 and 8. Here it is seen that a second pass increased the yield of acceptable fiber by ten percentage points.

A sample of the pulp from Cook 8 was treated in the TAPPI beater and handsheets were made and tested for strength properties. Table 14A compares the results of these tests with those made on gray birch made by our standard sulfate process. The results are very encouraging. The cold caustic pulp is of course considerably weaker than the sulfate but it does have all the characteristics common to commercial grades of cold caustic hardwood pulps.

(3) Chipping Puckerbrush.

The Pulp and Paper Laboratory of the Chemical Engineering Department is equipped with a four-knife experimental size Carthage disk chipper. It has been entirely satisfactory for chipping roundwood since its installation many years ago. Because it was available and because of its satisfactory performance with roundwood it was used to chip puckerbrush. For convenience in handling inside the laboratory the branches, stems and roots were cut into sections not more than six feet long. It was immediately apparent that the disk type chipper would not cut the roots or branches into normal length as pieces up to nine inches in length came through the knives. The amount of overlength sections was considerably reduced by tying roots and branches into bundles with string for the first time through the chipper and then chipping each batch two more times. Following this it was necessary to remove the sections of string and it was still necessary for the crew to manually cut overlength branch and root sections separated in subsequent screenings. All of this added effort was time consuming on a research scale and completely unsatisfactory for any commercial application.

A chipper of different design was necessary to eliminate this problem. Letters were written to a number of manufacturers who replied suggesting some variation of a disk type chipper. The Carthage Company, however, suggested a drum type chipper with feed rolls designed and manufactured by the Klockner Company of Hirtscheid, West Germany. A 230 x 120 mm H-2 W type "H" chipper for pulp size chips was ordered through their American agents, U. S. Machinery Company of New York. It was installed in the Pulp and Paper Laboratory located in Aubert Hall in May 1971. The 1,500 pound chipper was placed on six inch plywood runners secured with bolts extending through the plywood to a depth of about six inches into the concrete floor. Appropriate electrical devices were included in the electrical connections for the 110 volt three phase system.

The two-knife drum-type roll revolves at approximately 800 rpm and is driven by a 25 horsepower motor. The two feed rolls are operated separately by a one horsepower motor attached to the chipper. The speed of the drum and the feed rolls is regulated at the factory for either short or long chips. The so called long chips produced are standard size pulp chips. The chipper was started in May 1971 and has operated satisfactorily ever since. There is only a negligible amount of vibration in the laboratory and only a moderate amount of noise is generated despite the fact that it is housed indoors.

Branches, stems, and stems and branches together of the six puckerbrush species were separately put through the Klockner and then the chips were carefully examined. Very few of the chips from the small branches were more than two inches in length. During the previous summer it had been found that branches of small diameter will pulp easily even though longer than one inch; therefore, none of the overlength branches had to be rechipped or manually cut into smaller pieces.

The pulp yield from hardwood leaves is negligible. Therefore, if the leaves are not removed prior to pulping, there will be additional cost due to the space occupied by the leaves in the digester and the additional chemicals necessary to digest the leaves. Consequently, in the initial tests of the Klockner and in all subsequent chipping for specific pulping studies, the leaves were manually removed before chipping.

It was, however, quite natural to wonder what the drum knives would do to the leaves. To test this, branches with leaves representing each of the six puckerbrush species were separately put through the Klockner. In each case most of the leaves were removed intact due to separation of the leaf petioles from the branches. Engineers who observed these demonstrations were of the opinion that a fan or some other winnowing device could be used to separate the leaves from the chipped material as the latter is being moved upward to a van for transportation to a mill.

Nearly everyone who has seen a demonstration of the Klockner seems to immediately extrapolate this small chipper in a stationary mount into a self-propelled puckerbrush harvester-chipper including a conveyor belt to move the chips into a transportation van. When such a machine is constructed, it probably will take everything in its path. This means that the occasional softwood tree that occurs in hardwood stands will be included. This raises the question of the efficiency of the Klockner on young softwood trees.

To partially answer this question a few White Pine, Hemlock, Red Spruce and Balsam Fir, all of puckerbrush size, were felled in the University Forest in Stillwater, Maine and brought to the laboratory. The material for each species was randomly separated into groups. For one group the needles were left on the branches and for the other group the needles were manually removed. The samples of each softwood species without needles passed through the chipper as satisfactorily as the puckerbrush species. Inasmuch as the material had been freshly cut in the summertime, some gum accumulated on the knives. The material from each softwood species with needles was then chipped separately and carefully examined. For each of the four species, approximately half of the needles were cut off with the remainder firmly in place.

Another question about the Klockner that has occurred to pulp and paper engineers is the percentage of chips in each size class it produces as compared to a disk chipper. To partially answer this, TAPPI T 16 ts-61 "Sieve Analysis of Pulpwood Chips" was meticulously followed to compare chips from the Carthage and the Klockner chippers in the laboratory. Branches were not included because the Carthage does not cut them all into short pieces.

Eight year old Red Maple stems ranging from 1.0 to 2.5 inches in diameter were cut into six foot lengths and brought to the laboratory in June 1971 where they were randomly separated into two piles of similar dimensions. The stems were allowed to dry for three days before conducting the tests.

Following the TAPPI standards, separate tests were made for both the Klockner and the Carthage indicating that a 5.0 minute shaking period was sufficient for both. According to the TAPPI standard, the third test results are accepted although more tests can be made. A fourth test was made with the results of all four shown in Table 15A. It is interesting to note the fairly uniform results by sieve classes for material from each of the chippers.

The oversize and dustpan categories when added are nearly the same for the two chippers. Although the percentages in each of the acceptable size classes vary somewhat from one chipper to the other, the totals do not differ by a significant amount. Based on all of the chipping studies conducted in the laboratory we concluded that the Klockner drum type chipper performs in a similar manner to the Carthage disk type chipper on stemwood but that the Klockner performance on small stems and branches is far better than the Carthage. Until such time as disk type chippers can be shown to produce satisfactory chips from small stems and branches we will recommend drum type chippers for puckerbrush and the tops of large trees where small stems and branches will be chipped.

Table 15A

Sieve Analysis of Pulpwood Chips Obtained from the Carthage Disk Type and the Klockner Drum Type Chippers

Chipper	Screen Mesh Size	Percent Retained by Screen			
		Test 1	Test 2	Test 3 (TAPPI choice)	Test 4
CARTHAGE					
	1 1/8	7.9	10.0	8.0	5.8
	7/8	17.9	18.9	19.4	19.4
	5/8	44.2	46.7	45.7	45.4
	3/8	25.2	21.2	22.5	24.0
	3/16	3.8	2.8	3.9	4.5
	dustpan	1.0	0.5	0.5	0.8
KLOCKNER					
	1 1/8	4.9	8.2	7.2	5.9
	7/8	24.1	24.1	25.2	27.4
	5/8	37.1	35.2	35.7	36.6
	3/8	26.2	25.9	23.9	24.1
	3/16	6.4	5.0	6.3	4.9
	dustpan	1.4	1.6	1.7	1.1

(4) Bark Component of Puckerbrush.

Between the wood and the bark lies the cambium, a thin sheet of dividing cells responsible for the diameter growth of the stem and branches of all woody trees and shrubs. Cell division on the internal side of the cambium forms cells which mature into wood; cell division on the external side of the cambium forms cells which mature into bark. Bark thickness is always much less than wood thickness because the bark cells are generally smaller, and fewer, and because some of the bark disintegrates as the stem and branches enlarge.

The standard mensuration textbooks for North America indicate that bark, on a volume basis, occupies between 10 and 15 percent of the merchantable bole with some variation due to tree size within a species and some between species. Dyer, Chase and Young (10) show that blueberry and willow stems of 1.5 inches in diameter and less have about 34% bark on a weight basis. From the available information it is apparent that the amount of bark is a function of species, age and diameter with the bark: wood ratio approaching 1:1 in small branches and as low as 1:9 at the base of large stems on either a volume or weight basis.

There is no indication that any of the bark-chip-separation-segregation processes that have been or are currently being investigated would be satisfactory for small stems and branches both large and small. Therefore, a basic philosophic tenet in the utilization of puckerbrush species is that the bark will be used in every industrial process that reconstitutes raw material from the forest. Chase, Hyland and Young (1) have demonstrated that pulp of slightly poorer physical properties can be made from puckerbrush with the bark included in all components: roots, stem and branches without leaves. Hakkila (21) has demonstrated that high quality fiberboard and particle board can be made from tops of Norway Spruce and Scotch Pine including the needles. These results raise two questions:

(1) How much fiber is in the bark and needles?

(2) How much of the above ground portion of each puckerbrush species is bark?

The first question is being studied by Professor Fay Hyland and will be reported in a separate bulletin at a later date. To partially answer the second question, a single tree or a single stem with branches from a clump of each of six puckerbrush species was felled at a three inch stump and brought to the laboratory. This was done in June, when the bark could be separated easily from the wood with a knife. The following procedure was used to estimate the amount of bark in the above ground portions of the tree:

1. The leaves were stripped from the branches.
2. The branches were cut from the stem and then the branches and stem were separately weighed.
3. Disks from the stem and sections of the branches were randomly selected to represent proportionately the various sizes of stem and branches.
4. A hand knife was used to separate the bark from the wood in the stem disks and branch sections.
5. Fresh weight of the bark and wood of the stem disks and branch sections was obtained and then the material was placed in an oven at 105°C for 24 hours.
6. Dry weight of wood and bark of stem disks and branch sections was obtained.
7. The moisture content and proportion of wood and bark in the stem and branch components was applied to the fresh weight data to estimate the fresh and dry weight of the wood and bark in the stem and in the branches separately and finally for the entire above ground portion except for the leaves.

The fresh weight data and the moisture content of the wood and bark in the stem and branch components of the individual specimens of the six species are shown in Tables 16A and 17A. The laboratory information was used to translate this into percent wood and bark on a dry weight basis in Table 18A. Table 19A shows that bark on a dry weight basis is slightly less than 20 percent of the total stem and branches above the stump, aspen being an exception.

It is important to bear in mind that there was only one specimen per species. A similar effort on 20 to 30 specimens per species would be necessary to determine variation within species and between species with any degree of confidence.

Table 16A

Fresh Weight in Grams of Individual Trees and Shrubs (Above Ground and exclusive of Leaves) and Proportion in Stem and Branches

Species	Stem	Branches	Total above stump	% Stem	% Branches
Gray Birch	4414	988	5402	81.7	18.3
Aspen	8745	1255	10000	87.5	12.5
Red Maple	6038	224	6262	96.4	3.6
Pin Cherry	2089	735	2824	74.0	26.0
Alder	2867	733	3600	79.7	20.3
Willow	3189	385	3547	89.9	10.1

Table 17A

Percent Moisture Content of Wood and of Bark by Component

Species	Stem Wood	Stem Bark	Branches Wood	Branches Bark
Gray Birch	43.9	43.3	39.4	46.5
Aspen	46.0	46.1	45.3	54.5
Red Maple	38.7	45.9	42.9	50.0
Pin Cherry	45.9	50.8	44.9	49.3
Alder	40.6	44.9	52.4	52.2
Willow	31.4	43.4	70.3	56.2

Table 18A

Wood and Bark as Percent of Dry Material by Component
(Above stump and excluding leaves)

Species	Stem Wood	Stem Bark	Branches Wood	Branches Bark
Gray Birch	85.1	14.9	73.0	27.0
Aspen	76.2	23.8	59.7	40.3
Red Maple	84 2	15.8	72.5	27.5
Pin Cherry	85.2	14.8	73.0	27.0
Alder	83.3	16.7	47.3	52.7
Willow	81.7	18.3	73.7	26.3

Table 19A

Wood and Bark as Percent of Dry Material
(Above stump and excluding leaves)

Species	Wood	Bark
Gray Birch	82.7	17.3
Aspen	74.2	24.8
Red Maple	83.9	16.1
Pin Cherry	81.8	18.2
Alder	80.2	19.8
Willow	81.0	19.0

(5) Pulping Puckerbrush Bark.

Barks from six puckerbrush species were obtained during the sap-peeling season. They were pulped by the sulfate process using the same conditions as those used for the whole puckerbrush. The yields of screened material and rejects obtained in these cooks are shown in Table 20A.

The yields are surprisingly high for some of the barks, particularly the aspen, maple, and gray birch. It was noted that a portion of this "accepted" material was not fibrous and may have resulted from incomplete cooking of the bark. It is possible that bark has a higher chemical demand and the cooking liquor may have been exhausted of active alkali before termination of the cook. A more complete study is required before definite conclusions concerning yield can be made.

The material from the bark cooks varied greatly in physical characteristics from essentially a non-fibrous element in the case of gray birch and alder to exceedingly long, fine fibers from the willow bark.

The material from the aspen and red maple barks appeared to be most nearly like that from the wood portion of the puckerbrush. Samples were treated in the TAPPI beater and handsheets were made and tested. Table 21A contains the results of those tests.

The results of this abbreviated study of puckerbrush bark pulping produced the following observations:

Bark pulp contains particles of widely varying shapes and sizes. Some elements are fibrous, others are short and chunky, some are very gelatinous in character. A mat could not be formed with the gray birch and alder so they could not be screened in the normal way. Components of the gray birch bark went through the cooking operation apparently without reacting with the cooking chemicals. The willow bark produced hair-like fibers, some being several inches long. There might be a potential for this kind of fiber; however, it is very difficult to handle in water, and of course is produced in very low yield.

Handsheets of the bark pulp were very weak, generally having only 10 to 15 percent of the strength of pulps from the complete puckerbrush.

Barks of the puckerbrush species have an adverse effect on pulp strength. They do contribute to the *overall yield* of material realized from a given amount of puckerbrush. However, this gain is negated to an extent by an increase in bleach chemical requirements, the possibility no changes in the chemical recovery system as a result of a different spent liquor composition, and by a loss in potential strength properties.

A separate discussion concerning the measurement of fresh weight and moisture content of bark in the stem and branch components of the six puckerbrush species is contained in Section 4 of the appendix of this report.

Table 20A

Pulping of Puckerbrush Bark

Type of bark	Screen Yield of Pulp %	% Rejects	Comments
Aspen	35.8	20.0	Fibrous. Some promise.
Red Maple	34.5	15.5	Fibrous. Some promise.
Gray Birch	40.5	—	Much uncooked material Gelatinous with little fibrous nature.
Alder	6.8	—	Mush. Most of material lost through screens. No fiber.
Cherry	27.8	5.3	Fibrous. Some promise.
Willow	25.7	—	Fibers very long and hair-like. Very difficult to handle or form into sheet.

Sulfate cook. Bark from stems of puckerbrush.

Table 21A

Properties of Pulp from Puckerbrush Bark

Type of Bark	Beating Time (min.)	C.S. Freeness (ml.)	Bulk (cc/gm)	Burst Factor	Tear Factor	Breaking Length (meters)
	0	103	2.94	5	13	1770
Aspen	5	77	2.88	6	15	1870
	10	53	2.82	7	15	2060
	0	136	2.56	11	30	3090
Red Maple	5	104	2.43	13	25	3450
	10	117	2.31	15	24	3780

Sulfate cook. Bark from stems.

(6) Dimensions of Puckerbrush Bark Fibers.

Table 22A shows the length, diameter, lumen diameter, and wall thickness of bark fibers from six puckerbrush species. The dimensions of fibers from the wood portion of the corresponding species are included for comparison.

It appears at first glance that the results shown in Table 22A and observations made in section 5 immediately preceding are contradictory. Is should be noted that prior observations concerning bark pulp referred to the appearance of the pulp in mass whereas the results in this section were obtained by observation of small samples using the microscope. There are, of course, fibrous elements in all barks, even the alder and birch, but their number and influence on pulp properties is probably overwhelmed by other elements of a non-fibrous character.

Comparing dimensions of the bark fibers and the wood fibers of the same species it is seen that the bark fibers are longer and thinner for all elements (branch, stem, and stump-root), of all species. The bark fibers have very small central cavities (lumens) and thick walls compared with the wood fibers.

It is not possible to relate fiber dimensions to properties of paper made of the bark fibers, shown in Table 21A, because the bark pulp from which those sheets were made contained other bark components whose effects are unknown. However, characteristics of the bark fibers, such as their relatively small diameter and thick walls, would tend to produce paper with low strength and low density, (high bulk).

(7) Sulfate Pulping of Conifer Needles

Needles from white pine, balsam fir, hemlock, and spruce were pulped using the sulfate process conditions the same as those used in puckerbrush pulping. Separate cooks were made for each species. Yields were determined and samples of the fibers obtained for microscopical examination (Table 23A).

Yields were very low and the products were very difficult to wash and screen. Some were very gelatinous and could not be handled with typical sheet forming and testing equipment. Others were short and chunky, or very long, hair-like and easily flocculated. It is suspected that the material was cooked insufficiently and that a treatment long and severe enough to eliminate most of the non-fibrous material would result in extremely low yields of fiber. Comments on the results of this brief study follow.

(a) White Pine. The yield was 19.6 percent. The fibers were very long and could not be made into a well-formed sheet because of flocculation. It is possible that they could be refined to shorter segments making them more manageable for the sheet forming operation. They were the lightest, in color, of the four species.

(b) Balsam Fir. The yield was 16.4 percent. The fibers were very short and dark. It was possible to make a sheet of these fibers but it was extremely fragile.

(c) Hemlock. The yield was 17.8 percent. Fibers were similar to those from the fir needles but lighter in color. This pulp washed and screened with relative ease. It also formed into a sheet which had a uniform appearance but, like the fir, was very weak.

(d) Spruce. The yield was 22.8 percent. Fibers were short but appeared to be more "fiber like" and longer than those from the fir and hemlock needles. It washed and screened easily and formed into a sheet of good appearance having significant strength.

Table 22A

Dimensions of Bark and Wood Fibers

Source of Fiber	Fiber Length (mm)	Fiber Diameter (max.) (microns)	Lumen Diameter (microns)	Fiber Wall Thickness (microns)
Aspen Stem Wood	0.73	27.5	23.5	2.0
Aspen Stem Bark	1.14	21.4	2.8	9.3
Aspen Branch Wood	0.51	23.4	17.2	2.0
Aspen Branch Bark	1.13	10.4	1.7	4.4
Aspen SR Wood	0.77	30.3	26.6	1.9
Aspen SR Bark	0.88	25.7	5.3	10.8
Alder Stem Wood	0.64	23.9	19.0	2.3
Alder Stem Bark	0.73	17.2	5.6	5.8
Alder Branch Wood	0.48	18.4	13.6	2.4
Alder Branch Bark	0.99	16.7	2.1	7.3
Alder SR Wood	0.68	28.9	23.3	2.8
Alder SR Bark	0.80	17.4	3.9	6.7
Birch Stem Wood	0.73	22.6	16.4	3.1
Birch Stem Bark	1.01	17.8	9.6	4.1
Birch Branch Wood	0.61	18.0	13.2	2.4
Birch Branch Bark	0.93	11.5	1.3	5.6
Birch SR Wood	0.68	24.7	19.8	3.0
Birch SR Bark	0.77	18.6	5.8	6.4
Maple Stem Wood	0.62	20.0	13.4	3.3
Maple Stem Bark	0.94	17.5	2.9	7.4
Maple Branch Wood	0.51	17.3	11.8	2.7
Maple Branch Bark	1.41	15.5	2.8	6.3
Maple SR Wood	0.61	27.6	21.9	3.3
Maple SR Bark	0.79	21.1	6.1	7.5
Cherry Stem Wood	0.64	18.6	12.5	3.1
Cherry Stem Bark	0.66	16.1	8.2	3.3
Cherry Branch Wood	0.50	15.3	9.8	2.7
Cherry Branch Bark	1.05	14.4	6.9	4.4
Cherry SR Wood	0.69	24.4	18.4	3.0
Cherry SR Bark	1.06	17.3	2.5	7.4
Willow Stem Wood	0.47	17.0	10.9	3.0
Willow Stem Bark	1.42	14.0	2.4	5.8
Willow Branch Wood	0.46	15.4	10.0	2.7
Willow Branch Bark	2.18	10.5	1.7	4.4
Willow SR Wood	0.50	22.1	16.7	2.9
Willow SR Bark	3.53	11.4	2.0	4.9

SR = Stump and Root
Stem wood debarked for all species
Branch wood and SR wood with bark intact for all species.
All length measurements based on 100 random measurements and diameter measurements based on 25 random measurements.

Table 23A
Sulfate Pulping of Conifer Needles

Needle Species	Pulp Yield (%)	Comments
Balsam Fir	16.4	Fibers very short, dark in color. Formed sheet of good formation but very weak.
Hemlock	17.8	Fibers very short, lighter than those from fir. Well formed but very weak handsheet.
White Pine	19.6	Fibers very long and lightest in in color of all species. Poor formation in handsheet because of flocculation of long fibers. Relatively good fiber strength.
Spruce	22.8	Fibers of medium length. Formed good sheet with best strength of all species.

Even as brief a study as is reported here must lead to the conclusion that inclusion of the foliage of conifers in the pulping operation can serve only as a detriment to the results. It consumes large amounts of chemical with no material return of fibrous product, and what little fiber there is has no outstanding characteristics that can contribute to the pertinent properties of paper.