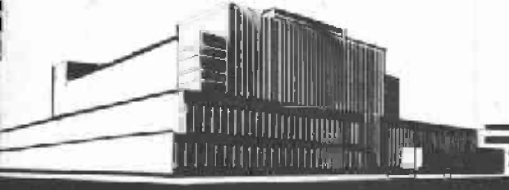
# BOND AND MAGAZINE BOOK PAPERS AND MILK-CARTON PAPERBOARD FROM OLD-GROWTH DOUGLAS-FIR AND RED ALDER PULPS

(Report)

No. 2042

November 1955





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FOREST SERVICE
In Cooperation with the University of Wisconsin

# BOND AND MAGAZINE BOOK PAPERS AND MILK-CARTON PAPERBOARD FROM OLD-GROWTH DOUGLAS-FIR AND RED ALDER PULPS

By

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## Summary

Bond and magazine book papers and milk-carton and punchcard paperboards were made from old-growth Douglas-fir bleached sulfate pulp, alone or mixed with red alder semibleached groundwood, chemiground, or neutral sulfite semichemical pulp. The bond and magazine book papers and milk-carton paperboards were of good quality. A punchcard paperboard was made that had good mechanical properties, but further experimentation would be necessary to develop a satisfactory formation.

The experimental processes were intended to show possible commercial applications. The conditions used and sheet properties characterizing these papers and paperboards are given.

## Introduction

This report presents experimental data on papermaking and papers from old-growth Douglas-fir residues and red alder pulpwood species that are of importance to forest management in the Pacific Northwest. This work was done at the suggestion of the Forest Utilization Service, Pacific Northwest Forest and Range Experiment Station.

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[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

## Objectives

The utilization of old-growth Douglas-fir for the better or stronger grades of paper has not, until the last few years, been extensive. The large standing reserve of this species is not being removed rapidly enough, in some instances, to avoid further deterioration in the woods or to make room for reforestation. To grow younger and more acceptable material for the next century, new outlets are badly needed for the over-age Douglas-fir stands and incidental harvesting residues. At present, mill residues are adequate for pulpmill requirements, and these residues constitute only a small part of the over-age available timber.

Upland red alder is generally not of sufficient size to yield good sawlogs. Consequently, greater utilization of red alder as pulpwood would permit clear cutting for reforestation of pure stands. In addition, the alder is an important source of short, deciduous fibers for certain grades of paper, especially book and magazine papers.

The objectives of this research were (1) to establish the process conditions for the production of pulps, bleached and unbleached, from these two species, and (2) to determine the suitability of these pulps, alone or mixed with each other or market pulps, for such high-grade papers as bond and magazine book papers, and paperboard for milk-carton and punchcard stock.

## Materials

### Woods

The Douglas-fir wood (Pseudotsuga menziesii) used in this study was a composite of three shipments from the Pacific Northwest. Eighty percent of the wood received was in the form of logging-residue bolts from the Oakridge area near Eugene, Oreg., 10 percent was in the form of blocks from Powell River, B.C., and 10 percent was in the form of old-growth chips from Longview, Wash. All material came from sapwood.

The red alder (Alnus rubra) used for the groundwood pulps in this study came from Longview, Wash. It had an average specific gravity of 0.385, based on weight when air-dry and volume when green, and a density of 24.0 pounds per cubic foot. Its average age was 21 years, average bolt diameter was 7.8 inches, and its growth rate was 5.4 rings per inch.

### Pulps

Douglas-fir sulfate pulp.--The Douglas-fir was cooked to a bleachable sulfate pulp. Digestion No. 1-4005 was made in a 225-cubic-foot digester

equipped with an external circulation system for indirect heating of the cooking liquor. The standard 5/8-inch chips had a moisture content of 10.5 percent. The equivalent of 2,120 pounds of moisture-free wood was used in this digestion. Each 100 pounds was cooked with 19.4 pounds of sodium hydroxide and 8.1 pounds of sodium sulfide. These chemicals, expressed as sodium oxide, were equivalent to an active alkali of 21.5 pounds per 100 pounds of moisture-free wood. The volume of liquid in the digester, including the moisture in the chips, was 48 gallons per 100 pounds of moisture-free wood. With this volume, the liquor-to-wood ratio was 4 to 1. Instead of using black liquor, as is done in sulfate pulping practice, water was used to obtain the desired volume in the digester. The cooking liquor had a sulfidity (based on active alkali) of 30 percent. The initial concentration of active alkali in the digester was 53.7 grams per liter. The temperature-pressure schedule was a straight-line rise from 30° C. to 170° C. in 1-3/4 hours, and the maximum temperature of 170°C. was maintained for 1-1/2 hours before blowing.

The yield of screened pulp was 40.6 percent and the yield of screening rejects was 1.5 percent, based on the weight of moisture-free wood. The pulp had a lignin content of 2.9 percent and a permanganate number of 14. Both of these values are sufficiently low to indicate a pulp that can be bleached with a normal amount of chlorine. The pulp had a holocellulose content of 96.2 percent, an alpha-cellulose content of 80.2 percent, and a very low pentosan content of 4.8 percent.

The pulping test data on the unbleached pulp are given in table 1. The brightness of the unbleached pulp was 27.2 percent (G. E. equivalent), while the hypochlorite bleachability test with 25 percent calcium hypochlorite gave a brightness value of 72.7 percent. Full bleaching data are given elsewhere in this report.

Red alder groundwood pulp.--The red alder was ground for a book grade of pulp (grinder run No. 935). The evaluation data on the bleached pulp of this run (bleach No. 2334) are given in table 1.

The energy consumption in grinding this wood was 69 horsepower-days per ton of wood (moisture-free basis). A sandstone pulpstone, burred with 10 by 1-1/2 spiral and 14-point diamond burrs, was used. The grinding pressure was 20 pounds per square inch, and the pit temperature was 140° F. The grinding rate was 0.65 ton of wood (moisture-free basis) per square foot of stone surface in grinding contact per 24 hours.

The pulp was about half as strong as the commercial magazine book grade spruce groundwood pulp (table 1). The low strength properties would limit the use of the groundwood to a "filler" pulp. The color of the pulp was dark, with a definitely reddish cast.

Red alder chemigroundwood pulp.--The strength and other properties of red alder chemigroundwood pulps can be improved by pressure-treating the wood before it is ground with an approximately neutral solution of sodium sulfite.[2] The increase in strength over that of pulp from untreated wood depends on the amount of chemical used, the temperature, and the duration of the treatment. Red alder treated under relatively mild conditions gave a well-fiberized chemigroundwood pulp with high freeness, but only slightly improved strength. A more completely treated wood, such as that used for grinder run C-988 (table 1), produced chemigroundwood that was stronger than any softwood groundwood, and approached red alder neutral sulfite semichemical pulp in strength and other properties. The pulp lacked bulk, absorbency, and other properties possessed by groundwood pulp, however, so it is not a complete substitute for softwood groundwood.

The 4-foot red alder logs were treated with a solution that contained sodium sulfite and sodium bicarbonate in a ratio of 6 to 1 (expressed as sodium carbonate) and a concentration of 1 pound of these chemicals per gallon of water. The treating time was 4.5 hours at maximum temperature and pressure (145° C., 100 pounds per square inch). The wood was ground at a pressure of 25 pounds per square inch on a dull-surfaced sandstone burred as for the groundwood pulp. The grinding rate was 1.61 tons of wood (moisture-free basis) per 24 hours per square foot of stone surface in contact with wood, and 37 horsepower-days of energy were consumed per ton of wood.

Red alder neutral sulfite semichemical pulp.--The red alder produced neutral sulfite semichemical pulp in a yield of 65 percent of the weight of the wood. The chips, after a brief steaming at atmospheric pressure, were covered with cooking liquor that contained 24 pounds of sodium sulfite and 5.3 pounds of sodium bicarbonate per 100 pounds of wood (moisture-free basis). The cooking schedule included a 2-hour temperature rise to 177° C., followed by 4-1/2 hours at that temperature.

Commercial blending pulps.--A standard book grade of balsam fir bleached sulfite pulp was obtained on the market for blending with the experimental pulps.

Also, a standard book-grade groundwood pulp made from spruce was procured for blending and reference standard purposes. Its evaluation data are given in table 1.

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[2] Hyttinen, A., and Schafer, E. R. Grinding of Pretreated Hardwoods: Experiments on Quaking Aspen, Sweetgum, Red Alder, Black Tupelo, Sugar Maple, Red Oak, and Cottonwood. Forest Products Laboratory Report No. 2015, March 1955.

## Pulp Bleaching

About 100 pounds of unbleached pulps (moisture-free basis) were used for pilot-scale bleaching runs. The pulps were treated in a rubber-lined tank with agitators, and were vacuum-washed between stages. The bleached pulps were dewatered over a wet machine and stored in refrigerated cans to prevent molding and reversion of color.

### Douglas-Fir Sulfate Pulp

The unbleached pulp from digestion No. 1-4005 was bleached by 4-, 5-, and 6-stage processes, and semibleached by a 3-stage process. Details of process conditions follow.

Bleach No. 2170.--The 5-stage bleach process was used to prepare a white pulp of sufficient strength to meet the requirements of a bond paper. The following chemicals were used for the five stages: 4.2 percent of free chlorine; 1.0 percent of available chlorine as calcium hypochlorite; 0.3 percent of caustic soda; 0.55 percent of available chlorine as chlorine dioxide. The fifth stage was a repeat of the fourth stage. The final bleached pulp had a brightness of 80.8 percent (G. E. equivalent). The strength and other data are given in table 1.

Bleach No. 2198.--Bleach No. 2198 was carried out in six stages to achieve utmost brightness with least loss in pulp strength. The following chemicals were used in sequence: 4.4 percent of free chlorine; 1.3 percent of available chlorine as calcium hypochlorite; 0.3 percent of caustic soda; 0.3 percent of available chlorine as calcium hypochlorite; and two stages of 0.5 percent of available chlorine as chlorine dioxide. The final bleached pulp had a brightness of 83.1 percent. The strength properties were between those of the pulps bleached by the other two processes, and are given in table 1. The bleached pulp was used in machine runs Nos. 3537 and 3538.

Bleach No. 2337.--The four-stage process was used for bleach No. 2337. The following chemicals were used in sequence: 5 percent of free chlorine; 1.5 percent of caustic soda; 1.0 percent of available chlorine as calcium hypochlorite; and 0.6 percent of available chlorine, in a repeat of the hypochlorite stage. This process yielded a pulp with a brightness of 81.6 percent, but with a relatively low strength. It was adequate, however, for the requirements of a magazine book sheet. The data for the physical properties of the test sheets made from this pulp are given in table 1.

Bleaches Nos. 2413 and 2414.--Bleaches Nos. 2413 and 2414 were duplicates and were intended to give a semibleached pulp of maximum strength suited to such specialties as milk-carton stock. Brightness values for pulps from these bleaches were 72.2 percent and 75.6 percent, respectively. The following chemicals were used in sequence: 4.5 percent of free chlorine; 1.5 percent of caustic soda; and 0.75 percent of available chlorine as calcium hypochlorite. The strength and other properties of the pulp are given in table 1.

## Red Alder Groundwood and Chemigroundwood Pulps

Bleach No. 2334.--Because of the low brightness of red alder groundwood pulp, a partial bleaching was used to make it suitable for magazine book papers. Ten percent and 3 percent of available chlorine as calcium hypochlorite were used in 2 stages on grinder run No. 935. This bleaching yielded a pulp with a brightness value of 75.0 percent, which was adequate for magazine book papers. The physical properties of the pulp are given in table 1.

Bleach No. 2844.--The red alder chemigroundwood pulp (grinder run No. C-988) was semibleached with 10 percent chlorine as calcium hypochlorite in a single stage. The brightness of the pulp increased from 47.2 to 72.9 percent. The results of physical tests on the bleached pulp are given in table 1.

## Red Alder Neutral Sulfite Semichemical Pulp

Bleach No. 2245.--The pulp was treated with 10.0 percent of free chlorine, 2.0 percent of caustic soda, and 2.75 percent of available chlorine as calcium hypochlorite. The final brightness was 82.2 percent. The yield was 53.2 percent of the wood and 82.1 percent of the unbleached pulp. The pulp strength properties are given in table 1.

## Bond Papers

A good commercial bond paper must have adequate strength for handling in typing and printing, together with the opacity, finish, and other requirements met in use. A No. 1 bond paper has a bursting strength of at least "a point to the pound" on a 17 by 22 - 500 ream basis, which is 0.374 point per pound on a 25 by 40 - 500 ream basis. It must take water-base inks without feathering, and be receptive to printing inks. Relatively wide ranges in its folding endurance, tearing strength, and tensile strength are tolerated.

## Beating Conditions

Beater run No. 2602.--Approximately 50 pounds (ovendry equivalent) of pulp from cook 1-4005, bleach No. 2170, were processed in the Forest Products Laboratory No. 1 experimental beater for 23 minutes with the roll down to the bed plate. The final freeness was 550 milliliters (Canadian Standard). The stock produced was used in machine runs Nos. 3364 and 3365.

Beater run No. 2603.--A run similar to run No. 2602 was made on the same type of pulp, except that the pulp was beaten with the roll 3 turns of the setting wheel off the bed plate for 15 minutes, then 1 turn off for 15 minutes, and finally 1/2 turn off for 5 minutes, to give stock with a freeness

of 510 milliliters. This stock was run in machine runs Nos. 3366 and 3367.

Beater run No. 2612.--This run was made under the following conditions: 3 turns off the bed plate for 15 minutes and 1 turn off for 20 minutes. The resultant stock had a final freeness of 525 milliliters. This stock was run in machine runs Nos. 3388, 3389, and 3390.

Beater run No. 2613.--In this beater treatment, the pulp was beaten for 15 minutes with the roll 3 turns off the bed plate, then 1 turn off for 37 minutes, and had a final freeness of 400 milliliters.

Beater run No. 2558.--Pulp from the final bleach, No. 2198, was used for this run. The final trial beater treatment consisted of 15 minutes with the roll 3 turns off the bed plate, then 1 turn off for 48 minutes. The freeness of the stock was 440 milliliters.

## Papermaking

In all bond paper runs, only Douglas-fir pulp was used, with a total of about 7 percent of clay and titanium dioxide fillers, 1 percent of rosin size, and 2 percent of alum. The data on the papers are given in table 2.

Two machine runs, Nos. 3364 and 3365, were made with the rapidly beaten stock. The first run was made with no jordaning, and the second run was made with 7 pounds gage pressure on the jordan plug. The formation of the second sheet was improved and "closed" by jordan action, as confirmed by the decrease in porosity from 8 to 81 seconds, and the increase in density from 0.72 to 0.77. At this higher density, all strength properties were within the range of a No. 1 bond sheet, although sheets from both runs lacked bond appearance.

Two machine runs, Nos. 3366 and 3367, were made with a more slowly beaten pulp, that from beater run No. 2603. Again, an additional jordaning effect was necessary to give the sheet acceptable strength. The formation of the sheet was not acceptable.

Three machine runs, Nos. 3388, 3389, and 3390, were made on the stock from beater run No. 2612. The stock had been beaten slowly and to a somewhat lower freeness than the previous stock. Two of the resultant papers, Nos. 3388 and 3389, were barely adequate in strength, apparently due to insufficient jordaning. The most highly jordaned sheet, No. 3390, showed good properties, although it still had a somewhat mottled or raggy "look-through."

Six machine runs were made on a stock that was beaten still longer, that from beater run No. 2613. The first of these runs, No. 3391, was not

jordaned, and, although its strength properties were adequate, its formation was not good, as indicated by the high porosity (table 2) and mottled look-through.

Three degrees of jordaning were tried, 1 of which (No. 3393) was too severe and produced a slow-draining stock. The resultant sheet was low in tear resistance, although it had a well-closed formation and finish. Of the 2 remaining sheets (Nos. 3392 and 3394) made without the addition of dry broke, machine run No. 3394 was superior. It was also the best overall sheet of this group. Its headbox freeness was sufficiently low to produce good formation, yet the tearing resistance and folding endurance did not suffer too much from the more intense fiber processing. The 2 remaining sheets from this stock were made with 10 percent and 100 percent of dry broke to determine the effect of dry broke on sheet density or bulk. The stock with 10 percent of dry broke had very good properties and appearance, and was nearly as good as stock from machine run No. 3394. The all-broke sheet was low in all strength properties.

In the final group of this series, 2 machine runs were made with stock from beater run No. 2558, which had been given an extra long, mild beating. Both of these machine runs, Nos. 3537 and 3538, produced good bond papers, especially from the standpoint of formation. The papers were somewhat cockled, however, and lacked the overall appearance necessary to qualify as top-grade paper. These deficiencies may have been caused by the extreme sensitiveness of Douglas-fir bleached sulfate pulp to beating and jordaning. The use of wider bars in the jordan would have been very helpful in the preparation of the stock.

The overall conclusion is that a very acceptable bond, writing, or ledger paper can be made from a bleached sulfate pulp made from old-growth stands or residues of Douglas-fir. The physical properties of the fiber are such that, with expert papermaking, a fine paper can be made that, in appearance and handling quality, closely resembles a rag-content sheet.

## Magazine Book Papers

### Furnish

The usual furnish, 60 percent of groundwood and 40 percent of bleached sulfite or sulfate pulps, was chosen for this series of magazine book papers.

Commercial pulps were used as a reference run (machine run No. 3655). Spruce groundwood and balsam fir bleached sulfite were the commercial pulps used. Sizing, alum, and about 12 percent of clay were added to enhance the opacity for printing purposes. The pulps were slushed but not beaten. The freeness of the stock was such that the wire drainage was good. Other details are given in table 3.

Papermaking

In machine run No. 3656, red alder groundwood (grinder run No. 935) that had been bleached in bleach No. 2334 was used with the same commercial bleached sulfite as was used in the reference standard. This paper ran well and required some jordaning. Its surface was rougher than that of the spruce groundwood sheet. Test data are given in table 3.

In machine run No. 3658, Douglas-fir bleached sulfate pulp was substituted for the balsam fir sulfite pulp in the reference standard. This run produced a book paper that was good except for its hardness. The hardness was no doubt due to the large amount of jordaning that had been necessary to shorten the Douglas-fir fibers. All sheet-test data are given in table 3.

In machine run No. 3703, Douglas-fir bleached sulfate pulp was run with alpine fir groundwood[2] from grinder run No. 940. All sheet properties except opacity were slightly below the reference standard, but not so low as to indicate that a satisfactory paper could not be made from similar pulps.

A run with all three pulps, Douglas-fir sulfate, red alder groundwood, and alpine fir groundwood, in the proportions of 20, 35, and 45 percent, respectively, produced a very good magazine book paper (machine run No. 3704). All the properties of this paper were satisfactory except brightness, which would be taken care of in the coating operation in commercial production. The test data are given in table 3.

The furnish for paper machine run No. 4036 (table 3) consisted of 20 percent of Douglas-fir sulfate (bleach No. 2337), 40 percent of red alder chemiground wood (bleach No. 2844), and 40 percent of alpine fir groundwood. The paper produced had good opacity and strength, and was equal to commercial magazine book paper.

These runs indicate that a satisfactory book sheet can be made from these western species.

## Milk-Carton and Punchcard Boards

Papermaking

Four paper machine runs (table 3) were made to evaluate the Douglas-fir and red alder pulps for milk-carton stock. One run included 40 percent of

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[2]For additional data on alpine fir and other red alder pulps, see Pulp & Paper Rept. No. 85, "Experiments on the Groundwood Pulping of Alpine Fir and Use of Pulp in Printing Papers," by Axel Hyttinen and E. R. Schafer, June 1, 1953.

bleached red alder neutral sulfite semichemical pulp, while in the other 3 only Douglas-fir was used.

In comparison with the commercial reference standard test data, all of the experimental boards had superior values for most properties. However, the formation in general was not good, so that the surface texture was poor. The formation could be improved by additional beating and jordaning, and heavy calendering. The sheet density would thereby be increased, which would restore most strength losses resulting from more physical processing.

Consequently, it can be concluded that a satisfactory milk-carton paperboard can be made from Douglas-fir sulfate pulp alone or mixed with neutral sulfite semichemical red alder pulp.

One paper machine run (No. 3701, table 3) was made on a mixture of 65 percent of bleached Douglas-fir (bleach No. 2413) and 35 percent of red alder groundwood pulp (grinder run No. 935) for punchcard paperboard stock. The results were not good, primarily because of poor formation. The mechanical properties of the stock appeared to be adequate, but a long easy beating schedule for the Douglas-fir pulp would be necessary to retain the required strength properties without lowering the freeness to a point where slow drainage on the wire would make paper machine operation uneconomical. Considerably more experimental work would be required to make a satisfactory punchcard paperboard from the Douglas-fir sulfate and red alder groundwood pulp combination.

## Conclusions

The evaluations of each series of papers -- bond and magazine book papers, and milk-carton and punchcard paperboards -- were given concurrently with the discussion of the various papers.

In conclusion, it may be stated that old-growth Douglas-fir bleached sulfate pulp: (1) can be made into a very good bond, writing, or other fine paper, with many characteristics resembling rag-content paper; (2) can be used mixed with semibleached red alder groundwood or chemigroundwood pulp to yield a good coating base for magazine book grade paper; and, (3) with careful papermaking, can be used to produce a good milk-carton stock.

The use of old-growth Douglas-fir for punchcard stock was not sufficiently investigated to report any favorable results.

Table 1.--Data on strength and other physical properties of pulps from old-growth Douglas-fir and red alder.

| Pulp | Beating time | Freeness (Canadian standard) | Bursting strength | Tearing resistance | Folding endurance (M.I.T.) | Breaking length | Sheet density | Fiber length index | Brightness (G.E.) |
|---|---|---|---|---|---|---|---|---|---|
| | Minutes | Ml. | Pts. per lb. per ream[1] | Gm. per lb. per ream[1] | Double folds | Meters | Gm. per ml. | Factor | Percent |
| Douglas-fir sulfate digestion No. 1-4005 unbleached | 5 | 740 | 0.40 | 3.84 | 34 | 3,940 | 0.40 | | 27.2 |
| | 20 | 690 | .79 | 3.83 | 380 | 6,720 | .52 | | |
| | 40 | 475 | .99 | 2.88 | 538 | 7,450 | .61 | | |
| | 60 | 270 | 1.10 | 2.49 | 616 | 8,630 | .64 | | |
| | 80 | 135 | 1.11 | 2.02 | 649 | 8,700 | .67 | | |
| Douglas-fir sulfate digestion No. 1-4005 bleach No. 2170 | 5 | 715 | .53 | 5.01 | 69 | 3,610 | .45 | | 80.8 |
| | 20 | 610 | .90 | 3.85 | 467 | 5,450 | .55 | | |
| | 40 | 370 | 1.20 | 2.84 | 696 | 6,810 | .61 | | |
| | 60 | 160 | 1.33 | 2.20 | 751 | 6,910 | .68 | | |
| Douglas-fir sulfate digestion No. 1-4005 bleach No. 2198 | 0 | 755 | .30 | 3.53 | 15 | 2,700 | .44 | | 83.1 |
| | 20 | 630 | .91 | 3.42 | 453 | 6,580 | .61 | | |
| | 40 | 405 | 1.08 | 2.52 | 654 | 7,540 | .69 | | |
| | 60 | 165 | 1.09 | 2.00 | 909 | 8,160 | .77 | | |
| Douglas-fir sulfate digestion No. 1-4005 bleach No. 2337 | 0 | 745 | .29 | 3.40 | 10 | 2,590 | .41 | | 81.6 |
| | 20 | 520 | .83 | 2.41 | 255 | 6,440 | .57 | | |
| | 40 | 165 | .88 | 1.56 | 284 | 7,140 | .68 | | |
| Douglas-fir sulfate digestion No. 1-4005 bleach No. 2413 | 0 | 730 | .27 | 3.54 | 6 | 2,380 | .36 | | 72.2 |
| | 15 | 660 | .81 | 3.92 | 348 | 6,080 | .51 | | |
| | 30 | 530 | 1.01 | 2.72 | 498 | 7,400 | .59 | | |
| | 45 | 320 | 1.12 | 2.29 | 542 | 7,970 | .63 | | |
| | 60 | 170 | 1.10 | 2.09 | 662 | 8,500 | .69 | | |
| Red alder groundwood grinder run 935 bleach No. 2334 | 0 | 55 | .11 | .32 | | 1,640 | .41 | 0.077 | 75.1 |
| Red alder chemigroundwood grinder run G 988 bleach No. 2844 | 0 | 405 | .63 | 1.09 | | 6,200 | .66 | .179 | 73.0 |
| Red alder neutral sulfite semichemical pulp digestion No. 5502-5 bleach No. 2245 | 0 | 380 | .94 | 1.24 | 106 | 7,400 | .79 | | 82.2 |
| | 5 | 350 | .99 | 1.20 | 260 | 8,000 | .83 | | |
| | 16 | 250 | 1.13 | .95 | 525 | 9,150 | .93 | | |
| Spruce groundwood commercial | 0 | 45 | .23 | .41 | | 2,470 | .46 | .079 | 60.1 |

[1]Ream size: 25 x 40 - 500.

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Table 2.---Bond papers from old-growth Douglas-fir bleached sulfate pulps[1].

| Machine run No. | Beater run No. | Beater freeness (Canadian Standard): Ml. | Jordan pressure: P.s.i.g. | Headbox freeness (Schopper-Riegler): Ml. | Calender freeness (Canadian Standard): Ml. | Calender Pressure: P.s.i.g. | Calender Number of nips | Ream weight (25 x 40 - 500): Pound | Bursting strength: Pts. per lb. per ream | Average tearing resistance: Gm. per lb. per ream | Tensile strength: P.s.i. | Average folding endurance: Double folds | Density: Gm. per c.c. | Opacity: Percent | Porosity (Gurley): Seconds | Brightness (G.E.): Percent | Ash: Percent | Size: No.: Percent | Gloss |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3364 | 2602 | 550 | ..... | 740 | 460 | 20 | 3 | 52.1 | 0.33 | 1.57 | 3,356 | 15 | 0.72 | 80 | 8 | 79.7 | 4.2 | 0.46 | 28.9 |
| 3365 | 2602 | 550 | 7 | 445 | 170 | 0 | 3 | 53.2 | .41 | 1.36 | 4,465 | 50 | .77 | ..... | 91 | 80.9 | 6.1 | .47 | 29.6 |
| 3366 | 2603 | 540 | ..... | 700 | 400 | 20 | 3 | 50.0 | .37 | 1.83 | 3,635 | 37 | .71 | 80 | 14 | 81.2 | 5.4 | .66 | 28.6 |
| 3367 | 2603 | 540 | 7 | 505 | 210 | 20 | 3 | 51.8 | .41 | 1.61 | 4,565 | 70 | .75 | 83 | 82 | 82.0 | 6.3 | .80 | 25.9 |
| 3388 | 2612 | 525 | 2 | 640 | 345 | 10 | 3 | 54.3 | .38 | 2.01 | 4,040 | 37 | .72 | ..... | 25 | 81.2 | ..... | .49 | 23.2 |
| 3389 | 2612 | 525 | 5 | 615 | 325 | 30 | 3 | 52.7 | .38 | 1.83 | 4,355 | 42 | .76 | ..... | 30 | 80.9 | ..... | .51 | 26.2 |
| 3390 | 2612 | 525 | 10 | 485 | 200 | 30 | 3 | 53.8 | .40 | 1.89 | 4,760 | 51 | .78 | ..... | 66 | 81.4 | ..... | .45 | 23.2 |
| 3391 | 2613 | 400 | ..... | 670 | 360 | 30 | 3 | 51.7 | .45 | 1.99 | 4,910 | 63 | .75 | ..... | 33 | 80.8 | 4.7 | .63 | 25.5 |
| 3392 | 2613 | 400 | 8 | 470 | 180 | 30 | 3 | 53.1 | .46 | 1.80 | 5,395 | 103 | .79 | ..... | 153 | 81.3 | 5.7 | .69 | 26.6 |
| 3393 | 2613 | 400 | 15 | ..... | ..... | 30 | 3 | 52.5 | .47 | 1.57 | 5,330 | 70 | .83 | ..... | 225 | 81.2 | ..... | ..... | ..... |
| 3394 | 2613 | 400 | 12 | 390 | 105 | 30 | 3 | 53.4 | .49 | 1.61 | 5,750 | 96 | .82 | ..... | 264 | 81.5 | 5.9 | .60 | 26.9 |
| [2]3395 | 2613 | 400 | 16 | 470 | 180 | 30 | 3 | 53.0 | .48 | 1.77 | 5,700 | 106 | .81 | ..... | 138 | 80.8 | 4.8 | .36 | 25.2 |
| [3]3396 | 2614 | 400 | 7 | 400 | 160 | 10 | 3 | 52.3 | .37 | 1.23 | 4,465 | 29 | .76 | ..... | 250 | 82.3 | 8.2 | .14 | 24.9 |
| 3537 | [4]2558 | 440 | 18 | ..... | ..... | 30 | 3 | 58.4 | .36 | 1.37 | 5,550 | 38 | .92 | 87 | 276 | 84.5 | ..... | ..... | ..... |
| 3538 | [4]2558 | 440 | [3]10/12 | 260 | 85 | 30 | 6 | 55.8 | .47 | 1.32 | 6,000 | 88 | .94 | 86 | 518 | 82.0 | 7.7 | ..... | 32.9 |

[1]Except as otherwise noted, the furnish of all papers consisted of Douglas-fir pulp from digestion 1-4005, bleach No. 2170, with about a 7 percent total of clay and titanium dioxide fillers, 1 percent of rosin size, and 2 percent of alum.

[2]Dry broke from machine runs Nos. 3391-3394 was used for 10 percent of this furnish.

[3]This run was made entirely from dry broke from machine runs Nos. 3391-3395, with an additional 3 percent of clay.

[4]Bleach No. 2198 was used instead of No. 2170.

Table 3.--Magazine book paper and milk-carton and punchcard paperboards from old-growth Douglas-fir bleached sulfate pulp, and bleached red alder groundwood and chemigroundwood pulps.

| Machine run No. | Furnish: Douglas-fir sulfate pulp: Bleach No. | Douglas-fir sulfate pulp: Amount | Red alder pulp: Kind[1] | Red alder pulp: Amount | Other pulp: Kind[2] | Other pulp: Shipment or grinder run No. | Other pulp: Amount | Beater run No. | Beater freeness (Canadian Standard) | Jordan pressure | Headbox freeness (Canadian Standard) | Calender: Pressure | Calender: Number of nips | Ream weight (25 x 40-500) | Bursting strength | Average tearing resistance | Tensile strength | Average folding endurance | Density | Opacity | Porosity (Gurley) | Brightness (G.E.) | Ring crush | Size No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Percent | | Percent | | | Percent | | Ml. | P.s.i.g. | Ml. | P.s.i. | | Pound | Pts. per lb. per ream | Gm. per. lb. per ream | P.s.i. | Double Folds | Gm. per. c.c. | Percent | Seconds | Percent | Pound | |
| **Groundwood Book Papers** | | | | | | | | | | | | | | | | | | | | | | | | |
| 3655 | | | | | Ground-wood | P-3214 | 60 | 2848 | 120 | 0 | | 0 | 1 | 36.9 | 0.30 | 0.67 | 3,150 | 7 | 0.62 | 89.1 | 61 | 70.2 | | 0.72 |
| 3656 | | | | | Sulfite | P-3213 | 40 | 2849 | 290 | 7.5 | | 0 | 1 | 36.1 | .26 | .59 | 2,515 | 3 | .57 | 87.5 | 49 | 73.4 | | .54 |
| 3658 | 2337 | 40 | | | Ground-wood | P-3214 | 60 | 2851 | | 10 | | 0 | 1 | 34.4 | .30 | .64 | 3,280 | 8 | .66 | 88.2 | 194 | 71.5 | | .81 |
| 3703 | 2198 | 20 | | | Do. | G.R. 940 | 80 | 2884 | | 10 | 130 | 0 | 1 | 38.6 | .29 | .55 | 3,675 | 3 | .63 | 90.0 | | 68.0 | | |
| 3704 | 2413 | 20 | Ground-wood | 35 | Do. | G.R. 940 | 45 | 2885 | | 10 | 125 | 20 | 6 | 36.2 | .25 | .98 | 2,430 | 4 | .57 | 89.8 | | 69.2 | | |
| 4036 | 2337 | 20 | Chemi-ground-wood | 40 | Do. | G.R. 950 | 40 | | | 15 | 130 | 15 | 3 | 38.7 | .28 | .95 | 2,845 | 5 | .63 | 88.8 | 44 | 69.3 | | |
| **Milk-Carton Paperboards** | | | | | | | | | | | | | | | | | | | | | | | | |
| Commercial paperboard[3] | | | | | | | | | | | | | | | | | | | | | | | | |
| 3699 | 2413 | 100 | | | | | | 2880 | 735 | 20 | 650 | 0 | 1 | 24.3 | .49 | 3.05 | 3,100 | | .82 | | 218 | | | |
| 3700 | 2413 | 60 | Neutral sulfite semi-chemical | 40 | | | | 2881 | 735 | 15/10 | 560 | 20 | 1 | 24.0 | .50 | 2.55 | 4,865 | | .77 | | | | 156 | 135 |
| 3705 | 2414 | 100 | | | | | | 2886 | 665 | 40/46 | | 20 | 6 | 27.0 | .33 | 2.84 | 4,395 | | .78 | | | | 161 | |
| 3706 | 2414 | 100 | | | | | | 2887 | 735 | 35/35 | | 20 | 6 | 25.4 | .37 | 3.31 | 3,640 | | .70 | | | | 120 | |
| **Punchcard Paperboard** | | | | | | | | | | | | | | | | | | | | | | | | |
| 3701 | 2413 | 65 | Ground-wood | 35 | | | | 2882 | | | | | | 11.0 | .43 | 2.01 | | | .67 | | | | | |

[1] Red alder groundwood from Grinder Run No. 935, bleach No. 2334; red alder chemigroundwood from grinder run No. C-988, bleach No. 2894; red alder neutral sulfite semichemical from digestion No. 5502-5, bleach No. 2245.

[2] Shipment No. P-3214, commercial spruce groundwood; shipment No. P-3213, commercial balsam fir bleached sulfite; grinder run Nos. 940 and 950, experimental alpine fir groundwood.

[3] Reference standard was a commercial milk-carton stock made of all southern pine kraft pulp.