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NEW ZEALAND.

PULP AND PAPER MAKING

(REPORT ON INVESTIGATIONS INTO SUITABILITY OF SELECTED NEW-ZEALAND-GROWN WOODS FOR).

Laid on the Table of the House of Representatives by Leave.

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The DIRECTOR OF FORESTRY to the Hon. the COMMISSIONER OF STATE FORESTS.

SIR,— New Zealand State Forest Service, Wellington, 8th October, 1928.

I have the honour to submit herewith a report transmitted to me by Mr. A. R. Entrican, Engineer in Forest Products, presenting the results of the studies made in co-operation with the Forest Products Laboratory, U.S.A. Department of Agriculture, Forest Service, at Madison, Wisconsin, into the pulping and papermaking properties of a number of selected New-Zealand-grown woods.

RESULTS.

The report shows that a commercial grade of newsprint can be produced either from insignis pine alone or from a combination of insignis pine and tawa; and of kraft papers (*i.e.*, wrappings, &c.) from rimu, insignis pine, Corsican pine, Austrian pine, and European larch. Coming as they do from one of the foremost pulp and paper research institutes in the world, these results may be accepted as conclusive, particularly so since they include both laboratory and actual commercial pulp- and paper-mill trials. They have, in fact, already been favourably commented upon by independent paper-manufacturers in North America and Great Britain.

PURPOSE OF TESTS.

Two considerations weighed with the Government in its decision to study the pulping and papermaking properties of New Zealand woods. It was a large seller of stumpage, and likely to become a still larger one in the near future. The Dominion at the same time was importing pulp and paper products valued at over £1,000,000 per annum, and increasing these imports at an annual rate of £55,000. Thirty years ago the Government initiated a tree-planting programme which has gained momentum steadily, until to-day the Forest Service has planted some 188,000 acres, including some 54,000 acres during the 1928 planting season. The Forest Service is administering, too, a forest domain of over 7,000,000 acres. All these plantations and forests are yielding large volumes of woods for which it is necessary to develop profitable markets. Some of the forest crop goes into building and constructional timber, some into poles and fencing-posts, and some into fuel-wood. Yet there still remains considerable material, in the shape either of woods and mill waste, or of unused species, or of thinnings and improvement cuttings, for which no outlet has appeared available, largely because little information as to how and for what purpose to use it was in existence. An intensive survey of this wood-use problem indicated that one of the most promising avenues of utilization lay in the pulp and paper industry, and it was therefore decided to first ascertain whether the principal woods were suitable for this purpose. A study of the domestic pulp and paper markets confirmed the advisability of making such an investigation, especially in its relation to the manufacture of newsprint, the imports of which have been increasing steadily over a long period, with promise of soon attaining a figure representing the output of an economically-sized mill.

LOCATION OF STUDY.

How to carry out the work was the first problem. Two alternatives presented themselves—that of building a laboratory in New Zealand, or, alternatively, of arranging for a recognized and established laboratory abroad to undertake the work. Eventually the second alternative was adopted. Not only did it promise to be several times more economical, as the capital cost of a local establishment would be high and the development of a good operational technique very costly, but the results from a recognized laboratory would be more readily acceptable by commercial pulp and paper financiers who might be interested in the development of the industry in New Zealand. Consideration of suitable institutions showed that none were available in the British Empire at that time. The Canadian pulp and paper laboratory attached to the Canadian Forest Products Laboratories at Montreal, was closed down pending the erection of a new building and the installation of new equipment, and the other laboratories in India and England were either not equipped for the work or did not possess the particular technique and experience required. Most unexpectedly, however, the Government of the

United States of America was found to be interested in some of the problems involved in the work, and the Forest Service entered into an agreement whereby the Forest Products Laboratory maintained by the United States Department of Agriculture, Forest Service, at Madison, Wisconsin, undertook to co-operate in a study of the pulping and papermaking properties of a number of New-Zealand-grown woods. The Madison laboratory is undoubtedly the foremost institute of its kind, and maintains a staff of highly trained specialists in all the principal lines of pulp and paper research. It has pioneered many developments in the industry, and achieved an international reputation for its contributions in the field of both science and commerce, so that reports issued under its ægis are accepted as representative of the best advice available.

Future Programme.

In addition to studying the technique of pulping and papermaking processes, Mr. Entrican made a comprehensive investigation of the operational and economic aspects of the industry in North America and Europe. A number of the New-Zealand-grown woods having, therefore, been proved suitable for the production of newsprint, wrappings, and other papers, a detailed field examination of various localities will be made by the Engineer in Forest Products during the approaching year, to ascertain the commercial possibilities of establishing the industry in the Dominion.

I have, &c.,
E. Phillips Turner, Director of Forestry.

The Engineer in Forest Products to the Director of Forestry.

Sir,— New Zealand State Forest Service, Wellington, 8th October, 1928.

There is submitted herewith for your information a report setting forth the results of the tests made by the Forest Products Laboratory, U.S.A. Department of Agriculture, Forest Service, at Madison, Wisconsin, in co-operation with this Service, to ascertain the pulping and papermaking properties of six New-Zealand-grown woods.

Originally the study was of a purely laboratory nature, but so promising were the results secured that its scope was extended to include a commercial pulp- and paper-mill trial, and through the courtesy and co-operation of the Great Western Paper Co. at Ladysmith, Wisconsin, and the Consolidated Water-power and Paper Co. at Wisconsin Rapids, Wisconsin, a shipment of New Zealand wood was successfully pulped and run into newsprint, rotogravure, and wrapping papers, the regular mill equipment at these plants being employed throughout.

Both the laboratory and pulp- and paper-mill trials were beset with difficulties, and a mark of appreciation is paid to the staffs of the Madison Forest Products Laboratory, the Great Western Paper Co., and the Consolidated Water-power and Paper Co. for their tenacity of purpose in bringing the study to a successful conclusion. To the following gentlemen in particular belongs the credit for the successful prosecution of the investigation :—

Madison Forest Products Laboratory, Pulp and Paper Section—Clarke C. Heritage, in charge; C. E. Curran, Chemist in Forest Products; P. K. Baird, Associate Chemist in Forest Products; E. R. Schafer, Associate Engineer in Forest Products; W. H. Monsson, Associate Chemist in Forest Products; G. H. Chidester, Assistant Engineer in Forest Products.

Great Western Paper Co., Ltd., Ladysmith, Wisconsin—Herbert H. Fish, jun., General Manager; the late Mr. Winnege, Pulp-mill Superintendent.

Consolidated Water-power and Paper Co., Ltd., Wisconsin Rapids Division, Wisconsin Rapids, Wisconsin—Stanton L. Mead, Esq., General Manager; Mr. Simpson, Mill-manager; L. Beeman, Esq., Paper-mill Superintendent.

I have, &c.,
Alex. R. Entrican, Engineer in Forest Products.

PULPING AND PAPERMAKING PROPERTIES OF SELECTED NEW-ZEALAND-GROWN WOODS

BY

C. E. CURRAN, Chemist in Forest Products; P. K. BAIRD, Associate Chemist in Forest Products; E. R. SCHAFER, Associate Engineer in Forest Products; W. H. MONSSON, Assistant Chemist in Forest Products; G. H. CHIDESTER, Assistant Engineer in Forest Products; United States Forest Service, Forest Products Laboratory, Section of Pulp and Paper (Clarke C. Heritage, in charge);

AND

A. R. ENTRICAN, Engineer in Forest Products, New Zealand State Forest Service.

GENERAL.

SUMMARY.

THIS report presents the results of a study made by the Forest Products Laboratory, U.S.A. Department of Agriculture, Forest Service, at Madison, Wisconsin, in co-operation with the New Zealand State Forest Service, into the pulping and papermaking properties of six selected New-Zealand-grown woods. Of these, two woods are indigenous to the Dominion of New Zealand—rimu (*Dacrydium cupressinum*), a softwood, and tawa (*Beilschmiedia tawa*), a hardwood.* The remainder are all introduced softwoods—insignis pine (*Pinus radiata*), better known in North America as the Monterey pine of California; and Corsican pine (*Pinus Laricio*), Austrian pine (*P. austriaca*), and European larch (*Larix europaea*), the natural habitat of all three species being, as the names indicate, the Continent of Europe.

To the co-operator the important conclusion to the study is that a good commercial grade of newsprint can be produced from insignis pine alone, or from a mixture of insignis pine and tawa or some similar hardwood. Of almost equal importance is the indication that high-grade kraft papers (*i.e.*, wrappings, &c.) can be manufactured from rimu, insignis pine, and the other softwoods. The tests further show that other classes of paper, such as book, fine printings, writings, &c., may be manufactured from some of the woods studied; but, since they are consumed in comparatively small quantities, they do not command the same attention as do newsprint and wrappings, which lead all papers in quantities consumed. Practically all of the woods investigated proved suitable, too, for various types of fibre-board, such as building-board, container-board, &c.

SIGNIFICANCE.

To the United States of America the study is of far-reaching significance. It provides both a semi and a full commercial demonstration of the wide range of papers and other products which can be manufactured from hardwood pulps suitably produced and processed, and intelligently combined with varying proportions of softwood pulps. The results, together with those secured from other hardwood-pulping studies carried out at the Madison Forest Products Laboratory, should be of great value in the solution of our entire future pulp-supply problem. Many mills established in the New England, the Middle Atlantic, and the Lake States especially are encountering ever-increasing difficulties in securing their pulpwood, either domestic or imported, at a price which will enable them to compete with Canadian and other foreign producers. The pulping of hardwoods available either on their own limits or on adjacent territory should be the chief means of reducing their raw-material costs, of lessening their dependence upon imported pulpwood-supplies, and of re-establishing the industry upon a stable economic basis. It should simplify the management of existing mixed stands, and should go a long way towards assisting to perpetuate the softwood content in the forests of these sections. In the Central, South Atlantic, and Lower Mississippi States it should open the way for new industries.

For obvious reasons it is impossible to give a concrete sum total of how much hardwood-pulping will reduce our dependence upon imported pulpwood, but the critical need of the industry is ample justification for a careful scrutiny of its possibilities. It is very certain that some such development will be one of the chief means of offsetting any pulpwood deficit to our present industry until increased amounts can be grown.

HISTORY.

The laboratory phase of the work was begun in July, 1927, when, at the instance of the New Zealand State Forest Service, the Forest Products Laboratory undertook to determine the pulping characteristics, and to a certain extent the papermaking qualities of a number of New-Zealand-grown woods.

In line with the desires of the co-operator, special attention was directed towards the production of a satisfactory newsprint paper. The study was not limited to conventional practices, and eventually

* Commercially the term "softwoods" refers to trees with needle or scale-like leaves, such as kauri and the introduced pines, and the term "hardwoods" to trees with broad leaves, such as beech, oak, poplar, &c.

it was found that combinations of tawa (hardwood) sulphite and groundwood pulps, with a small amount of insignis-pine (softwood) sulphite, produced a satisfactory paper.

The experimental products made were sufficiently promising, and their economic prospect, on the basis of future market conditions in New Zealand, favourable enough to warrant a recommendation to the co-operator that they be verified by a mill-scale demonstration. Such a course was decided upon and arrangements accordingly made with two Wisconsin mills—the Great Western Paper Co. of Ladysmith, and the Consolidated Water-power and Paper Co. of Wisconsin Rapids—for facilities to carry on the work. The pulp- and paper-mill trials carried on by courtesy of these two companies confirmed the laboratory semi-commercial tests, and yielded valuable data as to the design and operation of equipment required for the production of such newsprint. The results of the laboratory semi-commercial tests and the mill trials are discussed concurrently.

STANDARDS OF COMPARISON.

For purpose of comparison constant reference is made throughout the report to the standard North American pulpwoods. Of these, the white and black spruce (*Picea canadensis* and *P. mariana*) are easily the most important, followed by hemlock (*Tsuga canadensis*), jack-pine (*Pinus Banksiana*), and aspen (*Populus tremuloides*). The spruces are commonly used for the production of groundwood sulphite and sulphate pulps, hemlock for sulphite and sulphate pulps, jack-pine for sulphate pulps, and aspen for soda pulp.

MATERIAL FOR TEST.

SELECTION OF WOODS.

In the selection of woods for testing, the New Zealand State Forest Service was guided by the following considerations: (1) Pulpwoods should be available in large quantities and in fairly heavy stands per acre; (2) pulpwoods should be as whitish in colour and as free from resin as possible, thereby increasing the range of usefulness of their fibres.

Of the six woods selected for testing, the two native species (rimu and tawa) and the introduced softwood (insignis pine) were studied accordingly more intensively than the others, the rimu because it is the most widely distributed and commonly used softwood in New Zealand, and the insignis pine since it is the most widely propagated species in the intensive man-made forests established by Government and private interests. The tawa was studied not only as the principal hardwood of the North Island forests, but as being typical of a group of hardwoods—they all have the same type of fibre—such as blue-gum (*Eucalyptus globulus*) and Tasmanian stringybark (*E. obliqua*). All three woods—rimu, tawa, and insignis pine—are referred to throughout this report as the "major" species.

The remaining three species—Corsican pine, Austrian pine, and European larch—are referred to as the "minor" species. The Corsican pine, although one of the principal species in the Forest Service planting programme, was classed as a minor wood; this because it was known to have a resin content sufficiently high to limit its usefulness to kraft papers and boards, &c. Other species of importance in the Government forestation programme are Douglas fir (*Pseudotsuga Douglasii*) and western yellow-pine (*Pinus ponderosa*), but in view of the experiments* already carried out by the Madison Forest Products Laboratory further pulping and papermaking tests on these woods were considered unnecessary.

COLLECTION.

The woods used in the experiments were collected under the personal supervision of technical officers of the New Zealand State Forest Service, details of the forest stands from which they were selected being given in the shipment and forest descriptions attached as Annexure I of this report.

First Shipment for Laboratory Tests.

The first shipment consisted of material representative of all six species, and originated in the Rotorua Forest Conservation Region, from which it was railed to Auckland and despatched by the S.S. "Canadian Challenger" on the 30th April, 1927, to Montreal, Canada; thence by rail, via Port Huron, U.S.A., arriving at Madison, Wisconsin, on the 9th July.

The woods as received at the laboratory consisted of some 301 logs, 12 ft. in length and from 5 in. to 14 in. in diameter, and of 20 bundles of slabs in cord-wood length (about 4 ft.), making a total of 11 cords of log wood and 1 cord of slab wood. As soon as possible after their delivery on the laboratory skids, the logs were sawn into 4 ft. lengths and cross-piled in the standard manner, the stacks being raised slightly off the ground. The various species are identified in the records according to Table No. 1. The shippers identification marks were stencilled on the ends of the logs, and, while these were decipherable, better results would have been secured by the use of hammer-marks. Accordingly, after sawing into 4 ft. lengths, all bolts were marked with hammer brands.

All logs arrived at Madison in a fairly green state, varying from 14 to 111 per cent. of moisture, based on the oven-dry weight, and with few signs of checking, which, however, developed rapidly in

* "The Suitability of American Woods for Paper Pulp." U.S.A. Department of Agriculture, Bulletin No. 1485. 1927.

the case of the two native woods, rimu and tawa, after exposure to the unusually severe drying conditions which prevailed during the summer of 1927 in this locality. Except in the case of tawa and insignis pine, sap-stain of the wood was negligible at the outset of this study. That of tawa gave rise to a very light greyish cast, as shown in Plate 1, fig. i. The discoloration, however, did not appear to affect the pulping quality of the wood, whereas with insignis pine it was marked enough to introduce a factor into the pulping processes, as will develop later in the report. The radial depth to which the blue stain will penetrate is clearly indicated in Plate 1, fig. ii, the photograph for which was taken not more than nine weeks after felling the tree. The longitudinal penetration of the blue stain is still greater, and occurs also at a more rapid rate. Towards the end of the study this same blue stain developed rapidly in both Austrian and Corsican pine, but was not nearly so serious in European larch.

SECOND SHIPMENT FOR MILL TESTS.

For the commercial pulp- and paper-mill tests 910 cubic feet of insignis pine and 2,090 cubic feet of tawa were railed from the Auckland and Rotorua Forest Conservation Regions respectively, shipped at Auckland by the R.M.M.S. "Aorangi," and railed from Vancouver, B.C., by the Canadian Pacific Railway, arriving at Ladysmith, Wisconsin, on the 25th January, 1928, only nine weeks after cabled instructions for its collection had been despatched. Owing to the ease with which the two species are distinguished, no special identification marks were necessary.

As scaled by the rule in use at the Great Western Paper Co.'s plant, the wood delivered comprised 8·5 cords of insignis pine and 27·9 cords of tawa. The logs were in 12 ft. lengths, and much larger than those in the previous shipment, varying from 8 in. to 26 in. in diameter. As received they were quite green, but, due to its frequent transhipments, the tawa was almost completely barked, indicating the ease with which the bark of the species may be removed. Being cut in some cases from mature trees, however, the tawa logs were often dark in colour and contained a discoloured centre, a portion of which was found, on splitting, to yield dark-blackish deposits along the shakes of the log, similar to hemlock shake, one of the defects in this important pulpwood species of North America. Infiltrations from these same deposits appeared to have been responsible for the discoloration of the wood. It was necessary, therefore, to hack off this defective shake material, and to thus discard about 10 per cent. of the tawa available.

PHYSICAL PROPERTIES OF THE WOODS.

The major physical properties of the woods as received at the laboratory are shown in Table 2, which includes for comparative purposes the average values for these properties as determined by the New Zealand State Forest Service under Madison working plan No. 124.* The density determinations are based upon volume green and weight oven-dry, and the moisture content upon the oven-dry weight of the wood. This density (specific gravity) or unit weight of the wood is an important consideration affecting the economical production of pulp, since the yield per digester charge depends directly upon the weight per cubic foot of the wood. The native woods, with their comparatively slow rate of growth, are noticeably denser than the introduced rapidly-growing softwoods, and both in turn are denser than the standard North American pulpwoods.

In texture the wood of rimu is fine and even, the colour of the sapwood being pinkish-white and that of the heartwood varying from light brown to a deep reddish-brown. As this deep-brown colour develops only in the larger trees, few logs received at the Laboratory showed a colour deeper than light brown, as in Plate 1, fig. iii. Even in the slab and mill waste, few specimens of the deeper-coloured heartwood were found. There is little difference between spring and summer wood, the transition from one to the other being gradual. Free resin does not appear in small pulpwood-sized logs, but is common as resin shakes in the central heartwood of large mature trees. Such material would require to be excluded from mill waste used as pulpwood.

The tawa yields a wood of fine and even texture, with small pores prominent on every section. It is difficult to distinguish between heartwood and sapwood by macroscopic means, since the colour of both is much the same, varying from a creamy to a greyish white. In some of the larger and more mature trees, as previously indicated, a blackish stain develops in the heartwood. As with rimu, there is little difference between the density of early and late wood.

In logs from mature trees the sapwood and heartwood of insignis pine are distinctly marked, the sapwood being a very light brown in colour, and the heartwood a darker reddish-brown. Those shipped to the laboratory, however, were all cut from comparatively young stands, probably under twenty years of age, and did not, accordingly, display much heartwood, since the transformation from sapwood normally begins only when the tree is from twenty to twenty-five years old. As a pulpwood the logs display two serious defects, containing, as they often do, a rotten core or pith varying in diameter from ¼ in. to ½ in., and whorls of knots at distances of several feet along the log.

The sapwood of the three minor species—Corsican pine, Austrian pine, and European larch—is typically light-brownish in colour; but whereas the heartwood of the two pines is only slightly darker in colour, that of the larch is a deep reddish-brown. The differences between the three woods are indicated in Plate 2. Unlike the insignis pine, all three minor species displayed fairly heavy exudations of resin on their ends. The cores of either of the minor pines did not appear to be as large or as rotten as in the insignis pine, although whorls of knots were quite prominent.

* See "Current Tests of Timber Strength." Mimeographed report by the New Zealand State Forest Service Branch of Forest Products.

PHYSICAL PROPERTIES OF THE WOOD-FIBRES.

The principal dimensions of the wood-fibres of the different species are listed in Table 3. The fibres of the New Zealand softwoods are similar in shape to American softwood pulp-fibres, being typically long and slender, with cross-sections approximately uniform throughout their length. Tawa, on the other hand, although yielding a typically shaped hardwood-fibre, thick at the centre and tapering away to sharp points at the ends, has a fibre shorter than American hardwood-fibres, and with a low ratio of length to greatest cross-sectional dimensions. Photomicrographs of typical pulp-fibres of the various woods are shown in Plate 10.

CHEMICAL PROPERTIES OF THE WOODS.

The chemical constants of the several New Zealand woods and comparative data on certain American pulpwood species* are shown in Table 4. The analytical methods employed and the significance of the various determinations are given in Annexure II. Discounting the empirical character of the analytical methods, these data show the similarity of the various New-Zealand-grown pines to the American northern jack-pine (*Pinus Banksiana*), and of rimu, which is not a true pine, to the same species. Insignis pine possesses certain characteristics of both jack-pine and spruce. European larch corresponds closely to the western larch (*Larix occidentalis*) of the United States. Tawa, the hardwood, is similar to sugar-maple (*Acer saccharum*) so far as chemical composition is concerned. The physical and chemical properties of the several woods were important factors in the outlining of methods of pulping, as will develop later in the report.

PULPING TESTS.

OBJECTIVES.

In planning the laboratory or semi-commercial pulping-work three major objectives were set up, their improtance being considered in the order named:—

(1) To produce a pulp or pulps suitable for newsprint from the available species, particularly the major species:
(2) To produce a satisfactory kraft pulp from rimu, the three pines, and larch.
(3) To produce bleached chemical pulps.

In pursuance of the first objective, pulping tests were made by means of the mechanical, sulphite, and semi-chemical processes. The greater part of this work was devoted to insignis pine and tawa, although some attention was given to rimu and European larch. All of the pines and rimu were pulped by the sulphate process, in order to evaluate their possible utility for kraft papers. Pulping tests by the soda process were limited to tawa. Bleached chemical pulps were produced from insignis-pine sulphite pulp and from tawa sulphite and tawa soda pulps. For reasons which will develop later in the report, the pulping tests in the commercial pulp- and paper-mill trials were confined to the grinding of tawa and to the sulphite pulping of tawa and insignis pine.

In reporting the experimental work each process has been considered as a unit and discussed separately. The methods of attack in applying these processes were planned with a view to attaining the objectives mentioned above, and do not purport to cover the field of production of all possible types of pulps. The papermaking experiments constitute a separate part of the report.

PREPARATION OF WOOD.

Preparation of Wood at Laboratory.

Logs for chemical pulping tests were taken from the cord-wood piles as required, barked with a draw-knife, and sawn into sticks 3 in. by 3 in., which is a convenient size for handling by the chipper. This is a two-knife, 24-in.-diameter disk machine, manufactured by J. P. Devine Co., of Buffalo, N.Y., and with a capacity of about one-quarter of a cord of wood per hour, running at 240 r.p.m., and consuming about 20 horse-power. All the woods tested chipped with comparative ease, a chip length of ⅝ in. being used throughout the tests.

Until required for charging into the digester the chips were stored under cover in grain-sacks holding about 20 lb. of oven-dry wood. Just before charging, sufficient chips for a cook were raked by hand over a horizontal screen, 21 in. by 42 in., made of heavy wire, three meshes to the inch, the sawdust and dirt falling through, and the large pieces of wood, slivers, knots, &c., being picked out by the operator. The screened chips were packed in galvanized-iron cans preparatory to being charged into the digester, oven-dry weight determinations being made from samples of about 2 lb. of the chips as they were raked into each can. All calculations of chemical, yield, bleach, &c., were based on the oven-dry weight of either chips or pulp. Determinations of the loss of wood in sawdust and chips were made at the same time.

Logs for mechanical pulping tests were barked as described above, but not sawn, being used in round form in bolts about 9 in. long. In some instances the blocks were squared.

It is a prerequisite for all pulping-work, whether by mechanical or chemical processes, that the wood be cleaned of all dirt, bark, &c., as otherwise the value of the pulp will be considerably impaired. The chips, too, must be of uniform size to secure uniform cooking-conditions throughout the digester charge, and for this reason good screening equipment is very necessary in commercial operations.

* The analytical data reported here were compiled by Mr. M. W. Bray, Associate Chemist in Forest Products, U.S. Forest Products Laboratory, to whom acknowledgment is made.

PREPARATION OF WOOD AT PULP-MILL.

At the Ladysmith pulp-mill the tawa and insignis-pine logs, in 12 ft. lengths, were moved by conveyer from the piles in the wood-yard to the wood-room, where they were cut into 2 ft. bolts by a regular carriage type of slasher-saw. These 2 ft. lengths then passed by conveyer to a log-splitter, which reduced the bolts to a size—about 10 in. by 10 in. in cross-section—which would allow them to be handled in the barking-drums, the chipper, and grinders.

As already indicated, the tawa was almost entirely free from bark, and after sorting for discoloured heart, and, where necessary, hand cleaning, was conveyed direct either to the chipper or to the grinder-room. After chipping, the tawa was screened and passed to the chip-bins, located, as usual, over the sulphite digesters. The wood was sawn, split, and barked without difficulty, but the sorting for and disposal of discoloured heart will prove a real obstacle where large quantities of mature logs are dealt with. The chipper also handled tawa with ease, but a deposit of "gum"—probably some heartwood product—was noticeable on the chipper-knives, which would probably require more frequent sharpening than is usual when spruce is chipped.

In the case of insignis pine it was necessary to pass the whole of the wood through a continuous type of barking-drum before passing to the chipper. The split bolts are fed automatically into one end of the rotating drum, where they are tumbled about and automatically discharged at the other end. The tumbling rubs off the bark, which passes out through narrow slots between the structural sections of which the drum is built. In this installation the drum was run "dry" that is, without using water to loosen up the bark. Excellent results were secured, the insignis pine showing less "brooming" or fraying of the ends than was usual with the spruce and hemlock regularly employed in the mill. The removal of bark, even from knotty bolts, was remarkably good, and the proportion sent back for rebarking and hand cleaning was small. The wood split fairly easily, but the so-called "carrotty" fracture of the wood was very noticeable at this stage of the operations. The chipper yielded a high grade of uniform chip, quite up to, if not above, the usual grade of commercial chip.

GROUNDWOOD PULPING STUDIES.*

THE GROUNDWOOD PROCESS.

One of the most commonly used methods of reducing wood to pulp is by grinding. Usually this is accomplished by pressing short logs of wood, from which the bark has been removed, against a rapidly revolving grindstone. The axis of the log is placed parallel to the axis of the stone, which is kept cooled, and the pulp removed by a shower of water sprayed continuously on the stone-face. The product is variously termed "wood-pulp," "groundwood," or "mechanical pulp," and finds extensive use in newsprint paper, cheap catalogue and book papers, and boards.

Obviously, the production of pulp by this means is cheaply done. The principal items of cost are power used in grinding and the wood. The product, however, is of a somewhat unstable character. Containing all the wood substance, it is subject to rapid deterioration, and particularly to discoloration. It is thus limited to papers designed for temporary use or for filling in with more durable fibres. Groundwood fibres, however, possess certain qualities of opacity and stiffness which are often valuable, and the use of the pulp for these reasons is extensive. The greater tonnages go into newspapers and boards. Ordinary newsprint "furnishes" contain from 60 to 85 per cent. of groundwood, the amount being only limited by the strength requirements of the sheet, which are met by certain admixtures of sulphite fibre.

FACTORS AFFECTING THE QUALITY AND PRODUCTION OF GROUNDWOOD.

Detailed discussions of the factors affecting the quality and production of groundwood pulp have been published by Thickens†‡§, and McNaughton†‖. They will be only briefly mentioned here.

The most important factor affecting quality is the wood itself. Long-fibre wood, properly ground, will produce long-fibred pulp. The colour of the wood, whether natural or stained by decay, and the pitch or resin content are also important. Spruce is the most valued softwood for the manufacture of groundwood, because of its long fibre, low content of pitch, and light colour. The density of the wood determines the yield of pulp per cord, and therefore influences production. Green wood yields a longer-fibred pulp with a lower power-consumption than seasoned wood.

Next to the wood in importance is the quality of the pulp-stone, and the proper stone may be selected to produce the grade of pulp desired. In use, the surface of the stone is dressed with a certain pattern by means of a cylindrical bush-roll, termed a "burr." The purpose of burring is to present new sharp particles of grit to the wood, and to provide grooves to carry the fibres away. Grinder-men have certain preferences in regard to the various types of burrs, but experiments†§‖ have shown the particular pattern used is not very important, provided the grit is exposed to the same degree with each. A stone deeply grooved parallel to the axis, by what is called a straight-cut burr, will produce coarse fibres and a large quantity of screenings. Decreasing the depth of cut and increasing the number

* The wood-grinding studies reported here were made under the supervision of Mr. E. R. Schafer.

† Thickens, J. H., and McNaughton, G. C. "Groundwood Pulp." U.S. Department of Agriculture Bulletin No. 343. April, 1916.

‡ Thickens, J. H. "Experiments with Jack-pine and Hemlock for Mechanical Pulp." U.S. Department of Agriculture Bulletin, Forest Products Laboratory Series. June, 1912.

§ Thickens, J. H. "The Grinding of Spruce for Mechanical Pulp." U.S. Department of Agriculture, Forest Service Bulletin No. 127, Forest Products Laboratory Series. June, 1913.

‖ McNaughton, G. C. "Factors in the Quality of Groundwood." Paper. 3rd October, 1917.

of grooves reduces the screenings and disintegrates the wood more nearly to individual fibres. A stone grooved spirally to the axis produces, in general, a shorter-fibred pulp and less screenings than the straight cut.

The third most important factor affecting quality is the pressure with which the wood is pressed on to the stone. For a given species of wood, quality of stone, and the character of its surface, a shorter-fibred pulp and less screenings will be produced by a lower pressure.

The temperature of grinding, which is controlled by the amount of water used, is not as important as the foregoing factors. Pulp ground hot is freer and contains more long fibres. Practically it is only necessary to use enough water to prevent burning of the wood and to maintain the desired consistency of pulp in the grinder-pit.

Factors affecting quality and production are interrelated, and sometimes one must be sacrificed to the other. Production is increased by increasing the sharpness of the stone-surface, the peripheral speed, and the pressure. While an increase in the last two also requires an increase in the power-input, the power-consumption per ton will in general be lowered because of the increased production.

Laboratory Semi-commercial Grinding Tests.

Selection of Woods.

In carrying out the experiments reported here, the effort was directed entirely toward producing a newsprint grade of pulp. However, departing from conventional practice, considerable attention was devoted to the use of hardwood as a possible source of mechanical pulp. After due consideration two species were chosen for study. Insignis pine was selected from the softwoods, as being most suitable from the standpoint of colour, relative freedom from pitch, and quantity available as pulpwood. Tawa, the hardwood, was likewise selected on the basis of its excellent colour and the fact that it has at present little value for lumber. Of the other species, rimu, although also a softwood of low pitch content, was not considered, because of its dark colour, while the same objection, together with high resin contents, eliminated the other species from the picture.

The Grinder Equipment and Methods of Tests.

The experimental wood-pulp grinder (Plate 3), while much smaller than a commercial grinder, is very similar in design in all respects. It was made by the Bayley Manufacturing Co., Milwaukee, Wisconsin. It has two pockets, the principal dimensions of which are as follows: Cylinder, 7·25 in.; cylinder area, 41·25 sq. in.; pocket dimensions, 8 in. by 11 in.; pocket area, 88 sq. in.; hydraulic pressure foot within pocket, 7·5 in. by 9·5 in.; hydraulic-pressure foot within pocket area, 71·3 sq. in.

The Lombard pulp-stone is 25 in. in diameter, with 11 in. face. The grinder is driven by a Westinghouse 75 horse-power variable-speed motor, belted with a 10 in. leather belt. A Bristol recording tachometer and a Westinghouse indicating watt-hour meter respectively indicate the speed and the power-consumption.

The grinding pressure is controlled by a reducing-valve in the water-line to the cylinders. The pressure of the woods against the stone varies within certain limits for any given pressure on the cylinder. This is due to the constantly changing area of content, which in turn is partly influenced by the size and shape of the wood. In these experiments it is estimated that the average area of wood in contact with the stone was 74 sq. in. For insignis pine it was probably greater than this, as most of the billets were large and nearly covered the entire width of the pocket. The tawa was small round wood, and the entire width of the pocket was not always covered. The average area of contact for the tawa was undoubtedly less than 74 sq. in.

The water-showers are used to cool the stone and wash off the pulp. One of these is located on the top of the stone between the pockets; the other is low down at the back of the grinder. The lower one was found the more effective in keeping the stone cool and the pulp in the pit uniformly of the desired consistency. The upper one was used occasionally when excessive heat developed from such causes as the grinding of a knot or a wedged sliver.

Only one pocket was used at a time, mainly because of the limited power available. As one pocket was grinding while the other was being filled, a uniform load was being applied throughout a run, and reliable measurements of power-consumption were easily obtained.

The peripheral speed of the stone was 3,000 ft. per minute for all experiments.

Tests used to determine Quality of Pulp.

As the wood was being ground, the pulp was run over a wet machine, where an average sample was taken. The sample was used for the determination of the moisture content and freeness; also for a microscopic slide from which photomicrographs were taken. The moisture analysis was used in determining the yield of pulp. The freeness was measured with a Green's slowness-tester, which was of the type recently standardized by the Forest Products Laboratory of Canada, and was obtained from the Star Brass Manufacturing Co., Boston. The pulp from the wet machine was slushed in a beater and made into a dry sheet of waterleaf pulp by running it over the Fourdrinier machines without calendering. Samples of the pulp were cut from the sheet for the determination of the weight per ream, thickness, bursting and tearing strengths, colour, and dirt-particles. The strength-testing instruments are described in Appendix XI. The colour was measured by means of the Ives tint-photometer (Appendix IV). The dirt-particles were counted in 5 sq. in. of the pulp-sheet with the aid of a reading-glass.

Grinding of Insignis Pine and Spruce.

The first grinding tests (see runs Nos. 1 to 7 inclusive in Tables 5 and 6) were made to determine the best conditions for obtaining a newsprint grade of groundwood. The insignis pine was from shipment No. 1211, and the white-spruce was from shipment No. 1190. The white-spruce was ground to furnish a standard for comparison.

The eight-point (*i.e.*, eight grooves to the inch) straight-cut burr was used for dressing the stone in the first experiments, and, as a news grade of pulp was obtained without difficulty, the same burr was used in nearly all of the remaining runs. (See Plate 4.)

The comparative runs Nos. 1 to 7, inclusive, indicated that a pressure of about 30 lb. per square inch on the grinder-cylinder was suitable for spruce and about 35 lb. per square inch was suitable for insignis pine. Reducing the pressure reduced the freeness and increased the bursting and tearing strengths for both species. The strengths of the insignis-pine pulps were in nearly every case greater than those of spruce. Less variation in the yield, due to changing the grinder-pressure from 30 lb. to 40 lb., was noted for insignis pine than for spruce. The production of pulp per twenty-four hours was less, and the horse-power per ton per twenty-four hours was more for insignis pine than for spruce. Small variations in the horse-power per ton per day, caused by changing the grinding-pressure, produce greater variations in the quality of the pulp from insignis pine than from spruce. This point is of importance when the available power is a fluctuating quantity, as is frequently the case with installations depending upon water-power. The results of using a very rough stone are demonstrated in runs Nos. 6 and 7. The pulps obtained were quite free, and the strength was slightly lowered. The screenings were relatively high.

Grinder-runs Nos. 8 and 9 were made to prepare a large quantity of spruce and pine pulps for various runs of newsprint paper. The results of the newsprint runs, the data for which will be found in Table 6 and discussed under another heading, were not satisfactory, because of the dark colour and dirt-particles in the insignis-pine groundwood. Grinder-runs Nos. 13, 14, 16, 17, and 18 were made to eliminate, if possible, these undesirable qualities.

The dirt-particles were believed to be due to knots and the dark-coloured pith. Since most of the knots in insignis pine occur in whorls, they were easily eliminated when sawing the wood into billets. The pith was removed by boring a half-inch hole through the centre of each billet. It is recognized that such a means of preparing the wood would be quite costly and would also reduce the yield per cord. Runs Nos. 13 and 14 were made with wood prepared in this manner, the wood for No. 13 being selected free from blue stain, and No. 14 being badly infected with blue stain. The yellow colour previously observed in the insignis-pine pulps persisted in No. 13, but in No. 14 it was masked to a considerable degree by the blue stain. The dirt-particles in the pulp from No. 13 were greatly reduced in number, and compared favourably with spruce groundwood in this respect. The dirt count was higher for No. 14, but was considerably less than that obtained from wood containing knots and pith.

The desirable appearance and colour obtained when the pulp from grinder-run No. 14 was used with insignis-pine sulphite for newsprint (see Table 6, runs Nos. 13, 14A, and 14B) raised the question of the influence of the blue stain, and led to grinder-runs Nos. 16, 17, and 18. The conditions used in runs Nos. 13 and 14 respectively were duplicated as nearly as possible in runs Nos. 16 and 17, although the wood used in run No. 17 was not so badly blue-stained as that used in run No. 14. Run No. 18 was made with a mixture of blue-stained and uninfected wood representing, in a sense, customary operating-conditions. The results confirmed the previous experiments in regard to the greater amount of dirt in the infected wood. The colour obtained in run No. 17 was more yellow than that obtained in run No. 14, apparently because of the lower amount of blue stain. The dirt count for the run of mixed wood (No. 18) was not much greater than for the run of uninfected wood (No. 16). It appears from the foregoing that the dirt occurring in insignis-pine groundwood is due primarily to knots and pith, and secondly to blue stain. The colour of the pulp seems, however, to be improved by the presence of blue stain.

Grinding of Tawa.

Four grinder-runs were made with tawa (shipment No. 1210)—three short runs to determine the effect of several conditions, and a long one to prepare a quantity of pulp for blending with other pulps to produce newsprint paper. Runs Nos. 10 and 11 (see Tables 5 and 6) were made with a dull stone at pressures of 30 lb. and 40 lb. per square inch on the grinder-cylinder respectively. Run No. 12 was made with a sharper stone at 30 lb. pressure. The various conditions were found to cause very little change in the quality of the pulps, which were very short fibred and flour-like. The freeness-test values were found to be high, and to bear no relation to the quality of the pulps. Two of the pulps (Nos. 10 and 11) were relatively clean, but the dirt count for No. 12 was high. They were all lighter in colour than the pulps obtained from insignis pine. It was necessary to add 10 per cent. of commercial sulphite to each in order to run them over the Fourdrinier machine, and the strength of the water-leaf pulps so obtained was low. Tawa groundwood, because of its very short fibre, seems, therefore, to be suitable only as a filler, and its use would be limited to a relatively small proportion in a mixture with higher-grade pulps.

Grinder-run No. 15 was made to provide a quantity of pulp for use in newsprint-paper experiments, discussed in another section of this report.

Microscopic Classification of Groundwood Pulps.

From the work of Thickens* four pulps have been selected as representative standards of groundwood, and used as a means for evaluating the pulps produced in this study. Photomicrographs of these standards are included herewith, together with photomicrographs of the various experimental pulps.

* Thickens, J. H., and McNaughton, G. C. "Groundwood Pulp." U.S. Department of Agriculture Bulletin No. 343. April, 1916.

Classification No. 1 (see Plate 5, fig. i) represents pulp that is well disintegrated, and contains a large amount of long fibres. Classification No. 2 (Plate 5, fig. ii) is not disintegrated so well, and contains more shorter fibres. Classification No. 3 (Plate 5, fig. iii) contains many shives and a greater quantity of short fibres. Classification No. 4 (Plate 5, fig. iv) contains few long fibres, many short shives, and a large quantity of finely ground material.

None of the experimental pulps (See Table 6) were up to the No. 1 standard, although insignis pine ground under the condition of run No. 8 fell between classifications Nos. 1 and 2. The pulps obtained from tawa all fell below classification No. 4.

Commercial Grinding Trials at Ladysmith Pulp-mill.

Selection of Woods.

Since the semi-commercial grinding trials had shown insignis pine to produce a typical softwood mechanical pulp, it was considered unnecessary to carry this phase of the study to a commercial stage, especially as the pith or core, the chief source of dirt in the insignis-pine pulp, was almost absent in the Ladysmith shipment of pulpwood. The trials were accordingly limited to tawa, three groundwood runs being made for the purpose of producing a pulp naturally as strong as possible, but to act essentially as a filler and to give opaqueness to the news-sheet in which it was to be used. The first was of an exploratory nature, and in the second run certain conditions were slightly modified, due to points observed in the preliminary test. The third run was made to check up on white water-losses, as well as augment the supply of pulp.

Grinder Equipment and Method of Test.

A three-pocket "International" grinder, made by the Friction Pulley Co., was used. The stone was of medium hard grit, obtained from the Richard L. Cawood Co., East Liverpool, Ohio. The grinder dimensions are given in Table 7, together with comparative figures on the Forest Products Laboratory grinder used in the semi-commercial trials. The grinder was driven by a water-turbine capable of developing about 700 horse-power at full gate-opening. Filtered water was used in the cylinders according to standard practice, and for these tests a recently calibrated gauge was put in the water-line to indicate the cylinder-pressure.

The groundwood pulp passed from the grinder-pit to a stock-tank below the floor of the grinder-room. The tank was 33 in. wide and 60 ft. long. The depth of the stock in the tank under operating-conditions was 22 in. From the stock-tank the pulp passed into a sliver-screen, which was 12 ft. wide and 16 ft. 9 in. long. The depth of stock in the screen was 45 in. The pulp was pumped from the sliver-screen through three Ruth centrifugal screens. The screenings were passed through a fourth Ruth centrigugal screen and ejected on to a flat perforated screen, where they were washed with a hose and shovelled into a wheelbarrow. The screened pulp was pumped through a 6 in. pipe to the wet-machine room in another building about 540 ft. distant.

The groundwood was run into laps on one of three wet machines (designated as machine No. 3) The wet machines, which were built some years ago by the Kaukauna Machine Co., Kaukauna, Wisconsin, were equipped with 72 in. felts 25 ft. long. Sixty-mesh wire was used on the cylinders. The laps of pulp were "skinned" from the press-roll by hand. The "skinning" and folding of the laps of tawa was a little difficult at first because of the short fibre, but the workmen soon learned to handle them without much trouble. The laps were piled on skids, weighed, and samples taken for the determination of the moisture content.

Part of the white water from all of the wet machines was returned to the groundwood-mill, the rest being used in showers on the deckers or run into a save-all tank. The overflow from the tank, which was 5 ft. in diameter and 8 ft. high (inside measure), ran on to an inclined screen save-all about 30 in. wide covered with 60-mesh wire. The salvaged pulp was collected in a box fitted with a perforated-tile bottom (blow-pit tile) placed at the bottom of the incline. The water draining through the save-all ran to the river. Frequently, when all wet machines were operating, the flow of white water was so great that this box overflowed and the overflow water, containing varying quantities of fibre depending on conditions, also ran to the sewer. In running tawa groundwood the fine fibres filled the mesh of the save-all wire, allowing little clear water to drain through; the slow stock also prevented the box from draining freely, and consequently a large quantity of pulp was lost in the overflow to the sewer. The effect of this loss is discussed later.

The Grinder-runs.

Grinder-run No. 1.—The surface of the stone was smoothed with a smooth bush roll and dressed lightly with a sharp four-point straight-cut burr, followed by a new fourteen-point diamond-cut burr. Straight- and diamond-cut burrs were the only types used at the mill, and it was believed this combination would give results similar to those used in the Forest Products Laboratory tests, where a three-point straight cut followed by a ten-point spiral had been used. The cylinder-pressure was set at 30 lb. per square inch, and the speed of the stone, arbitrarily set by the groundwood foreman, was 180 r.p.m. A log of the run will be found in Table 8.

Two and three-quarter cords of wood were ground in the first run, which was of twenty-five hours' duration. The quality of pulp, as indicated by the blue glass, was much better than that produced at the laboratory. The fibres were separated to a greater degree, and there was less material ground to flour. The quantity of pulp produced was 3,938 lb. (dry basis). There were no slivers or screenings.

Grinder-run No. 2.—The stone was sharpened in the same manner as in run No. 1, and the interval between the successive sharpenings was decreased from four hours to three. This change was due to the fact that the best pulp was produced just after dressing the stone, and that more flour was being made after the third hour. The more frequent dressing produced slivers and screenings, however, and one wheelbarrow-full of each was collected during the run. Three and a quarter cords of wood were ground. The duration of the test was 30·5 hours, and 5,210 lb. of pulp (dry basis) were produced. The log of the run is given in Table 8.

The yield of pulp in runs Nos. 1 and 2 was an average of 1,500 lb. per cord. Indications that such a low yield was being obtained were not evident until the second run was about half-completed. An investigation of the cause was immediately started, and, after some difficulty, was found due to the white-water and save-all system already described.

Grinder-run No. 3.—Grinder-run No. 3 was made to determine the yield of pulp for comparison with the results obtained at the laboratory. Since all of the clean wood had been ground in the previous tests, the third run was made with the dirty centres left from the cleaning operations. The stone was dressed, as in the previous run, at intervals of about three hours. In order to be sure that no white water was lost through the deckers, and that the overflow at the save-all would be a minimum, the run was made on Sunday, when all the other units were shut down. Wet machine No. 1 was used. A rectangular weir 10 in. long, with end contractions, was placed at the top of the inclined screen save-all. The box back of the weir was not measured, but was approximately 30 in. wide and 24 in. long. The depth of water back of the weir was 14 in. Readings and samples were taken every five minutes during the periods when the weir was overflowing. In addition to the samples of white water taken at the save-all, several samples were taken at the cylinder of the wet machine. A summary of white-water and fibre losses in grinder-run No. 3 is given in Table 9.

When the test was ended, the system was washed clean. In other words, almost ideal conditions prevailed for the operation of a perfectly closed system. The weight of pulp obtained as laps, plus the slight determined loss in the white water, should approximate closely to the theoretical fibre-yield possible. The yield of lapped pulp (dry basis) was 3,145 lb., and the loss in the white water was 45 lb. One and a half cords of wood were ground in twelve hours, which is a yield of 2,125 lb. of pulp per cord and a production of 2·13 tons per twenty-four hours. The small amount of fibre lost at the save-all was due, of course, to the exceptional conditions under which the test was made. The comparatively high fibre content of the white water indicates the necessity for a closed white-water system in any contemplated installation. Even under the good conditions prevailing during this test, the apparent yield per cord was much lower than was secured in the laboratory runs.

Pulp-yields.

This discrepancy between laboratory and mill figures requires some analysis. All laboratory determinations were based on oven-dry pulp from oven-dry wood, and on a weight basis. For convenience of calculation, moreover, and to conform with a standard often used for such purposes, the solid-wood content of a cord was arbitrarily assumed as 100 cubic feet; whereas the average for hardwoods is nearer 75 cubic feet, which would reduce the average yield of the three laboratory runs to only 2,150 lb., corresponding closely with the yield of 2,125 lb. per cord obtained in grinder-run No. 3. Although these figures, when based on the weight of the wood, represent a yield of only 80 per cent., compared with a yield of over 90 per cent. often obtained in the grinding of spruce, the yield in pounds per cord is higher than that of spruce measured on the same basis.

The pulp from grinder-run No. 3, having been produced from discoloured and dirty heartwood, was of a deep reddish-brown colour in the grinder-pit, but as lapped on the wet machine was of a comparatively light colour. Some of the pulp from the grinder-pit was accordingly studied at the laboratory. It became darker on exposure to the air, but after washing with cold water in a Buchner funnel was materially brightened. This improvement in colour was measured by the Ives tint-photometer according to the principles laid down in Annexure IV of this report. As will be seen by reference to Table 10, the whiteness of the pulp was increased, while the tint remained about the same, indicating that the material washed out was black in colour, and in all probability came from black residue in the wood.

Physical Qualities of Tawa Groundwood Pulps.

The quality of the pulp was judged almost entirely by visual examination, using a blue glass. No freeness-tester was available, and this record could not be made. However, samples of pulp were taken from the grinder-pit at various intervals after dressing the stone, and photomicrographs were made illustrative of changes in the fibre as the stone became dull. The sample taken at thirty minutes appeared "choppy," the millman's term for short bundles of fibre. Samples taken at 60, 105, 120, 150, and 210 minutes were successively, although slightly, more disintegrated to individual fibres. The amount of finely divided material appeared slightly increased. However, in estimating pulp-quality by this method, due allowance must be made for the difficulty of preparing slides truly representative of the pulp. Plate 6, fig. v, is illustrative of pulp produced 105 minutes after sharpening the grinder-stone.

The stone at Ladysmith seemed quite suitable for producing a well-disintegrated fibre. A coarser-grit stone would probably produce a more choppy pulp.

As in the laboratory semi-commercial tests, it was impracticable to make 100 per cent. water-leaf sheets of the groundwood, but samples containing 10 per cent. spruce sulphite were easily prepared.

Summary of Groundwood Studies.

In general, groundwood pulps from insignis pine are equal to spruce in strength, but inferior from the standpoint of colour and dirt. Elimination of the pith or core rot in the growing tree by appropriate mycological and silvicultural control would reduce the dirt count materially. The power requirements of grinding insignis pine are relatively greater than those of spruce. While these power figures are on the basis of the experimental semi-commercial equipment, the same relation would undoubtedly hold for standard commercial-sized equipment.

Tawa, being a hardwood, produces a pulp much inferior to spruce in strength, but of excellent colour, and comparatively free from dirt. The power requirements per ton indicated were not excessive, and the possibilities of the fibre as a filler are good. In seems desirable, in grinding tawa, to use a comparatively sharp stone in order to minimize the loss of fine material in the white water. The matter of size of grit of the pulp-stone should also be given consideration. The pulp made at the Madison Laboratory was, in general, more finely divided than that made at Ladysmith, but a closed white-water system is essential in any proposed installation.

SULPHITE PULPING STUDIES.*

Objectives and Scope of the Work.

In line with the major objective of this study, the principal effort in the sulphite pulping experiments was directed toward the production of a grade of pulp suitable for newsprint. Incidentally some attention was given to the bleaching of certain of the pulps produced, and applying to the minor objective of producing a bleached sulphite stock.

The experimental work was limited to the three major species—rimu, tawa, and insignis pine—with the exception of one scout cook made upon European larch. The minor species, Austrian and Corsican pine, and the European larch, were eliminated from consideration on the basis of previous laboratory tests on various pines, which have shown that the high resin or pitch content of such species render them unsuited to the sulphite process.

The Sulphite Process.

Briefly, the sulphite process consists in delignification of wood by the action of a solution of sulphurous acid and bisulphite of lime. The wood, in chip form, is subjected to the action of these reagents in an acid-proof vessel, called a digester, at relatively high temperatures and under pressure. Presumably the principal reactions are hydrolysis and sulphonation. The sulphurous acid effects an hydrolysis of the ligno-cellulose, separating cellulose and lignin, at the same time sulphonating the latter. The lime present (often termed the " base ") acts to neutralize the lignin-sulphonic derivatives, forming soluble calcium salts, which are removed in the waste liquors. Cellulose fibre, or pulp, is left in a reasonably pure state.

The sulphite cooking-liquor is commonly termed the " acid," and its two components, the dissolved sulphur dioxide or sulphurous acid and calcium bisulphite, are known as the " free " and the " combined " sulphur dioxide respectively. The sum of the two is often referred to as the " total." As noted above, the lime is frequently referred to as the " base."† Its principal function is the formation of soluble lime salts of the lignin-sulphonic acids resulting from the cooking action. If the amount of " base " present is inadequate, these lignin compounds tend to resinify and darken the pulp, a phenomenon known as " burning." The maintenance of calcium bisulphite in solution depends upon the presence of an excess of sulphur dioxide, these components being in equilibrium. If for any reason excessive amounts of sulphur dioxide are removed from the system, the bisulphite will revert to the normal calcium sulphite, an insoluble salt. Such an action results in so-called " liming " (depositing of a lime-like precipitate), and the base is said to have " dropped out." A number of the above terms will be used in the following discussion.

The most important factor in cooking sulphite pulp is the control of temperature. The factor of second importance is acid strength and composition. The latter is so chosen as to ensure a thorough penetration of the wood prior to actual cooking, which has been found to start around 110° C. when the digester has reached so-called " pressure " (about 75 lb. per square inch). Thereafter the manner in which the steam is applied and the temperature controlled governs the rate of cooking and the quality of the product produced. Usually a definite schedule is followed, often termed a " cooking curve." The curve used depends upon the kind and quality of wood and the type of pulp desired. In normal operation it covers the temperature-range between 110° C. and 148–150° C. Various typical schedules or curves have been found to produce pulps of different properties and in varying yields, as will be brought out later in the report.

Unbleached sulphite pulp constitutes from 20 to 30 per cent. of the average newsprint paper, and the total quantity of sulphite pulp used for this purpose is quite large. Bleached sulphite pulp finds wide use in book, magazine, and writing papers when mixed with pulps of other types, and is also used in the production of specialties, glassine, and certain grades of wrappings.

At present practically all sulphite pulp is produced from the soft woods. Spruce is the species most commonly used. Hemlock is quite extensively employed for newsprint sulphite, and a limited quantity of hardwood is now pulped for use in certain specialties.

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* The sulphite studies were made under the supervision of Mr. W. H. Monsson.

† Calcium is the " base " most commonly used. Certain liquors, however, contain considerable quantities of magnesium, and practically any alkali or alkaline earth might serve as a base.

Laboratory Sulphite Pulping Studies.

Previous Work.

So far as the application of the sulphite process to the woods in question was concerned, precedent existed only in the case of insignis pine. A few scout cooks had been made on this species at the Forest Products Laboratory several years previously, and are reported in U.S. Department of Agriculture Bulletin No. 1485.* Due to certain developments in technique, it was found desirable to disregard more or less this previous work, and to base the experimental procedure upon observed results with spruce and with jack-pine (*Pinus Banksiana*).

Method of Attack.

In order to evaluate the three species, seven preliminary or scout cooks were made. In selecting the cooking-conditions some consideration was given to previous experience in the case of insignis pine, but the main reliance was placed upon comparative physical and chemical properties of the New Zealand species and certain American pulpwoods. Such information was secured by determining the fibre length and density and the chemical constants. (See Tables 2, 3, and 4.) The scout cooks indicated insignis pine and tawa to be most promising, particularly from the standpoint of the colour of the pulps, and the major effort was consequently directed toward these species. However, sufficient work was done upon rimu to properly evaluate its position in the general scheme.

Equipment and Manipulation.

The pulping tests were made in the experimental digester at the laboratory. Two views of the digester are given in Appendix III of this report. It consists of a vertical cylinder with tapering ends, made of steel, and lined with an acid-resistant earthenware lining. Capacity is between 60 and 70 gallons, and the limiting wood capacity about 100 lb., oven-dry, although the average wood charge is somewhat less than this figure. The digester is stationary. It is equipped with both direct and indirect steam lines, the latter being used alone when indirect cooking or Mitscherlich pulping tests are being made. The use of indirect steam is also necessary when making cooks under the co-called Ritter-Kellner or direct-steam (quick-cook) method, due to the greater ratio of digester-surface to contents than exists in commercial equipment. By this means the dilution effect on the acid is minimized, and operation made comparable with commercial practice.

Before charging, the moisture content of the wood was determined, and the quantities of cooking-chemical and volume of liquor were calculated on the basis of the oven-dry weight of wood. During cooking the pressure and temperature were carefully regulated, and observations recorded at fifteen-minute intervals. The progress of the cook was followed by analyses of the cooking-liquor and by observations of the colour of the liquor. At the end of the cooking period, the digester contents were discharged into the blow-pit, washed free of cooking-liquor, and drained.

The methods used for analysis of cooking and waste liquors, and for yield determination, bleach and strength tests, are given in Appendices V, VI, and VII.

Materials used.

The amounts of wood used in each cook are given in Table 11. The acid was made by passing sulphur-dioxide gas into a suspension of calcium hydrate in water containing the relieved gas from a previous cook. The analysis of acid for each cook and the volumes used are also given in Table 11.

Discussion of Results.

All cooking data have been summarized in Table 11. Strength data, as determined by the ball-mill method, are given in Table 12.

Rimu.

Due to the appearance and hardness of rimu, methods of attack were employed which had been previously found successful with hardwoods. Certain components of the wood produced a very highly coloured waste liquor towards the end of the cook, which rendered useless the chemical method commonly employed for ascertaining the completion of the cooking reaction. For example, in cook 3256–I, which had been originally scheduled to last ten hours, the pulp was blown at the end of nine hours and a half because of the highly coloured condition of the liquor and for fear that the pulp would be burned. In two subsequent cooks, Nos. 3257–I and 3258–I, the quantity of wood was decreased, and the reaction carried out for the desired length of time—ten hours.

In the case of cook 3256–I the pulp yield was 48·1 per cent.; cook 3257–I gave a yield of 47·7 per cent. The pulp in both cases was too dark for use in newsprint in the unbleached state. Cook 3256–I required 30 per cent. of bleaching-powder to produce a satisfactory colour, which is too high for economical commercial operation. The pulp from cook 3257–I bleached to a satisfactory white with 22 per cent. bleaching-powder.

Cook 3258–I was made with the idea of obtaining a lighter pulp. The same temperature-rise period from room-temperature to 110° C. and from 110° C. to the maximum was used as in the previous cooks, but the maximum temperature was increased to 153° C. It was planned to hold the temperature at the maximum for at least half an hour, but, due to the deep colour of the cooking-liquor, this period was reduced to fifteen minutes. No improvement in colour was noted over previous pulps, but a slightly greater yield was obtained, and the bleach requirement was less, than in the case of cook No. 3256–I.

* "The Suitability of American Woods for Paper Pulp," by Sidney D. Wells and John D. Rue. U.S. Department of Agriculture. Bulletin No. 1485. 1927.

Still another attempt to produce a light-coloured product was made in cook No. 3280. The temperature curve was modified (see Plate 7, fig. ii), but the same time to 110° C. and to maximum temperature was used as in cooks Nos. 3256–I and 3257–I. A somewhat lighter pulp resulted, but the colour was still too dark for newsprint. The results of cook No. 3280–I were confirmed by a check cook (No. 3284–I), in which the yield, bleach requirement, and ball-mill strength data agreed quite closely.

In considering the physical or strength tests of rimu pulps (see Table 12) account need be taken only of the bursting and tearing data, as other tests are not commonly applied to newsprint. The tearing-strength of all five pulps were adequate for newsprint. The bursting-strength of pulps from cooks Nos. 3256–I, 3258–I, 3280–I, and 3284–I were somewhat low, but should, nevertheless, be satisfactory for the ordinary newsprint furnish. All of the rimu sulphite pulps were too dark for use in the unbleached condition.

The pulping tests that have been made on rimu indicate that the species can be pulped by the sulphite process with yields averaging in the neighbourhood of 48 per cent. The product, although not suitable in the unbleached state for newsprint, can probably be used in such products as glassine, or wrapping-paper, or specialties.

Insignis Pine.

The resin content of insignis pine is similar to that of spruce. On this basis the first two cooks (Nos. 3259–I and 3260–I) were made by following the two typical temperature curves used for the production of newsprint-grade spruce sulphite (see Plate 7, figs. iii and iv). However, difficulties developed which have previously almost invariably been encountered in attempts to produce pine sulphite, and certain modifications in the procedure were necessary.

The pines present a distinct problem so far as the sulphite process is concerned. Comparative tests made at this laboratory on spruce and northern jack-pine (*Pinus Banksiana*) showed lower yields, higher bleach requirements, and inferior physical properties for pine pulps. The colour was particularly bad, the unbleached pulp having a decided grey cast. It was also dirty or "shivey." Almost invariably in the latter part of the pulping operation a reaction occurred, as yet unexplained, causing the rapid disappearance or "dropping out" of the base (calcium bisulphite). It was therefore necessary to "blow" the pulps before the cooking was complete, in order to prevent "burning." This behaviour seems to be characteristic of the various pines when subjected to sulphite pulping, and is indicative of the problems encountered in the present work with insignis pine.

Cooks 3259–I and 3260–I compared favourably with spruce pulped under similar conditions so far as yield and strength were concerned. The colour, however, was rather too dark for newsprint purposes, and the tests following were planned primarily to bring about an improvement of this quality. Cook No. 3259–I was the better of the two, and could possibly be used.

In making cook No. 3263–I the same type of curve was used as for cook No. 3259–I, but the original plan was to hold the cook at the maximum temperature (148° C.) for one hour. This plan was adhered to, although the base was practically exhausted at the end of eight hours and a half. As a result the pulp was "burned," as shown by its low strength. (See Table 12.) The colour, however, was somewhat lighter than that of the pulp from cook 3259–I.

The same temperature conditions were used in cook No. 3264–I, and the pulp blown after nine hours and a quarter, at which time the base was exhausted. The colour was the best of any up to this point. The strength qualities, though lower than those of pulps from cooks 3259–I and 3260–I, were still satisfactory for newsprint purposes. The yield was 49·4 per cent. Towards the end of cook No. 3264–I the characteristic precipitating or "dropping out" of the base was very noticeable. As stated, this phenomenon has not been satisfactorily explained.

In cook 3265–I (Plate 7, fig. iv) the temperature was raised to 153° C. and the pressure to 80 lb. per square inch, on the assumption that by so doing the final colour of the pulp might be improved. The cook was scheduled to last eight hours and a half, but had to be blown after eight hours and quarter, due to exhaustion of the base, even though a greater percentage of base had been added than in previous cooks. Both the yield and strength of the pulp were low, indicating that temperatures higher than 148° C. are unsuitable for pulping of insignis pine.

In cook 3266–I (Plate 7, fig. iv) the maximum temperature was lowered to 140° C., although the time used to reach 110° C. and the rate of temperature-increase to 140° C. was the same as followed in cooks 3259–I, 3263–I, and 3264–I. No definite time was set for the finish of the cook, but it was blown when the liquor analysis showed exhaustion of the base. This point was reached at the end of nine hours and a half, although at the ninth hour the liquor analysis showed 0·2 per cent. of the base remaining. In the case of a spruce cook this amount of base would ordinarily last from one to two hours longer. The pulp obtained bleached easily (12 per cent.), and the yield was high. However, on the basis of the strength data, apparently it was slightly overcooked. The colour was rather dark.

At this point a Mitscherlich, or indirect, cook was tried. In this modification of the usual cooking process only indirect steam is used, and the reaction proceeds quite slowly. The maximum temperature is considerably under that used in direct cooking, and the colour and strength of Mitscherlich pulps are generally considered superior to other sulphites. In this case (cook No. 3267–I) the same acid-strength was used as in previous cooks, but the volume was increased from 50 to 54 gallons. The chips were steamed for half an hour before the cooking-acid was run into the digester. The cooking curve is shown in Plate 8, fig. v. The cooking was scheduled to continue for thirty hours, but, due to exhaustion of the base, was blown at the end of the twenty-first hour. Although the base did not "drop out" so rapidly as in previous cooks, the reaction had the same characteristics as noted above. The yield was 48·2 per cent., the strength qualities were good, and the colour was the best of any of the insignis-pine pulps obtained up to this point.

In cook 3269–I (Plate 7, fig. iii) still another attempt was made to carry to completion a cook scheduled nine hours and a half, duplicating the cooking-conditions used in cooks 3263–I and 3264–I. As before, the cook had to be blown prematurely, this time at the end of eight hours and three-quarters. No improvement in the colour of the pulp was noticed, and the yield was unusually low. However, the strength qualities of this pulp were good.

Still seeking to carry a cook to completion (nine hours and a half total cooking-time) without the base "dropping out," the same temperature schedule was again tried with a higher ratio of acid to wood than had previously been used. In cook No. 3275–I (Plate 7, fig. iii) only 65·2 lbs. of wood were used, while the quantity of acid was unchanged. By some chance it was possible to carry this particular cook to completion (nine hours and a half). The base rapidly disappeared towards the end, as previously noted, but this reaction did not begin until about the ninth hour. However, a check was unsuccessful (cook No. 3283–I), the base disappearing quickly and requiring that the cook be blown after nine hours and a quarter. Cook No. 3275–I resulted in a high yield of pulp of good strength and equal in colour to the product from cook No. 3264–I.*

The pulp from the check cook, No. 3283–I, was quite similar to that from cook No. 3275–I. Yield figures, however, were not in close agreement, although they fall within the limits of experimental error.

In seeking to improve the colour, cook No. 3281–I was made, using a modification of the temperature curve employed for cook 3260–I (see Plate 8, fig. vi), the digester being held one hour at the maximum temperature. The colour was not improved, being somewhat more grey than previously obtained, but still light enough for use in newsprint furnish. The yield of 51·75 per cent. was high, and the strength of the product comparable to spruce newsprint sulphite.

In general, insignis-pine sulphite pulp was satisfactory for newsprint purposes from the standpoint of strength and colour, although not equal to spruce in these respects. However, the wood exhibited the same tendencies heretofore noted in applying the sulphite process to jack-pine, and presents a problem in cooking-control requiring careful handling.

Tawa.

Due to its physical characteristics, tawa was subjected to pulping conditions which have been found adapted to the hardwoods. The first four tests were made with the idea of producing a pulp suitable for book paper. The average fibre-length of tawa is only 0·88 mm., and fibres of this type produce a bulky, opaque stock which is desirable in book-paper manufacture.

In cook No. 3261–I (Plate 7, fig. i) two hours were used in raising the temperature to 110° C. and seven hours from 110° to 148° C. The cook was held at this maximum for one hour. A pulp-yield of 49·2 per cent. was obtained. Screenings were low, indicating that adequate time had been used for penetration (time to 110° C.). The bleach requirement was 10 per cent.†

In cook No. 3262–I the temperature curve was modified as shown in Plate 8, fig. vii, although the time to "pressure" and to maximum temperature was the same as before. After reaching 148° C. the cook was held there for two hours. The yield was 47·3 per cent., and the pulp somewhat better in appearance than the product of cook No. 3261–I. The bleach requirement was 12 per cent.

The strength qualities of both of these pulps were comparable with the grade of material going into book papers, although quite low in comparison with sulphite pulp from softwoods.

Cook No. 3268–I was a duplication of cook 3261–I, except that the time at the maximum temperature was extended half an hour. The pulp obtained was of better colour than any of the previous cooks. The pulp-yield was 48·5 per cent., and the bleach requirement 10 per cent. The strength properties seemed slightly better in all respects than for the pulps from cooks 3261–I and 3262–I.

Cook 3270–I was made as a check test on cook 3262–I. The yield of pulp, bleach requirement, and strength properties checked very closely.

The foregoing tests demonstrated that the pulps produced by means of the temperature curves indicated can be used for certain grades of book paper. They bleach readily, and are rather opaque, both desirable qualities in book papers.

The tests that follow were made for the purpose of producing a pulp from tawa that could be used in newsprint furnish.

Benjamin,‡ in Australia, had recently produced a satisfactory grade of newsprint pulp from eucalyptus, following the temperature curve shown in Plate 8, fig. viii, and using an acid of 6 per cent. total and 1·5 to 1·6 per cent. combined SO_2. Cook 3271–I was made following Benjamin's temperature schedule. The pulp produced seemed rather raw and dark, but upon proper rod-mill treatment (described in another section of this report) it gave promising results. A yield of 52·5 per cent. crude pulp was obtained, of which 3·2 per cent. were screenings. The high percentage of screenings gave indication that insufficient time had been allowed to permit thorough penetration of the acid into the chips. The bursting-strength of this pulp was relatively high—particularly so when the rawness of the cook is considered. The colour, although not as light as usually desired, was satisfactory for newsprint purposes.

Two cooks (Nos. 3273–I and 3274–I) similar to No. 3271–I were made, excepting that three hours and a half instead of two hours and a half were used in raising the temperature from 110° C. to 140° C.

* Pulp samples were not made for cook No. 3275–I.

† Bleach requirements throughout the report refer to standard bleaching powder which contains 35 per cent. of chorine available for bleaching.

‡ "Newsprint: Preliminary Experiments on the grinding of Eucalypts for Mechanical Pulp and Possibilities of Manufacturing Newsprint in Australia," by L. R. Benjamin. Bulletin No. 31. Australian Council for Scientific and Industrial Research. 1927.

The total time, therefore, being seven hours instead of six hours. In neither instance was there any marked differences in yield, quality, or colour from the pulp obtained from cook 3271–I. Sample sheets of these pulps were not run.

In order to obtain a lighter-coloured pulp and lower screenings, cook No. 3276–I was made, following the type of curve shown in Plate 7, fig. i. The pulp obtained showed a decided improvement in colour over any produced previously, and the strength qualities were superior to any of the other tawa pulps. Unfortunately, the yield of this pulp had to be estimated, due to the loss of some pulp upon blowing the cook. However, repeat cooks Nos. 3297–I and 3282–I were made, duplicating all conditions and verifying all points indicated by cook No. 3276–I.

The samples of tawa pulp produced exhibited a rather specky and dirty appearance, which is characteristic of hardwood sulphite pulps, such as are yielded by aspen, maple, and birch. Comparative cooking-strength data on these same species have been included in Tables 11 and 12.

Tawa - Insignis Pine Mixture.

In a papermaking experiment described in another section of this report successful use was made of a mixture of tawa and insignis-pine sulphite pulps in the proportion or 78 and 22 per cent. respectively. Cook No. 3277–I was made on such a mixture to determine the practicability of pulping the two species together. The result was quite successful. The curve illustrated by Plate 7, fig. i, was employed. A yield of 49·4 per cent. resulted, and by comparison of the strength data of this pulp with those from cooks 3279–I or 3282–I it will be noted that the mixed-species pulp is high in all respects.

European Larch.

Only one test (cook 3278–I) was made on European larch. The yield of pulp obtained was low, and the percentage of screenings high. The colour was dark, and the pulp rather "shivey," eliminating this species as a source of newsprint sulphite pulp. The data obtained on pulping western larch by the sulphite process have been included in Table 11 for comparison.

Adaptation of Laboratory Results to Mill-scale Operation.

In case the co-operator desires to translate the foregoing laboratory results into mill practice, cognizance should be taken of certain factors involved, and allowance made therefor. At present most mills have no means of ascertaining the weight of chips charged into the cookers, the measure being by cords. Yields, too, are rather hard to determine, most mills getting at this value by using the over-all mill-production figures and crediting each cook with its proportionate share, regardless of other factors involved. Besides lack of information regarding the actual weight of wood being pulped, there are also doubtful elements of moisture content and general physical condition of the wood, variations in chip-size, in acid composition, in accuracy of temperature measurements, steam available for cooking at a given time, &c. All of these items can be minimized by careful supervision, but never completely eliminated. Cooking-conditions should, therefore, be so arranged as to cover as many contingencies as possible, and should, above all, be flexible and designed to take care of the poorest operating-conditions which are likely to be met. With this in mind, tentative schedules for mill-scale operation have been drawn up for the production of newsprint grades of pulp from immature insignis pine and from immature tawa. In cooking mature wood from both species better results will probably be secured by increasing the penetration periods recommended for the immature wood.

Newsprint Sulphite Pulp from Immature Insignis Pine.

Acid composition: 5 to 5·5 per cent. total SO_2; 1·3 to 1·5 per cent. combined SO_2.

Temperature and pressure schedule: Two to two and a half hours to 110° C; a uniform rate of temperature-increase of 5° to 6° C. per hour from 110° to 148° C. A uniform pressure of 75 lb. should be maintained throughout the cook, with a half-hour gassing-down period at the end of the cook.

The time that will be consumed in raising the temperature from 110° C. to 148° C. will vary from seven to eight hours. The type of newsprint pulp desired will determine whether or not the digester should be blown upon reaching maximum temperature. If a hard stock is desired, no further cooking is necessary. If a softer stock is wanted, having a slightly better colour, the temperature should be maintained at the maximum for at least half an hour, and preferably one hour.

Another type of curve that could be used is that shown in Plate 8, fig. vi. This type of cooking schedule is somewhat harder to control under mill conditions:—

Acid-composition: Same as before.

Temperature and pressure schedule: Two to two and a half hours to 110° C.; 110° to 117° C. in two hours; 117° to 126° C. in two hours; 126° to 139° C. in two hours; 139° to 148° C. in one hour. One to two hours at the maximum temperature. A uniform pressure of 75 lb. throughout the cook, with a half-hour to one-hour gassing-down period.

Newsprint Sulphite Pulp from Immature Tawa.

Acid-composition: 5·5 to 6 per cent. total SO_2; 1·2 to 1·4 per cent. combined SO_2.

Temperature and pressure schedule: Two and a half to three hours to 110° C.; a uniform rate of temperature-increase of 5° to 6° C. per hour from 110° to 148° or 150° C. (seven to eight hours) 75 lb. pressure.

If a book stock is desired the temperature should be maintained at the maximum from one to two hours.

COMMERCIAL PULP-MILL TRIALS AT LADYSMITH, WISCONSIN.

General.

The commercial pulping tests comprised five sulphite cooks—three using tawa, one using insignis pine, and one using a mixture of equal parts insignis pine and white-spruce. The admixture of spruce in the latter instance was made necessary by the lack of sufficient pine to complete a second cook, and by the need for additional long-fibred stock to meet the papermaking requirements. All five cooks were made in line with the major objective of producing a hard sulphite pulp suitable for newsprint processing.

Sulphite Mill Equipment.

The Ladysmith mill is equipped with three digesters with a rated capacity of 6 cords of wood, or approximately 3 tons of pulp each. Actually the wood capacity varies from 5·5 to 5·75 cords. The digesters are 10 ft. in diameter by 32 ft. high. They are supplied with cooking-steam by means of a 5 in. steam-line carrying about 100 lb. steam-pressure.

The acid system comprises one flat stationary sulphur-burner, two wooden Jensen acid-towers, two acid-storage tanks, and one acid-reclaiming tank. The acid plant is so located that the cooking-liquor can be run into the digesters through the top by gravity. Under ordinary operating-conditions the acid composition ranges from 4·5 to 5 per cent. total SO_2 and 1·25 to 1·7 per cent. combined SO_2.

The pulp-screening equipment is rather limited, consisting of one flat screen, probably 40 ft. long, fitted with "eight cut" plates (screen slots 0·008 in. wide). Neither knotters nor rifflers are used. The screened pulp is formed into laps on three wet machines.

Cooking-conditions.

The composition of the cooking-acid is shown in Table 13. In order to simplify temperature-control, one type of curve was selected and followed in all cooks. This is shown in Plate 9, figs. 1 to 5, by means of a dotted line. The actual cooking-temperatures are shown in the same figures by solid lines. The selected schedule allowed two hours and a half to 110° C., and then a steady rise to 148° C. in an additional seven hours and a half. In making the cooks the time to 110° C. was actually three hours to three hours and a half, and to 148° C. correspondingly shortened.

The digester pressure was brought to 75 lb. and maintained at that point throughout the cook, with a slight "gassing down" just prior to "blowing" the digester.

The temperature-readings were taken from the recording-thermometer chart. The thermometer-well is located at the base of the upper cone of the digester. The thermometer was not calibrated, as this procedure was impracticable, and the temperatures noted in Plate 9, figs. 1 to 5, must be considered only approximate.

Discussion of Results.

In comparison with corresponding pulps previously produced in the laboratory, all of the commercially-made pulps were overcooked. This was evident, for example, in the lower strengths developed in the ball-mill tests recorded in Table 14. The insignis-pine pulps were much lighter in colour than their laboratory prototypes, while the tawa pulps were equivalent to the laboratory products in this respect, but softer and weaker.

This relative overcooking probably resulted from two causes. In the first place, lacking both time and material, no opportunity was afforded to make the necessary scout cooks and to calibrate the commercial digester and its recording thermometer in terms of the laboratory equipment. Because of this circumstance the cooking-conditions had to be selected with a view to meeting the most adverse conditions which could be foreseen. This suggests that, given opportunity, there should be no difficulty in modifying the cooking-conditions and improving both the yield and the quality of the pulp.

The tawa pulps were, however, surprisingly "shivey," particularly in view of the long penetration period used. It is believed that this was due largely to the wood supplied for these tests, which was more mature than that used in the laboratory tests, and possibly requires even more time for impregnation than was accorded it. Using young wood and properly selecting the cooking-conditions should greatly reduce the shives, and possibly result in practically eliminating them. A more efficient screening and riffling system would undoubtedly have substantially reduced the difficulties encountered with the shives.

For a similar reason the insignis-pine pulps were more "shivey" than their laboratory prototypes, probably because the logs used contained a fair percentage of heartwood, which was entirely absent in the pulp-wood employed for the laboratory semi-commercial tests.

Pulp-yields.

As is the case in most pulp-mills, no means of determining the actual weight of wood substance charged into the digester was available. The quantity was estimated at 5½ cords per cook. The screened and lapped pulp from each cook was weighed and moisture content determined, the oven-dry yield of pulp per digester being calculated from these figures. The weights and yield figures are given in Table 13.

The pulp-yields correspond closely to those obtained in the laboratory semi-commercial cooks. On the assumption that the digester capacity was 5·5 cords, the yields per cord were as follows: Cook No. 1 (insignis pine), 1,330 lb. per cord; cook No. 2 (tawa), 1,280 lb. per cord; cook No. 3 (tawa), 1,270 lb. per cord; cook No. 4 (tawa), 1,515 lb. per cord; cook No. 5 (50 per cent. insignis pine and 50 per cent. spruce), 1,100 lb. per cord. The yield per cord for insignis pine appears high, and is undoubtedly due to the overloading of the digester, so that on a basis of 6 cords it will be reduced to 1,220 lb. The high yield per cord for tawa in cook No. 4 may be due in part to the same cause. The approximate character of these values should not be lost sight of, but they indicate in a general way the pulp-returns secured and their general agreement with the laboratory semi-commercial results.

Summary of Sulphite Pulping Tests.

Insignis pine can be reduced to a suitable quality of pulp for use in newsprint paper without bleaching, the yields and strength quality being comparable with those of sulphite pulp from white-spruce, although not entirely equivalent to this pulp in all respects. Young, immature timber is preferable to older timber containing heartwood.

Immature tawa can be readily pulped, the nature of the product being determined by the cooking methods used. By employing a ten-and-a-half- or eleven-hour cooking schedule a satisfactory pulp for book paper, bleaching easily, can be produced. Reduction of the total time to about nine hours will result in a pulp suitable for newsprint purposes, and obtainable in high yield. Mature tawa can also be pulped, but, as will develop in the papermaking section of this report, requires special processing.

The cooking-conditions for immature insignis pine and tawa are similar, and mixtures of the two woods can be pulped without difficulty.

The experiments with rimu indicate that this species can be readily reduced to pulp by the sulphite method, and, while the product is too dark for use in newsprint unbleached, it can probably be used in such products as glassine, or wrapping-paper, or specialties. European larch, like the North American larches, is difficult to pulp by the standard sulphite process, and the product is of doubtful value.

ALKALINE AND SEMI-COMMERCIAL PULPING STUDIES.*

Objectives and Scope of the Work.

Four pulping processes come within the scope of this study, and were applied to one or more of the species under investigation The soda process was applied to tawa in producing a bleached pulp of book grade. Insignis pine, Austrian pine, Corsican pine, rimu, and European larch were all pulped by the sulphate or kraft method, the principal objective being a strong product suitable for wrapping-paper or board. Insignis pine, rimu, and European larch were further subjected to the so-called semi-kraft process recently developed at the Forest Products Laboratory. Tawa was pulped by means of the semi-chemical process, another newly developed method, in an effort to produce a suitable pulp for newsprint purpose. The methods of analysis of the various cooking liquors are set out in Appendices Nos. VIII, IX, and X.

Pulping Processes.

The Soda Pulping Process.

The soda process is so called because caustic soda (NaOH) is the chemical agent used to separate cellulose from the balance of the wood-components. The product is known as soda pulp. Although the method is applicable to both broadleaf and coniferous woods, it has come to be used practically entirely with the broadleaf or hardwood species. This is due to the fact that a better and more economical method—the sulphite process—is available for reducing long-fibred woods, and the soda method is employed only where a short-fibred stock of considerable bulk, opacity, and softness is desired. These characteristics are esteemed in book and printing papers, and a considerable proportion of such papers consists of soda pulp.

The method is applied in much the same fashion as the sulphite process, the wood, in the form of chips, being subjected to the action of an aqueous solution of caustic soda at high temperature and under pressure. The cooked pulp is discharged or " blown " from the digester in the usual way, washed thoroughly, and bleached. The waste liquors (termed " black liquors ") are collected, in contrast to the sulphite process, evaporated to dryness, and burned in a rotary furnace, which action converts the organic sodium compounds to soda ash or sodium carbonate. This so-called " black ash " is leached out with water and " causticized " back to caustic soda by treatment with hydrated lime. The recovered chemical is reused in the process, being supplemented by sufficient fresh caustic to replace that unavoidably lost during the pulping operation. Without such a system of chemical recovery the soda process would be economically impossible, due to the high chemical costs.

The Sulphate, or Kraft, Pulping Process.

The sulphate process is a modification of the soda process in which the active components of the cooking-liquor are caustic soda and sodium sulphide, usually in the proportion of 2 to 1. The name comes from the fact that the fresh chemical is added in the form of sodium sulphate, which is mixed with the recovered " black ash " and further subjected to a fusing operation during which the sulphate is reduced to sulphide. The wood-preparation, cooking operations, and pulp-handling are the same as with the soda process. Recovery involves the same steps as noted under the soda process, and in addition the reduction of sodium sulphate by fusion, as previously mentioned.

" Sulphate " liquors are not so drastic in their action as straight soda liquors, and the sulphate process gives better yields and stronger pulps than the soda method. Its use is limited almost entirely to conifers, although it could undoubtedly be applied to hardwoods as well. Very little sulphate pulp is bleached, and the greater proportion is used in the manufacture of kraft wrapping-papers, or, in combination with waste papers, for high-test container-boards. This widespread use in strong, or " kraft," papers accounts for the use of the term " kraft " as descriptive of the process.

The main drawback of the sulphate process lies in the disagreeable odours resulting from the cooking action. On account of this it has not replaced the soda process to the extent it potentially might, and the mills are necessarily usually located at points where population is sparse and the inconvenience of this factor slightest.

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* Alkaline and semi-chemical pulping studies were made under the supervision of Messrs. C. E. Curran and C. E. Peterson.

The Semi-kraft Process.

The semi-kraft process differs from the regular sulphate process in that the cooking-liquor is impregnated into the chips, under pressure, prior to the steaming or cooking action, and all unabsorbed chemical is removed before actual pulping begins. The chips are not completely pulped in the cooker, but merely softened, the final pulping being effected by disintegration in a grinding-device, such as a rod mill. The chief advantages are higher yields, savings in cooking-chemical, and savings in steam in the recovery operation, or dispensing with any recovery whatever. The method has been in process of development at the Forest Products Laboratory over a period of several years, but has not as yet come into commercial use. It has been included here because of its potential possibilities.

*The Semi-chemical Process.**

The semi-chemical method is quite similar to the semi-kraft process described above. In place of alkaline reagents, however, the liquors are practically neutral, consisting of solutions of normal sodium sulphite (Na_2SO_3) and sodium bicarbonate ($NaHCO_3$). The chips are impregnated with these chemicals under pressure, the excess being removed and used in a subsequent cook, and the pulping effected with the reagent absorbed by the chips themselves. The chips are merely softened by this operation, and must be reduced to pulp form by rod-mill or other mechanical action. Although the semi-chemical process is still largely experimental, several commercial applications have been successfully initiated. It is now in use for the manufacture of corrugated board from extracted chestnut chips, and semi-chemical gum pulp is being utilized for a low-grade wrapping-paper and as a part of a cheap print-paper furnish.

The principal advantages are exceptionally high yield, and savings in chemicals and steam. Yields in excess of 70 per cent. are customary, and this, combined with low chemical consumption and the cheap woods to which the process is applicable, results in production costs almost as low as those for groundwood pulp. Like groundwood, the colour of the pulp depends upon that of the raw wood, and if a light-coloured product is desired this point must be kept in mind. However, the slight chemical action results in a capacity for hydration absent from mechanical pulp, and semi-chemical pulps, even from short-fibred hardwoods, will develop considerable strength under proper conditions of beating. On the basis of the commercial operations already instituted and semi-commercial scale experiments at the laboratory, the semi-chemical process is believed to possess excellent possibilities in connection with the production of certain grades of cheap print papers, medium-grade wrappers, paper and building boards.

Experimental Equipment and Procedure.

The soda and sulphate cooks followed standard practice in all respects. They were made in a vertical rotary digester of approximately 100 lb. chip capacity. (This and other equipment is described in Appendix III.) The chips, prepared as noted previously, were charged into the digester, and the desired volume of cooking-liquor added. After closing the digester, steam was admitted at such a rate that the temperature-rise corresponded to a previously determined schedule. A certain amount of indirect steam was used to counteract excessive steam-condensation and liquor-dilution, thus more nearly approximating commercial cooking-conditions, the digester pressure being relieved from time to time to maintain the pressure and temperature corresponding to conditions of saturated steam. The digester was rotated throughout the cook. When the cook was completed a sample of black liquor was withdrawn for analysis, and the digester contents blown into the blow-pit and thoroughly washed with hot water. The washed pulp was screened through a diaphragm screen with "cuts" 0·02 in. in width. The screenings were oven-dried and weighed. The screened pulp was run over a wet machine to remove some of the water, and then weighed. During this run an average sample was secured, on which the moisture was determined. The percentage yields of screened pulp and of screenings were calculated from these data.

A representative sample of pulp from each cook was saved, upon which strength tests were made by the standard ball-mill method. In some instances bleachability determinations were made. The remainder was converted either into water-leaf pulp sheets or paper by running over the small Fourdrinier paper-machine. Certain of the pulps were bleached before being run over the machine.

In the case of the semi-kraft and semi-chemical pulps the cooking procedure was modified to permit the impregnation of the chips with chemical and the "blowing back" of the excess liquor before the cooking was begun. The softened chips were converted into pulp in the rod mill. Yield determinations were based upon the weight and moisture content of the softened chips, hydraulicly pressed, and the pulp was not run over the wet machine. All subsequent operations were the same as for soda or sulphate pulps.

Discussion of Results.

Complete pulping data for all soda, sulphate, and semi-kraft cooks are given in Table 15. The strength data on machine-made sheets are shown in the same table. Similar data for the semi-chemical cooks are given in Table 16. Strength data as determined by the standard ball-mill method for all sulphate, soda, and semi-chemical pulps are shown in Table 17, with the exception of semi-chemical cook No. 2220, which was tested in the rod mill and the results reported in Table 18. Ball-mill strength data were not obtained for the semi-kraft pulps.

* "A Semi-chemical Pulping Process," by John D. Rue, Sidney D. Wells, Francis G. Rawling, and J. A. Staidl. *Paper Trade Journal*, 23rd September, 1926.

Soda-process Pulping Tests.

Pulping experiments by this process were limited to the hardwood, tawa. Three cooks were made (cooks Nos. 2241, 2242, and 2243), using the same maximum temperature (170° C.), but varying the quantity of chemical per unit weight of chips and the time of cooking. Cook No. 2241, in which 25 per cent. of chemical was used, produced the most-readily-bleachable pulp. The yields varied inversely with the quantities of cooking-chemical used.

As would be expected, the tawa soda pulps were weak. They possessed excellent bulk and opacity, however, and would undoubtedly serve for book or similar grades of paper.

Sulphate-process Pulping Tests.

As previously noted, this process was applied to insignis pine, Austrian pine, Corsican pine, rimu, and European larch—all long-fibred woods. All of these species pulped without difficulty. The cooking-conditions were chosen as nearly as possible comparable with commercial operation. A standard ratio of 14·3 lb. of caustic soda and 5·7 lb. of sodium sulphide per 100 lb. of oven-dry wood was used. The chemical concentration was 80 grams per litre. In most instances two sets of temperature conditions were tried, as follows: (1) The cook was brought to a maximum of 170° C. in 90 minutes, and maintained at this point for 120 minutes; (2) a maximum of 180° C. was reached in 120 minutes, and maintained for 60 minutes. The variations from these schedules are noted in Table 15.

An analysis of the data in Tables 15 and 17 leads to the conclusion that the several species are all adapted to pulping by the sulphate method. Rimu produces the best pulp, while Corsican pine, Austrian pine, insignis pine, and European larch follow in the order given. Rimu slab wood yielded a slightly inferior pulp to that secured from the round wood. This same fact has been noted with other species in various instances, but no good explanation is at hand. The bleaching of cook No. 2232 on insignis pine indicated that satisfactory bleached pulps might be produced from this species when reduced by the sulphate process.

The relatively low yields and freedom of the pulps from screenings, combined with the texture of the pulp-samples secured, leads to the observation that overcooking took place in practically all tests, and that less drastic conditions would result in even better pulps and higher yields. The products made were entirely satisfactory, however, and confirmation of this indication was omitted.

Semi-kraft Process Pulping Tests.

Rimu, insignis pine, and European larch were pulped by this method. As with the sulphate process, rimu yielded the best pulp and European larch the poorest. The savings in chemical were as noted in Table 15, and the increases in pulp-yield are given in the same table. These are remarkable in view of the quality of pulp produced.

Ball-mill strength data were not secured on semi-kraft pulp, as these had to be reduced in the rod mill. However, the strength of machine-made sheets from the same pulps rod-milled for different lengths of time give an index to this value. For example, rimu cook No. 2245 showed a progressive increase in strength with rod-milling, and the same tendency is noticed with cook No. 2246 on European larch. The semi-kraft pulps were darker and somewhat inferior to straight kraft pulps in feel and appearance, but the method is thought to offer possibilities in the way of lower grades of kraft, or in the utilization of wood waste from the species in question.

Semi-chemical Pulping Tests.

Tawa was the only species subjected to the semi-chemical process, the objective in this case being a light-coloured pulp suitable for newsprint paper. Five cooks were made, in which the chemical ratios, proportions of sulphite and bicarbonate, and the cooking temperatures were varied as noted in Table 16. Strength data for the semi-chemical pulps are given in Tables 17 and 18. By proper selection of the cooking-conditions it was possible to produce a pulp of satisfactory strength, but the colour was not up to the desired standard, and the pulp was comparatively "specky" and dirty. It also showed a tendency towards transparency, which is an undesirable feature in newsprint.

In cook No. 2218 the proportion of sulphite to bicarbonate was in the ratio of 2 to 1. This produced a somewhat alkaline condition, which, combined with the relatively low cooking-temperature, resulted in a soft pulp of very low strength. In cooks Nos. 2219, 2229, 2247, and 2248 the ratio of sulphite to bicarbonate was increased, and the maximum cooking-temperature raised 10 degrees. These conditions produced pulps of better strength and colour.

The use of tawa semi-chemical pulp for newsprint is discussed later in the report. However, it may be said that it is not entirely satisfactory for this purpose. Nevertheless, semi-chemical pulps undoubtedly possess certain qualities which make them excellent possibilities in the field of fibre-boards, both container and building boards, and in various other products. This should be a point for serious consideration in connection with any pulping development which the co-operator may contemplate.

Summary of Alkaline and Semi-chemical Pulping Tests.

In summing up the results of this phase of the experimental pulping-work it seems obvious that tawa is suitable for pulping by the soda process, and adapted to the manufacture of a bleached product for book or similar grade paper production.

The sulphate process can be readily applied to rimu, or to any of the pines, or European larch, and a pulp produced comparing favourably with the so-called "No. 1" kraft pulps on the American market. Of the several species, rimu yielded the most satisfactory pulp from the standpoint of strength. The application of the semi-kraft process to rimu, insignis pine, and European larch shows that savings in chemical and increased yields are possible at some sacrifice of pulp strength and appearance by the use of this method. The expenditure of additional power in beating semi-kraft pulps would undoubtedly result in materially increased strength.

The application of the semi-chemical process to tawa was only moderately successful in its principal objective of producing newsprint paper. The strength developed in these pulps by continued rod-mill treatment, however, indicates possibilities in the way of wrapping, boards, and other products.

PAPERMAKING TESTS.

GENERAL.

Practically all the experimental and commercial papermaking work was concentrated upon the production of newsprint from various pulps and furnishes, as will be evident by examination of Tables 20, 21, *et seq.* A few papers were made from sulphite and sulphate pulps, as noted under "Remarks" in Table 15 and in Table 26. In general, the various pulps resembled so closely the corresponding North American products that the results of the ball-mill tests and the water-leaf sheets produced from each cook were taken as sufficiently indicative of their papermaking properties, and further papermaking experiments were considered unnecessary.

NEWSPRINT STANDARDS.

A number of commercial newsprint papers were assembled and tested. These data have been compiled in Table 19. They were made the basis of comparison in evaluating laboratory results, and represent averages of newsprint papers from various sections of the United States and Canada. These tests gave an average of 0·28 points per pound per ream in bursting and 0·74 grams per pound per ream in tearing strength; and a minimum of 0·30 points per pound per ream bursting and 0·70 grams per pound per ream tearing were therefore set up as desired standards. Two methods of procedure were employed:—

(1) Insignis-pine sulphite and groundwood pulps were used in the production of standard newsprint,* varying proportions or furnishes of sulphite and groundwood being tried.

(2) Conventional practice was disregarded, and various mixtures of insignis-pine sulphite and groundwood; tawa sulphite, groundwood, and semi-chemical pulp; and bleached rimu and European-larch sulphite were tried, with interesting results. Data on all runs are given in Tables 20, 21, *et seq.*

LABORATORY PAPERMAKING STUDIES.

Standard Newsprint Paper from Insignis Pine.†

The value of insignis pine for standard news was determined by mixing varying proportions of the groundwood and sulphite pulps under different conditions, and running into water-leaf paper. The standards of comparison were commercial newsprint papers collected from various sources (see Table 19) and two runs of commercial pulps made on the small Fourdrinier machine at the laboratory. The two runs of commercial pulps (runs Nos. 1 and 2, Table 20) served for comparison of strength, but not of colour, due to the fact that the groundwood from which they were made had become discoloured during storage. As a further comparison, spruce groundwood (run No. 9, Table 20) was mixed with a commercial sulphite and run into a newsprint paper (see runs Nos. 3 and 4, Table 20).

In runs Nos. 5 and 6, Table 20, insignis-pine sulphite and groundwood pulps, in the proportions of 30 per cent. to 70 per cent. respectively, produced papers equal in tearing-strength and higher in bursting-strength than the commercial pulps (runs Nos. 1 and 2). Increasing the groundwood to 80 per cent. (run No. 7) lowered both the tearing and bursting strengths slightly, but the latter was still higher than that obtained with the commercial pulps. The experimental papers were, in general, stronger than the commercial papers listed in Table 19. From the standpoint of colour and dirt, however, the papers produced in runs Nos. 5, 6, and 7 were inferior to standard news. This was largely because of the dark-yellow colour and the dirt in the insignis-pine groundwood, previously mentioned in discussing the preparation of these pulps. An attempt was made in run No. 10 to improve the colour by bleaching the sulphite pulp, but the colour analysis indicated that little was gained by this procedure.

Runs Nos. 11 to 14B inclusive, and runs Nos. 37A to 39 inclusive, were made with the groundwood prepared from wood without knots and with the centres bored out. The qualities inherent in the respective groundwood pulps were found to be reflected in the quality of paper produced and to a proportionate degree, cleaner papers resulting from the pulp produced from carefully cleaned wood.

The papers from runs Nos. 37A, 38, and 39 were run over the press of the *Wisconsin State Journal*, of Madison, Wisconsin. Because of the narrow width of the paper, the press was operated at about

* "Standard newsprint" consists of 80 parts of mechanical pulp and 26 parts of chemical pulp, nearly always unbleached sulphite.

† The papermaking studies reported here were made under the supervision of Messrs. P. K. Baird and E. R. Schafer.

one-quarter of the normal speed. The paper ran well, only one break occurring, near the end of the roll. The quality of the printed sheet was equal to the average American newsprint in regard to both colour and bursting-strength. Its behaviour was entirely satisfactory from the pressman's standpoint.

Newsprint from Tawa, Insignis Pine, Rimu and European Larch Mixtures.*

Following the precedent of Miller,† and of Benjamin‡ in Australia, attention was directed toward the use of hardwood sulphite and hardwood groundwood for newsprint. Various amounts of insignis-pine groundwood and sulphite, and of bleached rimu and European larch, were also tried at different times. Data on the various furnishes and strength of the papers produced are given in Table 21.

Tawa Sulphite, Tawa Groundwood, and Insignis-pine Sulphite Mixtures.

The first run (No. 15, Table 21) was made with a furnish of 70 per cent. tawa sulphite and 30 per cent. tawa groundwood, and was not beaten. It was found impossible to bring the weight of this sheet below 60 lb. per ream, a circumstance which was later found to be due to a bulge in the machine-wire and not because of any markedly inherent weakness in the tawa fibre as had been at first assumed. The colour of this first run was within the range of newsprint, but the sheet was full of specks and shives.

A second run (No. 16) was made with the same furnish, but the sulphite pulp was beaten for ten minutes in the rod mill to increase the strength and disintegrate the specks and shives. In this run the colour and strength were satisfactory, but it was still impossible to bring the paper down to news weight, for the reason above noted.

Subsequently a 100-per-cent. tawa sheet (run No. 32) was made from a furnish of 30 per cent. groundwood and 70 per cent. sulphite, which was beaten five minutes in the rod mill and twenty minutes in the beater, and which was run as a 40 lb. sheet without difficulty, a new wire having been installed.

In run No. 17 approximately 15 per cent. of insignis-pine sulphite was added, with the object of strengthening the sheet. The defective wire was still a bar to successful machine operation, but satisfactory strength and colour were secured, and the sheet was run at about 45 lb. per ream.

These preliminary trials gave evidence that a satisfactory paper could be made from tawa groundwood, tawa sulphite, and insignis-pine sulphite when combined in suitable proportions and with proper conditions of beating. A series of runs was planned, therefore, to run down the principal variables —namely, the percentages of tawa sulphite and groundwood and insignis-pine sulphite practicable to use, and the optimum beating-conditions. The tawa groundwood has practically no strength, and acts as a filler only. The hydrated tawa sulphite acts as a cementing binder, the strength of which is enhanced by beating. The long fibre of the insignis pine makes up the strength lacking in the other two pulps. An exhaustive study of the variables was impossible, and it is quite likely that the most satisfactory furnish used can still be improved. It may be possible to develop a 100-per-cent. tawa sheet having the necessary strength.

In Runs Nos. 18 and 19, the insignis-pine sulphite was increased to 30 per cent., and the weight of the paper was brought down to approximately that of standard 32 lb. news. A new wire was installed at this juncture, and thereafter no difficulty was experienced in running weights of approximately 32 lb. per ream, the insignis-pine content being brought to as low as 8 per cent. in the furnish for run No. 21.

The beating-conditions were varied in machine runs No. 22 to 28 inclusive, with practically the same furnish. Allowing about one minute per pound of pulp in the rod mill was found to give the highest test for the amounts used. In some of the runs only small amounts of pulp were available, and in these cases the maximum strength was not developed; the treatment was more drastic, and the fibres were probably injured before full strength was developed. The best beating combination was found by partly beating the tawa sulphite in the rod mill to hydrate it to some extent and break up the specks and shives, followed by a light brushing of the entire furnish in the beater. It was then found that with proper treatment a furnish of 35 per cent. tawa groundwood, 50 per cent. tawa sulphite, and 15 per cent. insignis-pine sulphite gave the required strength tests.

The paper from machine run No. 28 was run through the large press of the *Wisconsin State Journal*, and, in the opinion of the pressmen, was a satisfactory sheet. Because of the width of the sheet it was impossible to run the press at a high speed. At low speeds a harder impression is given by the type, and more ink is picked up, which increases its tendency to strike into the paper and show through on the opposite side. Since the same result will occur with any sheet of standard newsprint, this is not necessarily a defect in the paper. A sheet wide enough to permit its being run at a high speed would undoubtedly have satisfactory printing-qualities.

Runs Nos. 26 and 27 were beaten in the Marx beater in view of the possibility of a later mill-scale trial where no rod mill was available. Although the strength in both runs was considerably higher than in any of the other machine runs, the effect of using a small amount of pulp was also

* This work was done under the supervision of Mr. G. H. Chidester.

† "The Use of Eucalyptus Wood in the Manufacture of Newsprint," by R. N. Miller. U.S. Forest Products Laboratory Report—Project 7168–J25. 8th January, 1926. (Unpublished.)

‡ Newsprint: Preliminary Experiments on the Grinding of Eucalypts for Mechanical Pulp and Possibilities of Manufacturing Newsprint in Australia," by L. R. Benjamin. Bulletin No. 31. Australian Council for Scientific and Industrial Research. 1927.

noticed here. With a furnish of 10 lb. the consistency was very low, and the treatment given the pulp so drastic that the full strength was not developed. The colour was satisfactory in both runs, but the specks and shives were not thoroughly broken up, and the sheet was dirty.

In a later run (No. 42) the furnish was beaten a longer time in the beater, and given a lighter brush, with the hope of breaking up more of the fine specks. A fairly clean sheet was produced, which was apparently satisfactory for a news sheet. Satisfactory strength and printing-qualities were shown by this sheet when run through the press of the *Wisconsin State Journal.*

Run No. 29 was made, using sulphite cook No. 3277–I, in which insignis pine and tawa were cooked together. The pulp was overbeaten, however, and the strength was low.

Substitutions of Rimu and European Larch for Insignis-pine Sulphite.

Runs Nos. 31, 33, and 42 were made with substitutions of rimu and European larch for insignis pine. Run No. 31, in which 15 per cent. of bleached larch was substituted, gave a low bursting and a high tearing strength, indicating that more beating would have made a satisfactory news sheet. The colour was above the average. A considerably smaller amount of bleach should produce a colour satisfactory for this furnish. In run No. 33 15 per cent. unbleached rimu was substituted. The strength was low and the colour was rather dark. It would probably be necessary to partly bleach the rimu pulp to give the desired colour, if used in the amount necessary to give the required strength. In run No. 43 15 per cent. of bleached rimu was used, with an improvement in colour, but the sheet was not up to the desired strength standard.

Newsprint Runs using Semi-chemical Pulp.

Run No. 35 was made on a furnish of 80 per cent. tawa cooked by the semi-chemical process, and 20 per cent. tawa groundwood. The strength and colour were poor, and it was impossible to run a light-weight sheet. Runs Nos. 36 and 40 were made on a furnish of 100 per cent. semi-chemical pulp. The strength was satisfactory, but the colour was dark and the sheet rather brittle. In run No. 41, 55 per cent. of semi-chemical pulp was substituted for the tawa sulphite in the news furnish with bleached larch. The strength and colour were slightly below the desired limits, and the paper was less opaque than some of the other samples. It is quite possible, however, that a satisfactory paper can be made by using the semi-chemical pulp in smaller amounts.

One of the main difficulties in making a newsprint paper from semi-chemical pulp has been brittleness and hardness. In the tawa runs a consistency of 9 per cent. was used in refining the chips in the rod mill, which seemed to give a softer and less-hydrated stock that could be worked up in the beater.

COMMERCIAL PAPER-MILL TRIALS.

General.

So far as the Forest Products Laboratory was concerned, only one factor was not covered in the experimental semi-commercial tests—namely, the translation of certain phases of the papermaking experiments to a mill-scale basis. As this is the customary practice of the laboratory, and all projects are considered incomplete until such times as a mill-scale test is possible, it was recommended that arrangements be made to establish commercially the results already reported. This recommendation was adopted by the co-operator, and arrangements made accordingly for the pulping and papermaking tests on a commercial scale.

Previous laboratory experience had shown that the two major problems in connection with the production of a news-grade paper from tawa and insignis pine would be—(1) The development of sufficient strength from the tawa sulphite to offset the complete lack of this quality in the finely ground tawa mechanical pulp; and (2) the elimination of shives from the tawa sulphite in the interests of a clean paper.

The laboratory tests previously reported had shown that the first requirement involved hydration or beating of the tawa-sulphite stock, and the second a refining action of some sort by means of either Jordan, beater or rod mill. It had been demonstrated on a laboratory scale that both of these objectives could be accomplished by proper processing with any of the above-mentioned machines. The rod mill, however, was found to possess certain advantages, particularly in the elimination of shives.

Paper-machine Run at the Great Western Paper Co. Mill.

The operations of the Great Western Paper Co. at Ladysmith, Wisconsin, may be considered as typical of a newsprint or catalogue-paper mill. The sulphite and groundwood furnish is mixed in beaters, but all hydration and refining depends upon the action of the Jordan.

Previous to carrying the laboratory results to the mill scale, papermaking runs had been successfully carried out at the laboratory, using the small Jordan for all of the necessary beating and refining. The results of these tests are shown in Table 22 under machine-runs Nos. 1 and 2. On the basis of these tests it was decided to make a trial run at the Ladysmith mill, and compare the processing possible in a newsprint mill, having only Jordan equipment, with results obtained at the laboratory. Accordingly several attempts to produce news-grade paper were made at Ladysmith, as shown in Table 25.

The paper-machine and auxiliary equipment at the Ladysmith mill was as follows:—

Description of Paper-mill Equipment used at Great Western Paper Co., Ladysmith, Wisconsin.

Machine.	Make.	Size.	Power Requirement.
Beater	Pusey and Jones ..	..	About 70 h.p.
Jordan	Appleton Machine Co. ..	No. 2 ..	100 h.p. motor.
Paper-machine	Beloit	81 in. trim	About 70 h.p. at 300 f.p.m.
Pumps, screens, &c. ..	..	..	25 h.p.

This machine is equipped with wooden first and second presses, and a brass third press. It was in rather bad condition, the driers being slightly out of line, with the result that unless the draws were kept quite tight the paper would wrinkle badly.

Various furnishes were tried, and a new filling placed in the Jordan between the first and second runs. The results of the runs were unsatisfactory. Difficulty was encountered in putting the paper over the machine, both at the press and particularly in the drier section. The paper produced was low in strength and dirty. The colour and finish were judged satisfactory.

Subsequent to the run at Ladysmith, samples of the commercially produced pulps were forwarded to the laboratory and subjected to various processing in order to compare the behaviour of the commercial paper-machine and the laboratory equipment, and to develop possible methods of improving the strength, quality, and cleanliness of the paper. A record of the furnishes used and various methods of processing employed is given under machine-runs Nos. 3 to 11 in Table 22. The strength qualities of the several sheets prepared are shown in the same table. It should be noted that where the weight per ream of the paper is high correspondingly high values are secured in the strength tests, and values obtained under such circumstances must be discounted somewhat when they are translated to the lower-ream-weight basis. This led to discarding the results of certain tests which, taken at their face value, indicated excellent-quality pulps.

Runs Nos. 3, 4, and 5 in Table 22 were accorded the same treatment as had been given laboratory-made pulps prior to the mill-scale tests. They very definitely showed that the commercially prepared pulps were not the equivalent of the laboratory pulps in the strength qualities, particularly in tear. Runs Nos. 6 to 11 included various beater and rod-mill treatments on the commercial pulps to determine the treatment necessary in developing strength in these products.

These experiments demonstrated the possibility of attaining satisfactory strength in the pulps by proper processing, and were used as a guide in the subsequent mill-runs.

Papermaking Runs at Wisconsin Rapids.

The papermaking equipment at the Wisconsin Rapids mill of the Consolidated Water-power and Paper Co. is better adapted to handling the type of stock with which this study is concerned, being in process of changing from the manufacture of newsprint to the production of higher grades, including machine-finish book, rotogravure papers, &c.

The available paper-machines and auxiliary equipment consisted of the following items:—

Description of Paper-mill Equipment used at the Consolidated Water-power and Paper Co.

Machine.	Make.	Size.	Power Requirement.
Two beaters	E. J. Jones ..	2,000 lb.	About 150 h.p.
Jordan	E. J. Jones ..	Majestic	94 h.p.
Two screens	Bird and Sons ..	..	25 h.p.
Paper-machine*	Beloit	122 in. trim ..	335 h.p. at 450 f.p.m.
Pumps	..	..	114 h.p.

* The paper-machine is equipped with a granite first press, wooden second press, and brass third press.

The beaters had been newly installed and ground in with sand. The Jordan had also been freshly filled and conditioned by grinding in with sand just prior to the first experimental run.

The laboratory tests (see Table 23) having shown the necessity for strength-development in the beater, this factor was put under control and the strength-development followed by means of freeness tests at regular intervals, and determinations of the bursting-strength on oven-dry hand-sheets. In the course of the trial runs several variations in beater treatment were tried, as recorded in Table 24.

The order of furnishing the beater was 1,000 lb. of tawa sulphite at approximately 4½ per cent. consistence, and all of the hydration studies were made on this pulp. The remainder of the components of the furnish were added just before the beaters were dropped, and freeness, &c., determined on these total furnishes. These data are also given in Table 24.

The first machine-run (see Table 26) was made on the 13th March, using the pulp from beater-run Nos. 1 and 2. These pulps had been subjected to rather drastic beating-conditions, and gave considerable trouble on the machine, many breaks occurring, particularly at the third press. It was found impossible to bring the paper down to weight, but the strength factors of such paper as was made were satisfactory. The sheet, however, was shot through with shives, and was very dirty.

An attempt was then made to knock out these shives in beater-runs Nos. 3, 4, 5, and 6, in which the roll was set down quite hard and the beating continued over a long period. The machine-run on this stock was made on the 15th March, and recorded as a part of machine-run 1 in Table 26. The same difficulty with sticking at the third press was encountered in the early parts of this run, and breaks were very frequent until such time as beaters 7 and 8 came into the run, when the machine ran for over an hour without difficulty.

Beaters 7 and 8 had been furnished with tawa sulphite and beaten with the roll at hard brush for only about sixty minutes. The remainder of the furnish had then been added, the roll put down for a few moments, and the stock dumped into the beater-chest. This short beating period was due to the necessity for keeping the machine supplied with stock. In other words, the beater treatment in these cases was much less drastic than in any of the previous instances, and the paper produced from them was quite as satisfactory, as regards strength, colour, cleanliness, and finish, as any of the previous beater-runs, indicating that excessive beater treatment was unnecessary, and even undesirable, from the standpoint of strength quality. It also showed the ineffectiveness of the beaters in refining the shives and eliminating this source of difficulty.

Several tons of the tawa sulphite were therefore forwarded to the laboratory and put through the rod mill in order to eliminate shives. A run of this rod-milled stock was made on the laboratory paper-machine as shown under machine-run 12, Table 22. This pulp was reshipped to Wisconsin Rapids, and the final machine-run was made on the 17th April.

All of the beaters in this instance were handled in the same way. The entire furnish was placed in the beater, the roll set at a hard brush for thirty-five minutes, and then lifted.

This product went over the paper-machine with very little difficulty. Some sticking was encountered at the second press, which is a wood press, but otherwise the run was made without any trouble. The paper was satisfactory as regards strength, colour, and cleanliness, and finish. Data on all machine-runs at Wisconsin Rapids are given in Table 26.

At the conclusion of the news runs, as had been noted in the introduction, one reel each of machine-finished book, and of dry-finish wrapping-paper was made, the finish and the quality of the sheets being shown in Table 26 under beater-runs Nos. 10, 11, 12, and 13.

Discussion of Results.

The unsatisfactory results at Ladysmith were probably due to a combination of circumstances. In the first place, the pulps were somewhat overcooked and soft. This resulted in lower initial strength than the laboratory-made pulps, and necessitated a development of strength which was impracticable in the equipment available. Another factor was the machine. As previously noted, certain mechanical factors required the maintenance of rather tight draws, which caused many breaks and undoubtedly impaired the strength of the sheet. Comparative tests made upon wet "broke" at the laboratory confirmed this latter point.

The outstanding points in the runs at Wisconsin Rapids were the failure of the beater to eliminate shives and the need for limiting the beater treatment. The fact that the beaters scarcely functioned at all in removing the shives, which was contrary to laboratory evidence that they should be effective in this regard, was probably due to their condition, and not inherent in the equipment. In the first mill-run at Wisconsin Rapids, the beaters had just been "ground in"—in fact, the run was delayed while this "grinding-in" was being done. It is a common experience that beaters do not reach their optimum operating efficiency for some time after this breaking-in operation, and such a condition undoubtedly existed in this instance. This presumption is supported by the increasing efficiency of the beaters as the run proceeded. In the second mill-run the rod-milling had largely eliminated the shives, and no measure of their removal was possible. However, the beaters in this instance operated much more smoothly, and showed the effects of the several weeks' service intervening between the runs.

The fact that the stock easily passed the optimum of hydration can probably be attributed to its overcooked condition and the resulting necessity for caution in beater treatment. The hydrating-capacity of the beaters was undoubtedly less impaired by reason of the newly ground-in condition than their cutting action, and went forward even while the removal of shives was retarded. It was noted that a certain amount of beater treatment was necessary, but that any excess beater action increased the difficulties of handling the sheet without a corresponding increase in strength quality. As a matter of fact, in all runs at Wisconsin Rapids it was not practicable to use the Jordan, because the beater action had already exceeded somewhat the needs of the stock.

Due to the above-noted circumstances, recourse to the rod mill was necessary in order to remove the shives and produce a satisfactory sheet. This device is undoubtedly effective for the purposes used, but not, we believe, indispensable. The same results should be obtainable with suitable beaters and Jordan equipment. Adequate screening and riffling of the pulp should also serve to reduce the number of shives and miminize this difficulty.

The paper-machine speeds employed were below those now common in newsprint-mills. The machine-speed at Ladysmith was 300 ft. per minute, and at Wisconsin Rapids 450 ft. per minute. These rates are more comparable to those customary in book-paper production. However, the lower speeds were chosen to assure the production of sufficient paper to prove the furnish used, and in view of the limited quantity of pulp which was available. With a machine designed for this type of stock greater speeds would undoubtedly be possible.

Undoubtedly the few machine difficulties met with in the finally prepared pulp could be eliminated by a properly designed machine. The "tender" qualities of the sheet on the couch and presses could certainly be remedied by the use of a suction-couch and suction-presses, by aiding formation with an increased length of wire, or by the use of granite press-rolls in place of the wooden rolls. A representative of a paper-machinery-manufacturing firm who witnessed the tests suggested these and several other artifices which, he seemed sure, would easily remedy all difficulties encountered.

Rather large quantities of sulphite were purposely used in the furnishes tried in the mill-runs, but it seems entirely possible that these quantities could be reduced in mill operation and the proportion of groundwood increased. Satisfactory papers were made on a laboratory scale, using much greater proportions of groundwood, and, in our opinion, could be reproduced in mill operation.

One remarkable point was the ease with which the paper took a finish, and this factor could be capitalized by its conversion into book stock. The M.F. book paper made after the news runs had been completed furnished evidence of the practicability of this suggestion.

SUMMARY OF PAPERMAKING STUDIES.

In the laboratory semi-commercial tests insignis-pine groundwood and insignis-pine sulphite pulps have been blended in various mixtures for the production of standard newsprint paper. The experimental papers were, in general, stronger than the average for American newsprint. The presence of dirt and the yellow colour inherent in the groundwood pulp lowered the quality of the paper in respect to its appearance, but had the pulpwood used in these experiments been as free from core-rot as that employed in the commercial trials the complaints as to dirt would have been much less serious. The experimental insignis-pine papers were found to run well on a modern newspaper-press, and produce a printed paper of satisfactory quality.

From both the laboratory tests and commercial paper-mill trials it is evident that a furnish of 20 per cent. insignis-pine sulphite with 50 per cent. tawa sulphite and 30 per cent. tawa groundwood can be converted into a satisfactory newsprint paper by the use of standard mill equipment at speeds varying from 300 ft. to 450 ft. per minute. Greater speeds would undoubtedly be possible with a machine built to handle this type of stock. The colour, strength, cleanliness, and finish of the papers produced are equivalent to standard news. A certain amount of hydration or beating is necessary to reach the required strength quality in the case of tawa sulphite, and a refining effect, such as rod-mill treatment, is necessary for the elimination of shives. Minor alterations in the design of the wire, couch-roll, and wet presses of a standard newsprint-paper machine would greatly improve the behaviour of the stock on the machine. The same pulps may also be employed in the production of machine-finish book (rotogravure) and dry-finish wrapping papers.

Bleached European larch can, according to the laboratory semi-commercial tests, be substituted for the insignis-pine sulphite pulp in the above mixed softwood-hardwood furnish in approximately the same amount to produce a satisfactory news sheet. Bleached rimu, too, can be substituted for insignis-pine sulphite, but it is probably necessary to use a greater amount to give the required strength.

Tawa cooked by the semi-chemical process did not produce an entirely satisfactory newspaper, but may possibly be used to some extent in a news furnish.

SIGNIFICANCE OF STUDIES.

CONCLUSIONS.

The conclusions relative to each division of the work have been set down in connection with the discussion of that particular section.

The major objective—namely, the production of pulps suitable for newsprint—has been attained, and the supporting evidence is considered conclusive so far as the technical features of pulping and the quality of the resulting papers are concerned. In arriving at the above conclusion newsprint pulps have been produced from insignis-pine mechanical pulp combined with insignis-pine sulphite in the customary way. This produces the standard type of newsprint of approximately 70 per cent. mechanical pulp and 30 per cent. sulphite. Other furnishes, comprising varying proportions of tawa groundwood pulp and sulphite pulps from tawa, insignis pine, rimu, and European larch (the latter two bleached), have likewise resulted in newsprint equal to available standard grades. Proportions of tawa sulphite as high as 50 per cent. have been employed, and, in combination with insignis-pine or other sulphite, sulphite to the extent of 70 per cent. of the total furnish has been used, the balance being tawa groundwood. The quality of the various papers has been evaluated by comparative strength tests, colour, and dirt determinations, &c., on both the laboratory and mill-produced samples, and on commercial products secured from a large number of sources; the printing and other press characteristics have been ascertained by actual printing tests on a high-speed press of the modern type.

The production of kraft pulps from the various New-Zealand-grown conifers, the secondary object of this work, has also been accomplished. Rimu and the various pines and larch all yield very satisfactory pulps by the sulphate process, rimu particularly. It is believed that the proper selection of cooking and other conditions will produce first-quality kraft products commercially from any of the species mentioned.

Bleached pulps for book paper and similar products were easily produced from tawa by both the soda and sulphite processes, and from insignis pine by the sulphite process only. The pulping of insignis pine by the sulphite process involves rather careful control, but is entirely practicable.

The so-called semi-kraft process was successfully applied to rimu, insignis pine, and European larch, greatly increased pulp-yields resulting, but the colour characteristics and strength of the sheets were not quite up to those of standard kraft papers. The suitability of this method to the production of boards and low-grade papers, however, seems amply demonstrated.

The recently developed semi-chemical process was tried in an effort to produce a news-grade pulp, but results were indifferently successful. The strength developed by these pulps on beating, however, might be advantageous in their use for building and insulating boards, or in products of a similar character. Small quantities may also be used in connection with other components in newsprint.

RECOMMENDATIONS.

The commercial practicability of establishing a newsprint industry in New Zealand will depend primarily upon the ability of the local manufacturer to compete with imported newsprint in common use. The New Zealand market is apparently in the undisputed possession of the Canadian and English manufacturers. There exists a preferential tariff of 20 per cent. in their favour, which seems more than adequate to assure them of the market even against depressed Scandinavian prices close to their cost of production. Of the two, the Canadian manufacturer, by virtue of his advantages in raw materials, seems in the better position to dominate the market, and any study of the economics of newsprint-production in New Zealand should presumably be based upon the manufacturing costs and selling-price of Canadian newsprint. Such a study should include woods and market surveys, and in general it may be said that, provided a sufficient supply of wood is available at prices comparable with those paid for Canadian pulpwood, a newsprint development in New Zealand should be reasonably certain of a fair return upon the required capital investment. The co-operator is recommended accordingly to initiate a field study to determine the commercial possibilities of establishing the industry in New Zealand. The available market statistics are taken as evidence that New Zealand should soon be able to absorb an output of 100 long tons daily production, which should be an economical operating unit in a newsprint development.

ACKNOWLEDGMENTS.

Mill Tests.

The authors and the Forest Products Laboratory wish to gratefully acknowledge the interest and aid of both co-operating mill organizations. At both the Great Western Paper Co. and the Consolidated Water-power and Paper Co. every assistance was cordially extended, and every effort made by all executives and employees concerned to make the mill trials a success. Any success attained has been in a large measure the result of this co-operation.

TABLES.

TABLE 1.—SHIPMENT DESCRIPTION OF NEW-ZEALAND-GROWN WOODS, TOGETHER WITH COMMON AND BOTANICAL NAMES OF ALL WOODS REFERRED TO IN REPORT.

Madison Shipment No.	New Zealand Identification Marks.	Name of Species.		Quantity (in Cords).	
		Common.	Botanical.	Logs.	Slabs.
		NEW-ZEALAND-GROWN WOODS.			
1208	5	Rimu	*Dacrydium cupressinum*	2	..
1209	5	Rimu	*Dacrydium cupressinum*	..	1
1210	6	Tawa	*Beilschmiedia tawa*	3	..
1211	4	Insignis pine	*Pinus radiata*	3	..
1212	2	Austrian pine	*Pinus austriaca*	1	..
1213	1	Corsican pine	*Pinus laricio*	1	..
1214	3	European larch	*Larix europea*	1	..
		AUSTRALIAN WOODS.			
..	..	Blue-gum	*Eucalyptus globulus*	..	..
..	..	Tasmanian stringybark	*Eucalyptus obliqua*	..	..
		NORTH AMERICAN WOODS.			
1190	..	White-spruce	*Picea canadensis*	..	..
..	..	Black-spruce	*Picea mariana*	..	..
..	..	Hemlock	*Tsuga canadensis*	..	..
..	..	Jack-pine	*Pinus Banksiana*	..	..
..	..	Aspen	*Populus tremuloides*	..	..
..	..	Maple	*Acer saccharum*	..	..
..	..	Western larch	*Larix occidentalis*	..	..
..	..	Balsam fir	..	..	..

TABLE 2.—MAJOR PHYSICAL PROPERTIES OF WOODS.

Species.	Determination.	Density (oven-dry).	Moisture (green).
	NEW-ZEALAND-GROWN WOODS.		
		lb. per cubic in.	Per Cent.
Rimu	As received	31·7	67
	New Zealand average	31·2	102
Rimu slabs (seasoned)	As received	31·7	14
	New Zealand average	31·2	16
Tawa	As received	32·2	35
	New Zealand average	33·3	63
Insignis pine	As received	24·5	117
	New Zealand average	26·0	102
Austrian pine	As received	26·6	110
	New Zealand average	..	..
Corsican pine	As received	26·8	111
	New Zealand average	29·0	..
European larch	As received	27·5	60
	New Zealand average	27·0	..
	NORTH AMERICAN WOODS.*		
White-spruce	..	24	..
Black-spruce	..	23	..
Hemlock	..	24	..
Jack-pine	..	24	..
Aspen	..	23	..

* "The Suitability of American Woods for Paper Pulp," Bulletin No. 1485, U.S.A. Department of Agriculture.

TABLE 3.—FIBRE-MEASUREMENTS OF WOODS.

Species.	Fibre-lengths. Average.	Maximum.	Minimum.
NEW-ZEALAND-GROWN WOODS.*			
	mm.	mm.	mm.
Rimu	3·14	4·13	2·05
Tawa	0·88	1·10	0·63
Insignis pine	2·61	3·78	1·89
Austrian pine	2·46	3·21	1·58
Corsican pine	3·91	5·48	1·86
European larch	3·45	4·63	1·89
NORTH AMERICAN WOODS.†			
White-spruce	2·8	..	..
Black-spruce	2·6	..	..
Hemlock	3·0	..	..
Jack-pine	2·5	..	..
Aspen	1·0	..	..

* Fifty measurements made upon each species.
† Values from "The Suitability of American Woods for Paper Pulp," Bulletin No. 1485, U.S.A. Department of Agriculture

TABLE 4.—CHEMICAL ANALYSIS OF WOODS.

Material.	Sample No.	Ether Soluble.	Alcohol-benzene Soluble.	1 per Cent. NaOH Soluble.	Chlorine Consumption	Lignin.	Cellulose.	Alpha Cellulose.	Pentosans. Total.	In Cellulose.	Not in Cellulose.
CHEMICAL ANALYSIS OF NEW ZEALAND WOODS.*											
		Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Corsican pine	1	1·9	3·3	13·7	34·2	28·4	58·5	41·0	12·9	4·9	8·0
Austrian pine	2	3·4	3·9	15·1	34·2	28·2	58·0	39·8	11·9	5·4	6·5
European larch ..	3	1·1	2·5	16·7	35·3	30·5	55·4	38·2	12·1	4·7	8·4
Insignis pine	4	0·8	2·0	11·1	38·1	29·6	58·9	42·9	14·1	5·6	8·5
Rimu	5	0·2	1·8	10·9	39·1	32·0	57·4	43·2	12·8	5·3	7·5
Tawa	6	0·3	2·0	16·9	34·5	28·5	56·2	42·4	19·2	10·8	8·4
COMPARATIVE CHEMICAL ANALYSIS OF AMERICAN WOODS.											
Spruce†	..	..	1·7	9·8	35·9	29·5	62·5	45·9	12·5	6·3	6·2
Aspen	..	..	..	16·9	..	23·4	62·1	43·2	18·7	..	..
Balsam fir	..	..	..	9·3	..	30·7	57·1	..	..	..	..
Jack-pine	..	..	..	10·7	..	32·8	59·8	42·6	..	..	..
Western larch (*Schorger*)	..	0·8	..	22·1	..	..	57·8	..	..	..	..
Sugar-maple	..	0·6	..	19·2	..	26·4	56·4	36·8	20·4	..	..

* Results based on oven-dry weight of wood. † Wood extracted with alcohol-benzol mixture previous to making chemical analysis.

TABLE 5.—LABORATORY GRINDING TESTS OF NEW ZEALAND AND NORTH AMERICAN WOODS: GRINDING, YIELD, POWER, AND PRODUCTION DATA.

(All quantities oven-dry basis.)

Grinder-run No.	Species	Surface of Ston	Grinding Pressure.* In Cylinder.	Grinding Pressure.* On Wood.†	Temperature of Stock in Pit.	Wood ground.	Yield of Screened Pulp. From Wood ground.	Yield of Screened Pulp. Per 100 lb. of Wood.	Yield of Screened Pulp. Per 100 cub. ft. of Wood.	Screenings per 100 lb. of Wood.	Duration of Grinding.	Production per Twenty-four Hours.	Power Requirement. During Run.	Power Requirement. Input to Grinder.	Power Requirement. Per Ton per Twenty-four Hours.
			lb./sq. in.	lb./sq. in.	Deg. C.	lb.	lb.	lb.	lb.‡	lb.	Min.	Tons.	KW.H.	H.P.§	H.P.
1	Spruce ..	Dressed with 8-point straight-cut burr. Stone sharp	40	23	50	49·0	42·1	86·0	2,060	1·0	55	0·55	22	28	51
2	Insignis pine ..	Stone as left from run 1. Medium sharp ..	40	23	60	39·7	31·6	79·7	1,990	1·9	55	0·41	30	39	94
3	Spruce ..	Dressed with 8-point straight-cut burr. Stone sharp	30	17	55	54·3	41·8	77·0	1,850	0·4	72	0·42	34	34	80
4	Insignis pine ..	Stone as left from run 3. Medium sharp ..	30	17	55	45·8	37·2	81·1	2,030	0·2	125	0·21	37	21	97
5	Spruce ..	Dressed with 8-point straight-cut burr. Stone sharp	20	11	55	59·6	41·7	69·8	1,680	0·6	155	0·19	50	23	118
6	Insignis pine ..	Stone as left from run 5 dressed with 3-point straight-cut burr. Stone very sharp ..	40	23	48	36·9	28·6	77·5	1,940	3·2	50	0·41	27	38	93
7	Insignis pine ..	Stone left from run 6. Sharp.	30	17	55	39·6	34·4	86·8	2,170	1·3	55	0·45	30	39	85
8	Insignis pine ..	Dressed with 8-point straight-cut burr for first part of run; last part of run, 3-point straight-cut superimposed upon 8-point straight-cut	30 to 40	16 to 22	..	..	..	..	..	..	330	..	..	..	..
9	Spruce ..	Stone as left from run 8 dressed lightly with 8-point straight-cut burr	30 to 40	16 to 22	..	..	..	..	..	..	210	..	..	..	..
10	Tawa ..	Stone as left from run 9 dressed lightly with 10-point spiral-cut burr. Stone dull	30	17	55	64·2	46·7	72·7	2,620	0·03	85	0·40	31	26	66
11	Tawa ..	Stone as left from run 10	40	23	55	64·9	52·4	80·7	2,900	0·03	65	0·58	28	31	53
12	Tawa ..	Dressed lightly with 8-point straight-cut burr. Stone medium sharp	30	17	55	64·2	55·0	85·6	3,080	0·03	55	0·72	21	27	38
13	Insignis pine‖ ..	Stone dressed with 8-point straight-cut burr. Medium sharp	35	19	55	..	..	..	..	..	..	..	..	..	..
14	Insignis pine¶ ..	Stone as left from run 13. Medium sharp ..	35	19	55	..	..	..	..	..	..	..	..	..	..
15	Tawa ..	Stone as left from run 14. Moderately dull ..	30	17	..	..	..	..	..	..	..	..	..	..	..
16	Insignis pine‖ ..	Stone dressed with 8-point straight-cut burr. Fairly sharp	35	19	..	..	..	..	..	..	..	..	..	..	..
17	Insignis pine¶ ..	Stone as left from run 16. Sharp	30 and 25	17 and 14	..	..	..	..	..	..	..	..	..	..	..
18	Insignis pine** ..	Stone as left from run 17. Sharp	30	17	..	..	..	..	..	..	..	..	..	..	..

* The peripheral speed of the stone was 3,000 ft. per minute. † The average area of wood against the stone was estimated to be 74 sq. in. ‡ The oven-dry weights per cubic foot, green volume, without bark, for insignis pine and tawa were found to be 25 lb. and 36 lb. respectively. The value used for white-spruce was 24 lb. per cubic foot as given in U.S. Department of Agriculture Bulletin No. 1485. § The power required by the motor was corrected for the motor efficiency (91 per cent.) and efficiency in the belt transmission (97 per cent.) to obtain the power input to the grinder. ‖ Wood selected free of blue stain. Centre of billets bored out and knots removed. ¶ Wood contained blue stain. Centre of billets bored out and knots removed. ** Mixture of blue-stained and uninfected wood. Centre of billets bored out and knots removed.

TABLE 6.—LABORATORY GRINDING TESTS OF NEW ZEALAND AND NORTH AMERICAN WOODS: QUALITY AND STRENGTH OF WATER-LEAF PULPS.

Grinder-run No.	Species.	Freeness.	Microscopic Classification Number.*	Strength of Water-leaf Pulp.					Dirt Particles per Square Inch.	Colour Analysis.			Interpretation of Colour Analysis.				
				Weight per Ream. (24 in. by 36 in. —500.)	Thickness.	Bursting per Pound per Ream.	Tearing.			Red.	Green.	Blue.	White.	Primary Hue.		Secondary Hue.	
							Tearing.	Per Pound per Ream.						Tint.	Luminosity.	Tint.	Luminosity.
		Cc.		lb.	In.	Points.	Grm.	Grm.	Number.	Per Cent.	Per Cent.	Per Cent.	Per Cent.		Per Cent.		Per Cent.
1	Spruce	122	Below No. 4	86	0·0146	0·17	44·0	0·51	9	82	73	63	63	Orange	5·8	Yellow	5·0
2	Insignis pine	167	No. 3	96	0·0156	0·25	75·2	0·78	37	77	66	58	58	Orange	7·0	Yellow	2·3
3	Spruce	88	No. 4	98	0·0146	0·28	59·2	0·60	5	83	75	66	66	Orange	5·1	Yellow	4·5
4	Insignis pine	40	Between Nos. 2 & 3	113	0·0161	0·41	115·2	1·01	11	80	71	63	63	Orange	5·8	Yellow	3·2
5	Spruce	67	No. 2	97	0·0149	0·31	75·2	0·78	11	81	74	67	67	Orange	4·5	Yellow	3·2
6	Insignis pine	233	No. 4	92	0·0158	0·24	76·8	0·84	6	79	70	61	61	Orange	5·8	Yellow	4·1
7	Insignis pine	147	No. 3	86	0·0144	0·29	74·4	0·87	9	80	72	63	63	Orange	5·1	Yellow	4·5
8	Insignis pine	86	Between Nos. 1 & 2	101	0·0139	0·38	85·6	0·85	46	75	65	58	58	Orange	6·4	Yellow	1·8
9	Spruce	105	Below No. 4	118	0·0153	0·27	71·2	0·61	5	84	75	64	64	Yellow	5·9	Orange	5·8
10	Tawa†	133	Below No. 4	86	0·0118	0·16	34·2	0·40	7	84	76	69	69	Orange	5·1	Yellow	2·7
11	Tawa†	228	Below No. 4	228	0·0157	0·17	63·6	0·54	6	84	75	69	69	Orange	5·8	Yellow	1·4
12	Tawa†	100	Below No. 4	104	0·0157	0·11	44·2	0·43	18	83	71	66	66	Yellow	4·5	Orange	3·8
13	Insignis pine‡	..	..	..	..	..	..	..	6	82	72	63	63	Orange	6·4	Yellow	3·6
14	Insignis pine§	..	..	..	..	..	..	..	15	80	71	65	65	Orange	4·5	Yellow	2·3
15	Tawa‖	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
16	Insignis pine‡	..	..	76·5	0·0127	0·33	66·8	0·87	0	79	68	62	62	Orange	7·0	Yellow	0·5
17	Insignis pine§	..	..	127·3	0·0189	0·37	98·0	0·77	5	77	67	60	60	Orange	6·4	Yellow	1·8
18	Insignis pine¶	..	..	106·4	0·0169	0·33	82·8	0·78	1	80	70	61	61	Orange	6·4	Yellow	3·6
P655	Commercial groundwood** ..	120	Between Nos. 1 & 2	57	0·0121	0·22	57·6	1·01	5	84	75	68	68	Orange	5·8	Yellow	2·3
P658	Commercial groundwood** ..	77	No. 2	36	0·0077	0·31	44·0	1·22	3	77	72	65	65	Yellow	4·1	Orange	3·2

* Based on standards selected from U.S. Department of Agriculture Bulletin No. 343. See Photomicrographs. † It was necessary to add commercial sulphite pulp (10 per cent. of the total) to the Tawa groundwood in order to run it over the Fourdrinier machine. The freeness and colour analysis were made on the pulp before mixing with the sulphite. ‡ Wood selected free of blue stain. Centre of billets bored out and knots removed. § Wood contained blue stain. Centre of billets bored out and knots removed. ‖ Not made into waterleaf pulp. Used for newsprint-paper runs. ¶ Mixture of blue-stained and uninfected wood. Centre of billets bored out and knots removed. ** The strength tests on the commercial pulps were made on hand sheets.

TABLE 7.—COMPARISON OF THE "INTERNATIONAL" GRINDER USED IN THE MILL TESTS AND THE EXPERIMENTAL-SIZE GRINDER USED AT THE FOREST PRODUCTS LABORATORY.

Details.		International Grinder.	Laboratory Grinder.	Ratio Laboratory Grinder to International Grinder.
1. Cylinder, diameter	(in.)	16	7·25	1 to 2·2
2. Cylinder, area	(sq. in.)	201	41·25	1 to 4·9
3. Pocket, width	(in.)	15	8	1 to 1·9
4. Length of wood ground	(in.)	24	9	1 to 2·7
5. Area of wood in contact with stone in one pocket (3 × 4)	(sq. in.)	360	72	1 to 5
6. Ratio of cylinder area to area of wood in contact with stone in one pocket (5 ÷ 2) ..		1 to 1·79	1 to 1·74	1 to 1
7. Number of pockets		3	2	1 to 1·5
8. Face of stone	(in.)	24	12	1 to 2
9. Diameter of stone	(in.)	57	25	1 to 2·3
10. Total area of wood in contact with stone (7 × 5 ÷ 144)	(sq. ft.)	7·5	0·5*	1 to 15
11. Speed of stone	(r.p.m.)	180†	460	1 to 0·39
12. Peripheral speed	(ft./m.)	2,685	3,015	1 to 0·89
13. Effective grinding area per minute (12 × 10)‡	(sq. ft.)	20,170	1,508	1 to 13·4

* Only one pocket was used at a time on the laboratory grinder when grinding tawa.
† Speed used when grinding tawa.
‡ If 1 square foot be taken as the unit of area, the area of stone passing a unit area of wood per minute will be (the peripheral speed × 1) sq. ft. The "effective" grinding-area per minute will be therefore: Peripheral speed × total area of wood in contact with the stone.

TABLE 8.—GRINDING OF TAWA AT GREAT WESTERN PAPER CO. MILL, LADYSMITH, WISCONSIN: LOG OF GRINDER-RUNS.

Date.	Shift.	Hour.	Stone Surface.*†	Duration of Grinding.	Wood. Racks filled.‡	Wood. Wood ground.	Production. Pulp Laps. Wet Weight.	Pulp Laps. Moisture Content.	Pulp Laps. Dry Weight.	Pulp (dry). Per Cord.	Pulp (dry). Per 24 Hours.
				GRINDER-RUN No. 1.							
1928.				Hours.		Cords.	lb.	Per Cent.	lb.	lb.	Tons.
Feb. 7 ..	1	9.30 a.m.	A, B, C								
		2.00 p.m.	C								
		3.00	..	5·5	5	..	2,400	73·5	636		
	2	6.30	B, C								
		10.30	C								
		11.00	..	8	3	..	4,660	73·5	1,235		
Feb. 8 ..	3	2.30 a.m.	B, C								
		6.30	C								
		7.00	..	8	3	..	4,705	73·5	1,247		
	1	10.30	..	3·5	..	..	2,985	72·6	818		
				25	11	2·75	14,750	..	3,938	1,432	1·89
				GRINDER-RUN No. 2.							
Feb. 9 ..	1	1.15 p.m.	B, C	2	3						
	2	4.00	B, C								
		7.00	C								
		10.00	B, C								
		11.00	..	8	4	..	4,410	72·0	1,235		
Feb. 10 ..	3	1.00 a.m.	C								
		4.00	B, C								
		7.00	C	8	3	..	5,055	72·0	1,415		
	1	10.00	B, D								
		2.00 p.m.	D								
		3.00	..	8	3	..	5,305	74·0	1,380		
	2	5.00	D								
		7.30	..	4·5	..	..	4,540	74·0	1,180		
				30·5	13	3·25	19,310	..	5,210	1,600	2·05

* Types of burrs used were as follows: A, smooth roll used for removing old surface; B, four-point (four teeth per inch) straight-cut burr; C, 14-point diamond-cut burr; D, 12-point diamond-cut burr. All burrs were new. They were used in the order indicated.
† Average pressure in cylinder, 30 lb. For other conditions see Table 7.
‡ One rack equals ¼ cord. These were the number of racks filled on each shift, and not the number of racks ground.

TABLE 8.—GRINDING OF TAWA AT GREAT WESTERN PAPER CO. MILL, LADYSMITH, WISCONSIN: LOG OF GRINDER-RUNS—*continued.*

Date.	Shift.	Hour.	Stone Surface.*†	Duration of Grinding.	Wood: Racks filled.‡	Wood: Wood ground.	Production: Pulp Laps: Wet Weight.	Production: Pulp Laps: Moisture Content.	Production: Pulp Laps: Dry Weight	Production: Pulp (dry): Per Cord.	Production: Pulp (dry): Per 24 Hours.
					GRINDER-RUN No. 3.						
1928.				Hours.		Cords.	lb.	Per Cent.	lb.	lb.	Tons.
Feb. 12 ..	1	9.30 a.m.	B, C								
		1.00 p.m.	C								
		3.00									
	2	4.30	C	5·5	2	..	3,285	69·9	985		
		7.30	C								
		9.30	..	6·5	4	..	7,180	69·9	2,160		
				12·0	6	1·5	10,465	..	3,145	2,095	2·10
		Loss of fibre at white-water saveall§ ..			..		..	..	45		
		Total yield of pulp (grinder-run No. 3)			..		..	..	3,190	2,125	2·13

* Types of burrs used were as follows: A, smooth roll used for removing old surface; B, four-point (four teeth per inch) straight-cut burr; C, 14-point diamond-cut burr; D, 12-point diamond-cut burr. All burrs were new. They were used in the order indicated.
† Average pressure in cylinder, 30 lb. For other conditions see Table 7.
‡ One rack equals ¼ cord. These were the number of racks filled on each shift, and not the number of racks ground.
§ See Table 9.

TABLE 9.—GRINDING OF TAWA: SUMMARY OF WHITE-WATER AND FIBRE LOSSES IN GRINDER-RUN No. 3.

Average Sample No.	Time: From.	Time: To.	Fibre per 1,000 Gallons.	Total Overflow during Period.	Fibre lost in White Water.
			lb.	Gal.	lb.
1	10.05 a.m. ..	3.23 p.m. ..	5·3	4,340	23·0
2	3.23 p.m. ..	6.46 p.m. ..	4·5	564	2·5
3	6.46 p.m. ..	10.45 p.m. ..	4·5	4,546	20·5
Total for the run	..	..	..	9,450	45·0

TABLE 10.—COLOUR MEASUREMENTS OF TAWA MECHANICAL PULP PRODUCED FROM DISCOLOURED HEARTWOOD BEFORE AND AFTER WASHING.

—	White.	Primary Colour: Hue.	Primary Colour: Luminosity.	Secondary Colour: Hue.	Secondary Colour: Luminosity.
	Per Cent.		Per Cent.		Per Cent.
Before washing ..	34	Orange ..	9	Red ..	0·19
After washing ..	46	Orange ..	9	None ..	..

TABLE 11.—LABORATORY SULPHITE PULPING TESTS: YIELDS AND COOKING DATA.

Cook No.	Species.	Oven-dry Weight of Wood.	Acid added.	Acid Composition.			Cook-time.	Time to 110° C.	Maximum Temperature.	Time to Maximum Temperature.	Maximum Pressure.	Yield of Pulp (Oven-dry).			Bleach based on 35 per Cent. B.P.	Remarks.
				Total SO_2.	Free SO_2.	Combined SO_2.						Total Pulp.	Screened Pulp.	Screenings.		
		lb.	Gal.	Per Cent.	Per Cent.	Per Cent.	Hours.	Hours.	Deg. C.	Hours.	lb./sq. in.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	
3256–I	Rimu	86·6	50	5·60	4·30	1·30	9·5	2	148	9	75	48·1	46·7	1·4	30	
3257–I	,, ...	76·8	50	5·63	4·29	1·34	10·0	2	148	9	75	47·7	46·3	1·4	22	
3258–I	,, ...	78·2	50	5·65	4·31	1·34	9·25	2	153	9	75	48·35	47·0	1·35	28	
3280–I	,, ...	86·8	52	5·60	4·15	1·45	10·5	2	148	9	75	48·1	46·6	1·5	24–26	
3284–I	,, ...	91·4	52	5·50	4·10	1·40	10·5	2	148	9	75	48·4	46·7	1·7	..	
3259–I	Insignis Pine	68·7	50	5·57	4·37	1·20	8·5	1·5	148	8·5	75	47·7	46·5	1·2	15	
3260–I	,, ...	75·7	50	5·50	4·27	1·23	8·5	1·5	148	8·5	75	52·9	51·3	1·6	28	
3263–I	,, ...	72·2	50	5·50	4·29	1·21	9·0	1·5	148	8·5	75	47·5	46·6	0·9	..	Cook burned.
3264–I	,, ...	70·0	50	5·60	4·36	1·24	9·25	1·5	148	8·5	75	49·4	48·6	0·8	12	
3265–I	,, ...	70·4	50	5·65	4·37	1·28	8·25	1·5	153	8·25	80	43·5	42·3	1·2	10–12	
3266–I	,, ...	71·9	50	5·50	4·18	1·32	9·5	1·5	140	7·0	75	49·4	48·4	1·0	12	
3267–I	,, ...	73·2	54	5·60	4·30	1·30	21·0	5·0	127	21·0	65	48·2	47·6	0·6	11–12	
3269–I	,, ...	74·1	50	5·42	4·10	1·32	8·75	1·5	148	8·5	75	44·7	44·3	0·4	15	
3272–I	,, ...	71·7	52	5·60	4·15	1·45	9–5 min.	1·5	148	8·5	75	46·1	45·2	0·9	12–13	
3275–I	,, ...	65·2	52	5·50	4·13	1·37	9·5	1·5	148	8·5	75	49·5	48·2	1·3	10–11	
3281–I	,, ...	67·6	52	5·50	4·06	1·44	9·5	1·5	148	8·5	75	51·75	50·0	1·75	20	
3283–I	,, ...	62·4	52	5·65	4·25	1·40	9–20 min.	1·5	148	8·5	75	47·3	46·1	1·2	..	
3261–I	Tawa	82·4	50	6·00	4·70	1·30	10·0	2	148	9·0	75	49·2	48·3	0·9	12	
3262–I	,, ...	80·4	50	6·00	4·78	1·22	11·0	2	148	9·0	75	47·3	46·6	0·7	10	
3268–I	,, ...	82·4	50	6·10	4·82	1·28	10·5	2	148	9·0	75	48·5	47·6	0·9	10	
3270–I	,, ...	81·0	52	5·95	4·53	1·42	11·0	2	148	9·0	75	47·5	46·5	1·0	10–12	
3271–I	,, ...	81·0	50	5·85	4·33	1·52	6·0	1·5	140	4·0	75	52·5	49·3	3·2	25	
3273–I	,, ...	82·2	50	5·75	4·23	1·52	7·0	1·5	140	5·0	75	52·5	50·0	2·5	25	
3274–I	,, ...	78·7	50	5·50	4·00	1·50	7·0	1·5	140	5·0	75	52·0	48·0	4·0	25	
3276–I	,, ...	79·9	52	6·00	4·69	1·31	9·0	2	148	9·0	75	49·4	48·0	1·4	16	Yield estimated due to loss of pulp from blow-pit.
3277–I	22 per cent. insignis pine, 78 per cent. tawa	80·3	52	5·90	4·56	1·34	9·0	2	148	9·0	75	49·4	48·3	1·1	16	
3279–I	Tawa	80·2	52	6·10	4·80	1·30	9·0	2	148	9·0	75	50·7	49·3	1·4	16	
3282–I	,, ...	86·85	52	6·00	4·65	1·35	9·0	2	148	9·0	75	50·4	49·2	1·2	16	
3278–I	European larch	77·8	52	5·70	4·35	1·35	9·75	2	148	9·0	75	45·0	40·3	4·7	21–22	
555	Western larch	..	..	..	..	..	..	..	..	..	..	40·6	36·8	3·8	18	Bulletin No. 1485, U.S. Dept. Agriculture.
3130–I	White-spruce	80·0	45	5·50	4·30	1·20	8·5	1·5	148	8·5	75	50·2	48·2	2·0	22	Typical spruce - newsprint sulphite.
3171–I	Aspen	80·0	47	6·00	4·80	1·20	10·0	2	148	9·0	75	51·3	50·3	1·0	8	Unpublished data.
3167–I	Birch	80·0	47	6·00	4·70	1·30	10·0	2	148	9·0	75	46·7	45·5	1·2	18	
3176–I	Maple	80·0	47	6·00	4·70	1·30	10·0	2	148	9·0	75	47·6	46·2	1·4	29	

Table 12.—Laboratory Sulphite Pulping Tests: Pulp-strength Data.

Strength Properties of Unbleached Pulps by the Ball-mill Method.

Cook No.	Species.	Bursting-strength (Points per Pound per Ream).				Folding-endurance (Double Folds).				Tensile (Metres).				Tear (Grammes per Pound per Ream).				Stretch (per Cent.).			
		20 Min.	40 Min.	60 Min.	80 Min.	20 Min.	40 Min.	60 Min.	80 Min.	20 Min.	40 Min.	60 Min.	80 Min.	20 Min.	40 Min.	60 Min.	80 Min.	20 Min.	40 Min.	60 Min.	80 Min.
3256–I	Rimu	0·64	0·87	0·82	0·76	50	159	434	332	2,820	3,080	3,025	2,890	2·06	2·02	2·02	1·72	8·9	11·9	13·8	14·8
3257–I	,, ...	0·59	0·76	0·78	0·73	23	88	144	202	2,005	5,285	2,535	2,545	2·11	2·13	1·95	1·82	9·4	11·1	11·4	8·8
3258–I	,, ...	0·66	0·89	0·87	0·73	48	140	388	148	2,355	2,910	2,925	2,850	2·16	2·25	2·17	1·99	8·9	12·1	11·4	11·3
3280–I	,, ...	0·62	0·85	0·92	0·89	68	162	264	260	3,055	3,545	4,065	4,295	1·73	1·61	1·54	1·55	7·9	9·6	9·5	10·0
3284–I	,, ...	0·59	0·91	0·94	0·92	26	153	241	386	3,067	3,456	3,824	4,374	1·87	1·88	1·62	1·65	7·5	11·6	12·4	8·9
3259–I	Insignis pine	0·72	0·99	1·08	1·02	28	281	591	994	3,170	3,905	3,680	3,750	1·96	2·09	2·10	1·84	8·9	12·2	15·8	17·4
3260–I	,, ...	0·86	1·07	1·17	1·10	111	473	1,471	835	3,545	4,240	4,985	3,990	1·91	1·69	1·87	1·71	8·3	13·8	17·5	14·3
3263–I	,, ...	0·58	0·84	0·82	0·88	29	108	214	339	2,345	3,005	2,940	3,350	2·12	2·65	2·42	1·89	8·8	12·5	13·3	11·6
3264–I	,, ...	0·70	0·91	0·92	0·90	26	152	346	544	2,845	3,630	3,945	3,710	1·88	1·82	1·81	1·92	9·0	12·9	15·5	14·6
3265–I	,, ...	0·59	0·73	0·79	0·69	25	74	129	148	2,205	2,820	2,920	3,390	1·94	2·04	1·87	1·62	11·6	11·8	14·5	9·3
3266–I	,, ...	0·65	0·86	0·89	0·77	32	224	405	455	2,822	3,650	3,750	3,344	1·22	1·26	1·24	1·16	9·3	12·8	17·0	14·0
3267–I	,, ...	0·73	0·90	0·97	0·94	73	210	648	542	3,090	4,015	3,770	3,880	2·25	2·05	1·97	1·71	7·8	9·6	12·8	10·6
3269–I	,, ...	0·71	0·95	1·02	0·89	68	129	578	625	3,491	3,618	4,245	3,905	1·57	1·47	1·46	1·32	9·0	8·8	12·6	12·8
3272–I	,, ...	0·63	0·95	1·01	0·95	46	233	570	785	2,995	3,790	4,155	3,615	1·71	1·59	1·62	1·48	8·7	10·9	11·6	10·8
3275–I	,, ...	0·72	0·83	0·98	1·12	64	231	378	738	3,238	3,940	4,295	5,280	1·90	1·87	1·78	1·70	8·4	9·3	9·5	11·0
3281–I	,, ...	0·69	0·90	1·10	1·02	88	217	569	740	3,086	3,912	4,957	4,529	1·81	1·90	1·70	1·45	6·9	9·1	11·6	10·3
3283–I	,, ...	0·66	0·90	1·03	0·97	36	174	433	399	2,738	4,607	4,220	4,546	2·03	1·87	1·70	1·67	7·4	10·6	10·1	9·9
3261–I	Tawa	0·33	0·43	0·50	0·50	2	5	11	18	1,880	2,085	2,200	2,410	0·87	1·00	1·04	1·03	4·3	6·5	8·3	7·7
3262–I	,, ...	0·31	0·45	0·49	0·48	3	7	12	20	1,690	2,065	2,250	2,750	0·77	0·98	1·11	1·17	4·4	7·4	8·7	7·0
3268–I	,, ...	0·35	0·47	0·54	0·52	3	9	24	38	1,855	2,200	3,025	2,715	1·5	1·43	1·54	1·36	5·1	2·4	3·10	3·10
3270–I	,, ...	0·34	0·49	0·51	0·53	3	10	28	43	1,990	2,700	2,990	3,425	0·72	0·83	0·90	1·02	4·6	6·4	7·4	5·6
3271–I	,, ...	0·36	0·53	0·65	0·62	2	10	18	26	2,315	2,850	3,380	2,780	0·76	0·81	1·11	0·97	4·0	5·6	5·8	9·8
3273–I	,, ...	0·44	0·63	0·59	0·74	4	17	13	68	2,825	3,405	2,940	4,070	1·08	1·10	1·12	1·26	3·8	6·5	6·2	9·3
3274–I	,, ...	0·46	0·61	0·67	0·71	5	15	27	41	2,860	3,160	3,690	3,445	0·95	1·13	1·13	1·34	3·8	6·0	7·4	7·4
3276–I	,, ...	0·40	0·54	0·67	0·67	5	10	28	40	2,380	4,233	4,233	4,250	0·68	0·98	1·06	1·10	4·4	5·7	9·0	6·0
3279–I	,, ...	0·34	0·59	0·62	0·63	4	8	29	28	2,425	2,675	3,435	3,255	0·66	1·00	1·04	1·02	4·3	7·0	7·9	9·1
3282–I	,, ...	0·38	0·56	0·66	0·53	4	10	30	30	2,110	2,593	3,275	3,115	0·78	0·93	1·08	0·85	4·6	7·3	9·6	6·5
3279–I	22 per cent. insignis pine, 78 per cent. tawa	0·45	0·62	0·77	0·76	6	20	29	105	2,558	2,777	3,340	3,745	1·03	1·09	1·18	1·19	4·5	6·1	8·0	9·8
3278–I	European larch ..	0·43	0·65	0·75	0·75	13	37	120	170	2,800	3,075	3,380	3,190	1·17	2·05	2·20	2·00	7·3	11·5	10·0	10·3
3130–I	White-spruce	0·37	1·10	1·17	1·06	210	420	610	860	..	..	..	..	..	..	..	..	..	..	..	..
3171–I	Aspen	0·37	0·46	0·46	0·47	3	15	24	21	..	..	..	..	..	..	..	..	..	..	..	..
3167–I	Birch	0·72	0·91	0·91	0·81	51	200	318	270	..	..	..	..	..	..	..	..	..	..	..	..
3176–I	Maple	0·55	0·76	0·68	0·71	11	36	78	126	..	..	..	..	..	..	..	..	..	..	..	..

TABLE 13.—COOKING DATA AND YIELDS OF SULPHITE PULPS COOKED AT THE GREAT WESTERN PAPER CO. MILL, LADYSMITH, WISCONSIN.

Cook No.	Species of Wood.	Moisture Content, Oven-dry Basis.	Temperature and Pressure Curve.	Acid-composition. Total SO_2.	Free SO_2.	Combined SO_2.	Total Wet Weight of Screened Pulp.	Oven-dry Weight of Pulp.	Total Weight of Pulp, Oven-dry Basis.	Steam-consumption.
		Per Cent.	Figure.	Per Cent.	Per Cent.	Per Cent.	lb.	Per Cent.	lb.	lb.
1	Insignis pine ..	52·5	I	5·33	3·77	1·56	22,540	32·5	7,315	..
2	Tawa No. 1 ..	37·5	II	4·92	3·45	1·47	22,660	31·1	7,050	24,832
3	Tawa No. 2 ..	37·5	III	4·93	3·46	1·47	20,075	34·7	6,965	..
4	Tawa No. 3 ..	37·5	IV	4·75	3·10	1·65	24,075	34·6	8,330	29,184
5	50 per cent. Insignis pine, 50 per cent. spruce	..	V	4·92	3·67	1·25	17,890	33·7	6,030	..

TABLE 14.—COMMERCIAL SULPHITE PULPING TRIALS AT LADYSMITH, WISCONSIN: PULP-STRENGTH DATA.—PHYSICAL PROPERTIES OF THE UNBLEACHED SULPHITE PULPS COOKED AT THE GREAT WESTERN PAPER CO. MILL, LADYSMITH, WISCONSIN.

Cook No.	Species.	Bursting-strength as determined by the Ball-mill Method (Points per Pound per Ream).				Folding-endurance as determined by the Ball-mill Method (Double Folds).				Tearing-strength as determined by the Ball-mill Method, (Grammes per Pound per Ream).			
		20 min.	40 min.	60 min.	80 min.	20 min.	40 min.	60 min.	80 min.	20 min.	40 min.	60 min.	80 min.
1	Insignis pine	0·52	0·66	0·73	0·64	14	61	158	154	1·30	1·40	1·36	1·39
2	Tawa No. 1	0·29	0·42	0·51	0·52	1	4·5	11	31	0·50	0·74	0·81	0·93
3	Tawa No. 2	0·25	0·41	0·53	0·58	1·75	5·5	11·5	20·5	0·83	0·98	1·05	1·10
4	Tawa No. 3	0·23	0·37	0·47	0·51	1·75	4	12	7	0·51	0·66	0·78	0·89
5	50 per cent. Insignis pine, 50 per cent. spruce	0·57	0·71	0·82	0·78	38	93	155	266	1·48	1·75	1·66	1·61

Cook No.	Species.	Tensile-strength as determined by the Ball-mill Method (Metres).				Stretch as determined by the Ball-mill Method (Per Cent.).				Colour as determined by the Hess-Ives Tint-photometer. Red.	Green.	Blue.
		20 min.	40. min.	60 min.	80 min.	20 min.	40 min.	60 min.	80 min.	Per Cent.	Per Cent.	Per Cent. White.
1	Insignis pine	2,683	2,936	3,878	3,478	7·75	8·75	5·87	6·12	75	65	60
2	Tawa No. 1	2,068	2,754	3,077	3,380	3·25	5·75	6·12	6·37	73	63	60
3	Tawa No. 2	1,905	2,760	3,082	3,316	2·62	5·0	6·37	5·12	71	62	57
4	Tawa No. 3	2,033	2,661	3,032	2,788	3·87	4·75	5·62	4·62	69	62	58
5	50 per cent. Insignis pine, 50 per cent. spruce	2,970	3,210	3,970	3,905	8·25	10·0	8·37	7·5	76	70	63

Table 15.—Laboratory Sulphate, Semi-kraft, and Soda Pulping Tests: Yields and Cooking Data.

Species.	Shipment No.	Cook No.	Date.	Cooking Data. Wood used. Moist Weight.	Wood used. Oven-dry.	Impregnation Liquor. Before Penetration. Volume.	Before Penetration. Concentration NaOH.	Before Penetration. Concentration Na_2S.	After Penetration. Volume.	After Penetration. Concentration NaOH.	After Penetration. Concentration Na_2S.	Penetration. Duration.	Penetration. Pressure.	Penetration. Temperature.	Cooking-liquor. Concentration NaOH.	Cooking-liquor. Concentration Na_2S.	Per 100 lb. Bone-dry Chips NaOH.	Per 100 lb. Bone-dry Chips Na_2S.	Volume.	Black Liquor combined to Total Alkali.	Maximum Temperature.	Steam. Maximum Pressure.	Steam. Pressure, Increase Period.	Steam. Duration at Maximum Pressure.	Yield based on Oven-dry Weight of Chips charged. Crude Pulp.	Yield. Screenings.	Bleach required (35% Available Chlorine) per 100 lb. Oven-dry Pulp.	Strength Data.§ All Tests at 65% Relative Humidity and 72° F.§ Weight per Ream, (24in. by 36in.—500).	Thickness.	Mullen Test.	Strength Factor.	Average Stretch.	Average Breaking Length.	Average Double Folds.	Average Elmendorf Tearing Test.
Sulphate or Kraft Process.																																			
			1927	lb.	lb.	Gal.	Grm./litre.	Grm./litre.	Gal.	Grm./litre.	Grm./litre.	Min.	lb./sq. in.	Deg.C.	Grm./litre.	Grm./litre.	lb.	lb.	Gal.	Per Cent.	Deg.C.	lb./sq. in.	Min.	Min.	Per Cent.	Per Cent.	lb.	lb.	0·001 in.	lb./sq. in.	Pts./lb./rm.	Per Cent.	Metres		Grm./lb./rm.
Insignis pine ..	1,211	2,221	Sept. 1	131·2	92·5	..	..	..	..	..	..	..	..	..	57·2	22·8	14·3	5·7	30	67·2	180	142	120	60	42·28	0·08	..	93·0	8·1	116	1·25	4·82	2,345	5,635	2·79
Insignis pine ..		2,222	Sept. 6	124·5	94·6	..	..	..	..	..	..	..	..	..	57·2	22·8	14·3	5·7	30	71·2	170	113	90	120	44·88	0·78	..	93·0	8·8	108	1·16	3·44	2,597	3,425	2·67
Insignis pine ..		2,232	Sept. 27	136·4	92·8	..	..	..	..	..	..	..	..	..	77·2	30·8	19·3	7·7	30	73·4	180	145	120	90	39·21	0·31	20	98·2	9·2	86	0·88	3·18	5,470	826	1·69
																												126·4	11·1	93	0·73	2·98	5,090	4	1·23‡
Rimu slabwood ..	1,209	2,226	Sept. 14	113·1	99·4	..	..	..	..	..	..	..	..	..	57·2	22·8	14·3	5·7	30	69·0	170	125	85	120	45·67	0·27	..	89·0	8·9	82	1·08	2·57	5,815	3,218	2·61
Rimu	1,208	2,227	Sept. 15	127·0	99·3	..	..	..	..	..	..	..	..	..	57·2	22·8	14·3	5·7	30	73·0	170	126	90	120	47·02	0·52	..	87·0	9·4	89	0·98	3·30	6,130	2,399	2·88
Rimu ..		2,231	Sept. 26	126·5	100·0	..	..	..	..	..	..	..	..	..	57·2	22·8	14·3	5·7	30	79·5	170	112	90	120	45·36	0·47	..	78·5	7·6	95	1·21	3·79	7,245	1,764	2·05
Rimu		2,239	Oct. 7	123·9	100·0	..	..	..	..	..	..	..	..	..	57.2	22·8	14·3	5·7	30	74·3	180	139	120	60	44·60	0·34	..	103·8	10·2	115	1·11	3·72	6,488	3,243	2·71
Corsican pine ..	1,213	2,233	Sept. 28	212·4	104·0	..	..	..	..	..	..	..	..	..	57·2	22·8	14·3	5·7	30	..	180	141	120	25	49·16	1·94	..	96·2	10·9	78	0·81	3·45	5,270	2,456	2·61
Corsican pine ..		2,234	Sept. 29	199·4	98·4	..	..	..	..	..	..	..	..	..	57·2	22·8	14·3	5·7	30	79·0	170	..	90	120	45·96	0·26	..	107·6	10·7	81	0·75	2·39	5,270	1,748	3·15
Corsican pine ..		2,240	Oct. 10	211·4	100·0	..	..	..	..	..	..	..	..	..	57·2	22·8	14·3	5·7	30	75·5	180	133	120	60	41·19	0·33	..	97·0	10·7	70	0·72	2·40	5,655	1,565	2·46
Austrian pine ..	1,212	2,235	Sept. 30	209·0	100·0	..	..	..	..	..	..	..	..	..	57·2	22·8	14·3	5·7	30	78·7	180	..	120	60	43·90	0·33	..	103·8	11·2	92	0·88	3·49	5,565	2,941	2·09
Austrian pine ..		2,236	Oct. 4	205·0	97·4	..	..	..	..	..	..	..	..	..	57·2	22·8	14·3	5·7	30	77·8	170	100	90	120	44·39	0·39	..	80·5	10·9	46	0·57	2·58	4,045	733	1·82
European larch ..	1,214	2,237	Oct. 5	146·0	100·0	..	..	..	..	..	..	..	..	..	57·2	22·8	14·3	5·7	30	82·0	180	..	120	60	43·22	0·69	..	89·5	10·1	75	0·84	2·82	5,400	1,963	3·27‖
																												51·0	4·7	20	0·40	1·51	3,390	93	2·67‖
European larch ..		2,238	Oct. 6	160·0	100·0	..	..	..	..	..	..	..	..	..	57·2	22·8	14·3	5·7	30	78·6	170	100	90	120	44·65	0·48	..	89·5	10·3	78	0·88	2·77	5,845	2,160	2·64
Semi-kraft Process.																																			
Insignis pine ..	1,211	2,244	Oct. 18	169·0	81·5	50·7	60·2	33·2	49·4	43·0	30·0	15	100	57–70	..	..	12·3	2·6	..	..	160	80	30*	75	56·10	..	..	84·0	7·0	109	1·30	5·10	8,185	1,470	1·88¶
																												34·0	3·0	35	1·01	2·80	6,957	642	1·01¶
Rimu	1,208	2,245	Oct. 19	144·3	109·2	54·2	68·3	36·1	52·1	54·0	32·0	15	100	46	..	..	8·5	2·8	..	..	160	80	30*	75	66·15	..	..	35·0	3·4	34	0·97	3·16	6,931	423	1·15**
																												103·0	10·8	112	1·08	3·82	6,679	1,261	2·10††
																												107·0	9·8	146	1·36	4·52	8,055	1,451	2·23††
European larch ..	1,214	2,246	Oct. 20	161·3	112·4	52·8	54·0	35·5	47·3	42·2	32·8	15	100	53	..	..	7·8	2·7	..	..	160	80	40*	75	69·75	..	..	96·0	8·1	86	0·90	3·81	5,669	557	1·90‡‡
																												54·5	6·2	41	0·75	2·23	5,216	346	1·69**
Soda Process.																																			
Tawa	1,210	2,241	Oct. 11	129·0	100·0	..	..	..	..	..	..	..	..	..	100·0	..	25·0	..	30	68·2	170	100	90	90	34·93	0·02	14	98·2	11·5	38	0·38	1·71	4,087	26	0·76
																												127·3	11·3	51	0·40	2·17	4,800	1	0·60‡
Tawa		2,242	Oct. 13	127·0	100·0	..	..	..	..	..	..	..	..	..	88·0	..	22·0	..	30	70·4	170	105	90	240	39·30	0·02	18	92·0	12·0	29	0·31	1·54	3,980	20	0·90
																												111·0	11·0	39	0·35	1·79	4,547	1	0·64‡
Tawa		2,243	Oct. 14	130·0	100·0	..	..	..	..	..	..	..	..	..	77·4	..	20·0†	..	31	82·6	170	110	90	240	46·06	0·04	18	84·0	11·8	28	0·34	1·37	3,810	12	0·64
																												113·0	11·4	45	0·34	1·59	4,435	1	0·82‡

*This time represents the period to maximum pressure from the time that all the liquor has been blown back. † Two pounds elemental sulphur was added to the caustic soda. ‡ Bleached. § All pulps run as water-leaf sheets unless otherwise stated. ‖ Kraft-paper (water-leaf). ¶ Rod-milled-kraft paper (water-leaf) continuous rod-milled run. ** Rod-milled 120 min. †† Rod-milled 100 min. ‡‡ Rod-milled 150 min.

TABLE 16.—LABORATORY SEMI-CHEMICAL PULPING TESTS: YIELDS AND COOKING DATA.

Species.	Cooking Data. Shipment No.	Cook No.	Date.	Wood used. Moist Weight.	Wood used. Oven-dry Weight.	Impregnating-liquor. Before Penetration. Volume.	Before Penetration. Concentration. Na_2SO_3.	Before Penetration. Concentration. *$NaHCO_3$.	After Penetration. Volume.	After Penetration. Concentration. Na_2SO_3.	After Penetration. Concentration. *$NaHCO_3$.	Penetration. Duration.	Penetration. Pressure.	Penetration. Temperature.	Cooking-liquor per 100 lb. Bone-dry Chips. Na_2SO_3.	Cooking-liquor per 100 lb. Bone-dry Chips. *$NaHCO_3$.	Maximum Temperature.	Steam. Maximum Pressure.	Steam. Pressure, Increase Period.	Steam. Duration at Maximum Pressure.	Yields based on Oven-dry Weight of Chips charged.	Rod-mill Data. Consistence.	Rod-mill Data. Duration.	Rod-mill Data. Power-consumption.	Strength Data (Tested at 65 per Cent. Relative Humidity and 72° F). Weight per Ream (24 in. by 36 in.—500).	Thickness.	Mullen Test.	Strength Factor.	Average Stretch.	Average Breaking-length.	Average Double Folds.	Average Elmendorf Tearing Test.
			1927.	lb.	lb.	Gal.	Grm./litre.	Grm./litre.	Gal.	Grm./litre.	Grm./litre.	Min.	lb./sq. in.	Deg. C.	lb.	lb.	Deg. C.	lb./sq. in.	Min.	Min.	Per Cent.	Per Cent.	Min.	H.p./ton/24 hrs.	lb.	0·001 in.	lb./sq. in.	Pts./lb./ream.	Per Cent.	Met.		Grm./lb./ream.
Tawa	1,210	2,218	Aug. 9	129·4	100·0	62·4	91·0	16·5	66·0	71·6	8·9	120	100	100–133	7·9	3·7	160	92	30	150	83·20	10·3	90	53·3	76·0§	15·5	13	0·18	..	..	..	0·47
Tawa		2,219	Aug. 11	120·0	99·5	60·6	118·5	13·3	54·4	108·5	10·7	90	100	100	11·4	2·0	170	125	30	120	81·40	6·7	210	145·6	115·0‖	8·8	92	0·80	4·30	6,705	36	0·89
Tawa		2,220	Aug. 17	125·5	104·2	57·8	123·0	14·4	54·1	104·2	11·9	120	100	86–103	17·3	2·2	170	138	30	240	70·00	6·3	180	..	54·7‖	3·9	44	0·81	4·93	6,197	331	1·21
																						6·0	8·0 lb./hr.†		35·0	3·7	9	0·26	1·02	2 505	6	1·07
																						6·0	8·0 lb./hr.‡		32·0	2·5	10	0·31	1·26	2,955	7	0·82¶
Tawa		2,247	Oct. 25	158·4	127·7	51·5	106·8	36·5	42·8	94·8	29·7	60	100	102	12·3	5·2	170	115	15	120	81·60	10·0	60	42·5	**	..	..	..	..	..	..	..
Tawa		2,248	Oct. 27	167·8	135·7	48·5	117·8	39·2	42·4	102·7	31·7	75	85	86–124	9·8	3·1	170	135	30	165	72·70	10·0	180	121·4	69·0	5·7	56	0·80	2·82	6,105	90	0·80

* Expressed as Na_2CO_3. † Continuous rod-mill run; once through the mill. ‡ Continuous rod-mill run; twice through the mill. § Complete test not made because of evident weakness of sheet. Brushed out in beater, and small amounts of size, alum, and clay added. ‖ Alum added; no size. ¶ 20 per cent. sulphite, 10 per cent. clay, and 2 lb. alum added. Brushed in beater half hour. ** Used for newsprint run No. 41. No strength tests made on pulp.

TABLE 17.—LABORATORY SULPHATE, SODA, AND SEMI-CHEMICAL PULPING TESTS: PULP-STRENGTH DATA.

By the Ball-mill Method.

Material.	Process.	Cook No.	Bursting Strength: Points per Pound per Ream (24 in. × 36 in.—500). (Ashcroft Tester.) 20	40	60	80	100	120	160	Folding Strength: Number of Double Folds. (Schopper Folding Tester.) 20	40	60	80	100	120	160
Number of minutes in ball mill*			20	40	60	80	100	120	160	20	40	60	80	100	120	160
Insignis pine	Sulphate	2,221	..	0·81	..	0·81	..	1·12	0·92	..	95	..	242	..	990	672
Insignis pine	Sulphate	2,222	..	0·85	..	0·98	..	1·09	1·109	..	185	..	373	..	835	1,409
Insignis pine	Sulphate	2,232	..	0·99	0·82	0·70	0·50	..	..	..	102	68	103	39	..	..
Rimu (slabwood)	Sulphate	2,226	..	0·76	..	0·99	..	1·22	0·97	..	155	..	590	..	909	580
Rimu (roundwood)	Sulphate	2,227	..	0·75	..	1·10	..	1·36	1·21	..	120	..	935	..	1,314	1,013
Rimu	Sulphate	2,231	..	0·87	..	1·07	..	1·35	1·20	..	263	..	672	..	1,084	771
Rimu	Sulphate	2,239	..	0·86	..	1·16	..	1·20	1·16	..	180	..	561	..	723	504
Corsican pine	Sulphate	2,233	..	0·74	..	1·06	..	1·22	1·03	..	70	..	373	..	694	850
Corsican pine	Sulphate	2,234	..	0·76	..	1·08	..	1·12	0·94	..	84	..	463	..	395	507
Corsican pine	Sulphate	2,240	..	0·80	..	1·00	..	0·95	0·74	..	174	..	196	..	229	309
Austrian pine	Sulphate	2,235	..	0·65	..	0·92	..	1·15	1·09	..	50	..	199	..	568	837
Austrian pine	Sulphate	2,236	..	0·69	..	0·93	..	1·12	0·95	..	55	..	281	..	506	642
European larch	Sulphate	2,237	..	0·74	..	1·06	..	1·05	1·01	..	110	..	343	..	471	784
European larch	Sulphate	2,238	..	0·82	..	1·09	..	1·07	1·01	..	100	..	520	..	610	902
Tawa	Soda	2,241	0·51	0·50	0·40	0·30	..	..	..	6	6	8	8	..	..	..
Tawa	Soda	2,242	0·45	0·60	0·65	0·54	..	..	..	3	9	17	16	..	..	..
Tawa	Soda	2,243	0·42	0·57	0·74	0·80	..	..	..	4	10	14	26	..	..	..
Tawa	Semi-chemical	2,218	0·10	0·22	0·29	0·54	0·70	0·83	..	..	..	2	6	19	54	..
Tawa	Semi-chemical	2,219	0·18	0·29	0·48	0·67	0·76	0·94	..	..	2	7	20	64	165	..

Material.	Process.	Cook No.	Tearing Strength: Grammes per Pound per Ream. (Elmendorf Tearing Tester.) 20	40	60	80	100	120	160	Tensile Strength: Breaking-length in Metres. (Schopper Tensile Tester.) 20	40	60	80	100	120	160	Stretch: per Cent. (Schopper Tensile Tester.) 20	40	60	80	100	120	160
Number of minutes in ball mill*			20	40	60	80	100	120	160	20	40	60	80	100	120	160	20	40	60	80	100	120	160
Insignis pine	Sulphate	2,221	..	2·84	..	2·32	..	2·17	2·20	..	3,545	..	3,460	..	5,160	3,555	..	8·37	..	11·12	..	10·62	15·00
Insignis pine	Sulphate	2,222	..	2·69	..	2·49	..	2·21	2·30	..	3,845	..	4,335	..	4,385	4,080	..	9·37	..	11·00	..	13·50	15·62
Insignis pine	Sulphate	2,232	..	1·46	1·31	1·20	0·94	..	..	..	4,535	4,330	3,585	3,080	..	..	..	7·75	6·37	8·00	5·38	..	..
Rimu (slabwood)	Sulphate	2,226	..	3·65	..	2·73	..	2·49	2·19	..	3,205	..	4,105	..	4,620	4,325	..	8·37	..	10·00	..	11·37	11·12
Rimu (roundwood)	Sulphate	2,227	..	4·08	..	2·90	..	2·98	2·51	..	3,177	..	4,797	..	5,955	5,017	..	8·00	..	10·37	..	10·67	13·00
Rimu	Sulphate	2,231	..	2·81	..	2·51	..	2·39	2·04	..	3,408	..	4,330	..	5,890	4,800	..	7·62	..	10·25	..	11·50	12·50
Rimu	Sulphate	2,239	..	2·68	..	2·39	..	2·10	2·08	..	4,155	..	5,275	..	5,325	4,725	..	8·50	..	9·12	..	9·62	10·62
Corsican pine	Sulphate	2,233	..	2·35	..	2·30	..	2·24	1·93	..	3,285	..	4,430	..	5,250	4,330	..	7·62	..	9·00	..	12·50	16·75
Corsican pine	Sulphate	2,234	..	2·28	..	2·20	..	2·30	2·03	..	3,300	..	4,190	..	4,100	4,195	..	7·12	..	11·12	..	10·50	9·87
Corsican pine	Sulphate	2,240	..	1·98	..	1·83	..	1·72	1·42	..	4,265	..	4,190	..	4,555	3,660	..	7·75	..	10·00	..	8·12	10·25
Austrian pine	Sulphate	2,235	..	1·92	..	2·11	..	2·06	2·12	..	3,090	..	4,090	..	5,145	4,085	..	8·62	..	8·75	..	10·75	15·00
Austrian pine	Sulphate	2,236	..	1·88	..	2·04	..	1·90	1·86	..	3,565	..	4,550	..	5,370	4,275	..	7·00	..	5·62	..	11·37	13·75
European larch	Sulphate	2,237	..	2·57	..	2·34	..	2·40	2·31	..	3,675	..	4,160	..	4,375	4,355	..	6·37	..	9·75	..	12·25	12·50
European larch	Sulphate	2,238	..	2·94	..	3·02	..	2·72	2·60	..	3,890	..	4,515	..	4,280	4,115	..	7·50	..	10·12	..	14·00	14·00
Tawa	Soda	2,241	1·68	1·66	1·53	1·29	..	..	..	3,450	3,315	3,500	2,320	..	..	..	5·12	4·62	3·37	2·50	..	..	..
Tawa	Soda	2,242	0·85	0·95	0·94	0·80	..	..	..	3,023	3,452	3,548	3,617	..	..	..	3·63	5·00	6·75	5·50	..	..	..
Tawa	Soda	2,243	0·75	0·99	1·15	1·07	..	..	..	2,701	3,485	3,678	4,251	..	..	..	3·00	5·00	4·75	6·25	..	..	..
Tawa	Semi-chemical	2,218	0·61	0·64	0·80	1·05	1·20	1·19	..	..	1,580	2,390	3,260	3,536	4,406	..	..	7·50	5·97	4·05	4·38	7·63	..
Tawa	Semi-chemical	2,219	0·57	0·81	1·04	1·06	1·19	1·17	..	1,585	2,280	3,050	3,640	4,455	4,660	..	1·75	3·00	4·75	5·75	6·12	9·62	..

* 4·3 per cent. consistency—66 r.p.m. Tests made at65 per cent. humidity and 70° F.

Table 18.—Laboratory Semi-chemical Cook No. 2220: Pulp-strentgh developed by Rod Mill.

Minutes in Rod Mill ..	30	45	60	75	90	105	120	135	150
Bursting-strength ..	0·02	0·25	0·36	0·46	0·55	0·61	0·66	0·75	0·85
Folding-strength ..	..	2	3	21	26	49	69	87	195
Tearing-strength ..	0·63	0·77	0·93	0·96	1·18	1·29	1·14	1·38	1·44

Table 19.—Physical Tests of North American Newsprint Papers.

Mills grouped by Regions.	Weight per Ream (24 in. by 36 in.—500).	Thickness.	Apparent Density lb. per ream per point.	Furnish.		Bursting-strength.	Tearing-strength.	Folding Endurance: Machine Direction.			Tensile Strength: Machine Direction.			Stretch: Machine Direction.			Colour.			
				Sulphite.	Ground-wood.			In.	Across.	Average.	In.	Across.	Average.	In.	Across.	Average.	Red.	Green.	Blue.	White.
	lb.	In.		Per Cent.	Per Cent.	Pts./lb. /ream.	Grm./lb. /ream.	Number of Double Folds.			Breaking-length in Metres.			Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
General average ..	32	0·0036	8·9	26	80	0·28	0·74	6·3	1·5	3·9	4,020	1,930	2,980	1·85	2·06	1·95	67	62	59	59
U.S.A. average ..	33	0·0037	8·9	27	79	0·28	0·74	5·8	1·4	3·6	4,101	2,040	3,020	1·57	1·89	1·73	67	61	57	57
East U.S.A. average ..	33	0·0037	8·9	25	82	0·27	0·72	5·1	1·5	3·3	3,960	2,040	3,000	1·36	1·59	1·48	68	63	60	60
East Mills No. 1 ..	32	0·0037	8·6	25	83	0·26	0·65	2·8	0·6	1·7	4,000	1,380	2,690	2·12	2·20	2·16	..	..	..	..
,, 2 ..	33	0·0034	9·7	25	83	0·28	0·67	3·8	1·0	2·4	3,870	2,530	3,200	2·32	2·92	2·62	71	63	59	59
,, 3 ..	34	0·0039	8·7	19	86	0·25	0·71	4·6	1·4	3·0	4,030	1,710	2,870	2·04	2·56	2·30	67	61	58	58
,, 4 ..	33	0·0039	8·5	29	75	0·29	0·82	6·6	1·6	4·1	4,190	2,290	3,240	1·00	1·14	1·07	67	65	63	63
,, 5 ..	32	0·0036	8·9	..	..	0·30	0·81	12·8	2·6	7·7	4,150	1,690	2,920	0·82	0·94	0·88	69	63	60	60
,, 6 ..	34	0·0037	9·2	..	..	0·30	0·71	5·4	2·2	3·8	3,990	2,710	3,350	0·94	1·02	0·98	70	64	61	61
,, 7 ..	34	0·0040	8·5	22	87	0·23	0·73	3·2	1·6	2·4	3,610	1,730	2,670	0·78	1·06	0·92	68	64	60	60
,, 8 ..	32	0·0037	8·6	29	79	0·27	0·69	2·0	1·0	1·5	3,850	2,230	3,040	0·86	0·88	0·87	65	61	61	
West U.S.A. average ..	32	0·0037	8·6	32	71	0·28	0·77	7·6	1·1	4·4	4,150	2,040	3,090	2·13	2·69	2·41	63	56	52	52
West Mills No. 9 ..	33	0·0038	8·7	26	78	0·30	0·80	9·4	1·0	5·2	4,540	2,300	3,420	2·54	3·00	2·77	..	..	..	..
,, 10 ..	31	0·0037	8·4	37	64	0·29	0·84	8·2	1·2	4·7	4,240	1,800	3,020	2·04	2·60	2·32	60	52	46	46
,, 11 ..	33	0·0035	9·4	..	..	0·26	0·68	5·2	1·2	3·2	3,660	2,020	2,840	1·80	2·48	2·14	65	59	57	57
Canadian average ..	32	0·0035	9·1	26	80	0·29	0·74	7·2	1·8	4·5	4,040	1,770	2,900	2·29	2·33	2·31	68	64	61	61
East Canadian average ..	31	0·0034	9·1	26	82	0·29	0·72	4·9	1·6	3·3	3,750	1,720	2,730	2·26	2·37	2·31	69	64	62	62
East Mills No. 12 ..	31	0·0029	10·7	..	..	0·28	0·66	5·4	1·4	3·4	4,320	1,880	3,100	2·24	2·32	2·28	67	62	62	62
,, 13 ..	32	0·0035	9·1	..	..	0·32	0·72	7·8	1·6	4·7	3,970	1,770	2,870	2·24	2·28	2·26	66	63	61	61
,, 14 ..	31	0·0037	8·4	..	..	0·25	0·78	2·8	1·6	2·2	3,400	1,560	2,480	2·32	2·20	2·26	73	69	63	63
,, 15 ..	31	0·0038	8·2	26	83	0·31	0·73	5·0	1·6	3·3	3,910	1,630	2,770	2·50	2·84	2·67	72	67	65	65
,, 16 ..	31	0·0033	9·4	26	81	0·29	0·70	3·4	2·0	2·7	3,160	1,740	2,450	2·00	2·20	2·10	67	61	58	58
West Canadian average	33	0·0037	8·9	25	79	0·31	0·79	13·0	2·1	7·6	4,750	1,890	3,320	2·36	2·22	2·29	64	60	57	57
West Mills No. 17 ..	33	0·0040	8·3	25	79	0·27	0·86	13·0	2·2	7·6	4,280	1,720	3,000	2·20	2·08	2·14	..	..	..	..
,, 18 ..	32	0·0034	9·4	25	78	0·34	0·71	13·0	2·0	7·5	5,220	2,060	3,640	2·52	2·36	2·44	64	60	57	57
East U.S.A. and Canadian average	32	0·0036	8·9	25	82	0·28	0·72	5·0	1·6	3·3	3,880	1,910	2,900	1·71	1·89	1·80	69	64	61	61
West U.S.A. and Canadian average	32	0·0037	8·6	28	75	0·29	0·78	9·8	1·5	5·6	4,390	1,980	3,180	2·22	2·50	2·36	63	57	53	53

TABLE 20.—LABORATORY NEWSPRINT PAPERS FROM NEW ZEALAND WOODS: INSIGNIS-PINE PAPERS.

Machine-run No.	Cook and Grinder-run Nos.	Furnish. Pulp. Kind.	Furnish. Pulp. Amount	Furnish. Natural or Coloured.	Strength of Water-leaf Paper.*† Weight per Ream.	Strength: Thickness.	Strength: Bursting per lb. per Ream.	Strength: Tearing. Per Ream.	Strength: Tearing. Per lb. per Ream.	Strength: Folding.	Dirt-particles per Square Inch.	Colour Analysis. Red.	Colour Analysis. Green.	Colour Analysis. Blue.	Colour Analysis. White.	Interpretation: Primary Hue. Tint.	Interpretation: Primary Hue. Luminosity.	Interpretation: Secondary Hue. Tint.	Interpretation: Secondary Hue. Luminosity.
			Per Cent.		lb.	In.	Points.	Grm.	Grm.	Double Folds.		Per Cent.	Per Cent.	Per Cent.	Per Cent.		Per Cent.		Per Cent.
Commercial newsprint (P661) from fast machine			..	..	33·0	0·0033	0·30	40	1·22	1	2	74	67	62	62	Yellow	9·0	Orange	0·3
Commercial newsprint (P661) from slow machine			..	..	..	..	..	..	..	..	4	76	69	64	64	Orange	5·8	Yellow	0·5
U.S. Government Printing Office standard			..	..	32·0	..	0·31	..	..	..	..	70	63	60	60	Yellow	5·4	Orange	0·3
1	..	Commercial groundwood	70	Natural	33·0	0·0036	0·34	30	0·90	11	3	71	62	52	52	Orange	5·8	Yellow	5·0
		Commercial sulphite	30																
2	..	Commercial groundwood	70	Coloured	35·00	0·0031	0·38	29	0·82	20	5	59	57	53	53	Yellow	2·9	Orange	1·4
		Commercial sulphite	30																
3	9	Spruce groundwood	70	Natural	32·0	0·0030	0·33	21	0·65	5	5	79	70	63	63	Orange	5·8	Yellow	1·4
		Commercial sulphite	30																
4	9	Spruce groundwood	70	Coloured	32·0	0·0031	0·35	20	0·64	6	3	71	67	64	64	Orange	2·6	Yellow	0·9
		Commercial sulphite	30																
5	8	Insignis-pine groundwood	70	Natural	33·0	0·0032	0·52	30	0·90	30	42	66	56	48	48	Orange	6·4	Yellow	2·7
	3266–I	Insignis-pine sulphite	30																
6	8	Insignis-pine groundwood	70	Coloured	31·0	0·0030	0·41	22	0·70	15	27	52	50	52	50	Magenta	0·6	None	..
	3266–I	Insignis-pine sulphite	30																
7	8	Insignis-pine groundwood	80	Coloured	35·0	0·0037	0·39	24	0·69	6	54	57	55	51	51	Yellow	2·7	Orange	1·3
	3265–I	Insignis-pine sulphite	12·5																
	3266–I	Insignis-pine sulphite	7·5																
10	8	Insignis-pine groundwood	70	Coloured	33·0	0·0030	0·40	25	0·76	13	41	59	56	54	54	Orange	1·9	Yellow	0·5
	3265–I	Insignis-pine sulphite bleached	30																
11	13	Insignis-pine groundwood	80	Natural	32·0	0·0037	0·42	19	0·59	9	6	70	61	55	55	Red	1·1	None	..
		Commercial sulphite	20																
12	13	Insignis-pine groundwood	80	Coloured	31·0	0·0033	0·34	19	0·62	6	4	63	57	52	52	Orange	3·8	Yellow	1·8
		Commercial sulphite	20																
13	14	Insignis-pine groundwood	80	Natural	31·0	·00034	0·35	18	0·59	6	3	71	66	60	60	Orange	3·2	Yellow	3·2
	3265–I	Insignis-pine sulphite	16																
	3266–I	Insignis-pine sulphite	4																
14A	14	Insignis-pine groundwood	80	Coloured	..	..	..	..	..	..	4	67	63	61	61	Orange	2·6	None	..
	3265–I	Insignis-pine sulphite	16																
	3266–I	Insignis-pine sulphite	4																
14B	Same as 14A except more dye added in stock-chest			..	32·0	0·0037	0·35	21	0·64	10	2	59	58	58	58	Red	0·2	None	..
37A†	16	Insignis-pine groundwood	80	Coloured	28·0	0·0030	0·29	14	0·51	5	2	66	61	57	57	Orange	3·2	Yellow	1·4
	3281–I	Insignis-pine sulphite	20																
37B†	Same as 37A except more dye added in stock-chest			..	45·0	0·0052	0·40	22	0·49	2	2	56	56	55	55	Yellow	0·9	None	..
38†	17	Insignis-pine groundwood	80	Coloured	36·0	0·0037	0·33	16	0·33	4	3	60	59	59	59	Red	0·2	None	..
	3281–I	Insignis-pine sulphite	20																
39†	18	Insignis-pine groundwood	80	Coloured	32·0	0·0030	0·33	15	0·46	5	2	61	61	57	57	Yellow	3·6	None	..
	3281–I	Insignis-pine sulphite	20																

* All strength tests were made at 65 per cent. relative humidity and 72° F. † All papers were run water-leaf except 37A, 37B, 38, and 39.

TABLE 21.—LABORATORY NEWSPRINT PAPERS FROM NEW ZEALAND WOODS: PAPERS FROM TAWA, INSIGNIS PINE, RIMU, AND EUROPEAN LARCH.

Machine-run No.	Furnish.						Beating-conditions.				Strength Data.							Colour.			
	Tawa Groundwood.	Tawa Sulphite.	Cook No.	Insignis-pine Sulphite.	Cook No.	Clay.	Time in Rod Mill.	Weight.	Time in Beater.	Weight.	Weight per Ream.	Thickness.	Bursting.	Tearing.	Tensile.	Folding.	Strength.	Red.	Green.	Blue.	White.
	Per Cent.	Per Cent.		Per Cent.		Per Cent.	Min.	lb.	Min.	lb.	lb.	In.	Pts./lb./rm.	Grm./lb./rm.	Metres.	Double Folds.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
15 ..	30	70	3,271	..	..	5	Not beaten				70·8	0·0084	0·21	0·48	2,523	2·3	1·36	..	..	..	..
16 ..	30	70	3,271	..	..	5	10	10	..	..	71·7	0·0073	0·35	0·75	3,740	3·0	2·17	67	63	59	59
17 ..	25	65	3,271	15	3,272–I	5	10	10	..	..	50·0	0·0045	0·39	0·85	4,025	10·0	1·24	..	..	..	..
18 ..	40	30	3,270	30	3,272–I	5	6	8	..	..	39·5	0·0036	0·21	0·65	2,044	5·0	1·10	70	67	62	62
19 ..	30	40	3,270	30	3,272–I	2	8	10	..	..	34·0	0·0036	0·27	0·76	2,415	3·0	0·84	..	..	..	..
20 ..	40	40	3,270	20	3,269–I	..	7	9	..	..	30·0	0·0030	0·24	0·71	2,425	1·5	0·95	67	63	63	63
21 ..	46	46	3,273	8	3,269–I	..	15	15	..	..	36·0	0·0035	0·23	0·55	2,355	1·5	1·11	59	59	59	59
22 ..	40	45	3,273	15	3,269–I	..	13	11	..	..	33·0	0·0033	0·28	0·65	2,790	3·0	1·19	57	59	59	57
23 ..	30	55	3,273	15	3,269–I	..	8	8	..	..	32·0	0·0030	0·26	0·66	2,630	2·5	1·12	..	..	..	..
24 ..	30	55	3,274	15	3,269–I	..	17	14	..	..	35·0	0·0033	0·28	0·60	2,750	3·0	1·53	..	..	..	..
25 ..	30	55	3,274	15	3,275–I	..	13	20	15	..	32·0	0·0032	0·31	0·77	2,850	4·0	2·30	..	..	..	..
26 ..	30	55	3,274	15	3,275–I	..	..	..	30	10	36·0	0·0037	0·28	0·89	3,135	3·5	1·35	..	..	..	..
27 ..	30	55	3,274	15	3,275–I	..	..	..	40	15	31·0	0·0030	0·34	1·04	3,560	5·0	1·58	58	60	58	58
28 ..	35	50	3,276	15	3,275–I	..	20	25	20	..	36·0	0·0035	0·29	0·67	3,170	6·0	1·68	62	57	56	57
29 ..	35	50·7	3,277	14·3	3,277–I	..	20	20	20	..	30·0	0·0030	0·23	0·63	2,473	2·4	1·39	..	..	..	..
30 ..	50	23	3,277	27	3,277–75–I	..	..	..	30	20	28·0	0·0029	0·13	0·78	2,270	1·5	1·17	..	..	..	..
				Bleached larch sulphite																	
31 ..	30	55	3,279	15	3,278–I	..	5	10	20	..	34·0	0·0031	0·20	0·92	2,308	1·6	1·31	72	67	61	61
32 ..	30	70	3,279	..	..	..	5	10	20	..	40·0	0·0036	0·22	0·60	2,638	2·6	1·61	66	62	62	62
				Rimu																	
33 ..	35	50	3,279	15	3,280–I	..	6	8	30	..	36·0	0·0032	0·21	0·54	2,308	1·7	1·36	65	61	58	58
34 ..	Wet broke from first press of commercial machine.						Commercial paper from same machine.*				36·0	0·0034	0·32	0·72	3,471	6·5	1·32	68	60	59	59
											33·0	0·0033	0·31	0·58	2,479	2·9	0·87	67	63	60	60
		Tawa semi-chemical																			
35 ..	20	80	2,247	..	..	..	60	25	15	..	64·0	0·0087	0·24	0·55	2,827	1·0	1·17	..	..	..	..
36 ..	..	100	2,247	..	..	..	30	25	60	..	55·0	0·0064	0·44	0·83	4,480	5·7	1·74	..	..	..	..
40 ..	..	100	2,248	..	..	..	150	25	..	..	..	..	..	..	..	..	..	..	..	..	..
				Bleached Larch																	
41 ..	30	55	2,247	15	3,278–I	5	60	25	60	..	34·0	0·0034	0·28	0·59	3,040	2·5	1·68	64	58	55	55
42 ..	35	50	3,282	15	3,275–I	..	..	..	80	30	41·0	0·0034	0·39	0·75	3,743	9·1	2·00	..	..	..	..
				Bleached Rimu																	
43 ..	30	55	3,282	15	3,280–I	..	5	8	20	15	41·0	0·0038	0·25	0·60	2,849	2·5	1·35	..	..	..	..
				Insignis Pine																	
8 ..	..	90	3,268	10	3,265	..	..	..	..	..	39·0	0·0033	0·32	0·85	..	5·0	..	64	60	55	55
9 ..	..	90	3,268	10	3,265	..	..	..	..	..	36·0	0·0031	0·40	1·28	..	15·0	..	75	78	76	75

* This material supplied through courtesy of Consolidated Water-power and Paper Co., Wisconsin Rapids, Wisconsin, from their No. 1 machine.

TABLE 22.—LABORATORY PAPER MACHINE RUNS: BEATER FURNISH, PROCESSING AND STRENGTH DATA.

Machine-run No.	Furnish. Commercial Hemlock Sulphite.	Furnish. Insignis-pine Sulphite.	Furnish. Time beaten.	Furnish. Tawa Sulphite.	Furnish. Time beaten. Rod Mill.	Furnish. Time beaten. Beater.	Furnish. Tawa Groundwood.	Furnish. Time beaten.	Jordan.	Weight per Ream.	Thickness.	Tearing Factor.	Bursting Factor.	Tensile Breaking-length.	Number of Double Folds.	Stretch.
	Per Cent.	Per Cent.	Min.	Per Cent.	Min.	Min.	Per Cent.	Min.		lb.	In.	Grm./lb./rm.	Pts./lb./rm.	Metres.		Per Cent.
1	15	..	..	50*	..	..	35*	..	Medium	39·2	0·0047	0·61	0·25	2,208	2	0·7
2	15	..	..	50*	..	..	35*	..	Hard	34·4	0·0034	0·59	0·26	2,798	2	0·9
3	..	15†	30	50‡	..	30	35	30	..	34·4	0·0034	0·60	0·22	2,493	2	0·1
4	..	15†	30	50‡	..	30	35	30	Medium	31·2	0·0030	0·55	0·26	2,682	2	1·1
5	..	15†	45	50‡	..	45	35	45	..	34·4	0·0032	0·59	0·26	2,927	3	1·4
6	..	15	..	50	..	160	35	..	..	37·6	0·0035	0·55	0·33	3,534	3	1·3
7	..	25	..	50	..	160	25	..	..	38·4	0·0032	0·57	0·34	3,920	4	1·2
8	..	15	5	50	100	5	35	5	..	44·0	0·0041	0·59	0·29	3,135	1	1·3
9	..	..	..	65	100	..	35	5	..	71·2	0·0068	0·73§	0·32	3,167	2	2·0
10	..	15	5	50	..	135	35	5	..	35·2	0·0030	0·74‖	0·25	3,112	2	1·4
11	..	25	5	50	..	135	25	5	..	41·6	0·0034	0·92‖	0·23	2,784	3	1·2
12	..	15†	5	55	20	5	30	5	..	58·4	0·0051	0·69¶	0·30	2,808	3	1·6

* Pulp made at Laboratory. † Insignis-pine sulphite pulp from cook No. 1. ‡ Tawa sulphite pulp from cook No. 2. § Sixteen sheets used in tearing test instead of eight sheets. ‖ Twenty-four sheets used in tearing test instead of eight sheets. ¶ Twelve sheets used in tearing test instead of eight sheets.

TABLE 23.—STRENGTH-DEVELOPMENT STUDIES WITH TAWA SULPHITE: LABORATORY RUNS.

Run No.	Equipment.	Pulp used.	Beating-time.	Bursting Factor (on Oven-dry Hand-sheets).	Freeness.
		Cook No.	Minutes.	Pts./lb./rm.	c.c.
1	Marx-beater ..	2	20	0·16	385
			40	0·21	332
			60	0·33	295
			80	0·35	253
			100	0·37	217
			120	0·40	168
			140	0·46	104
			160	0·54	56
2	Rod mill ..	2	20	0·24	258
			40	0·32	235
			60	0·30	168
			80	0·37	124
			100	0·46	84
3	Marx-beater ..	2	40	0·17	323
			70	0·22	292
			100	0·32	157
			130	0·41	107

TABLE 24.—STRENGTH-DEVELOPMENT STUDIES WITH TAWA SULPHITE: COMMERCIAL BEATER RUNS —CONSOLIDATED WATER-POWER AND PAPER CO.

Beater-run No.	Date.	Beating-time.	Roll-setting.	Bursting Factor (on Oven-dry Hand-sheets).	Freeness.
		Minutes.		Pts./lb./rm.	c.c.
1	March 13, 1928 ..	Unbeaten	stock	0·08	498
		50	Light brush	0·12	430
		90	,, ...	0·15	..
		180	Medium brush ..	0·16	340
		240	,, ..	0·16	330
		300	Hard brush	0·16	340
		360	,, ...	0·15	340
2	March 13, 1928 ..	60	Medium brush ..	0·13	440
		120	,, ..	0·13	360
		180	Hard brush	0·14	315
		240	,, ...	0·20	320
		300	,, ...	0·16	320
3	March 14, 1928 ..	60	Light brush	0·17	375
		120	Medium brush ..	0·17	315
		240	Very hard brush ..	0·18	320
		375	,, ..	0·24	265
		525	,, ..	0·26	220
		Total	furnish*	0·22	175
4	March 14, 1928 ..	60	Light brush	0·16	380
		195	Medium brush ..	0·18	320
		330	Hard brush	0·19	270
		420	Very hard brush ..	0·25	270
		480	,, ..	0·24	250
5	March 14, 1928 ..	60	Hard brush	0·16	370
		120	,, ...	0·21	380
		210	,, ...	0·19	400
		Total	furnish*	0·24	160
6	March 14, 1928 ..	60	Hard brush	0·15	390
		120	,, ...	0·17	360
		210	,, ...	0·22	390
		Total	furnish*	0·24	175
7	March 15, 1928 ..	0	Hard brush	0·11	400
		60	,, ...	0·11	440
		Total	furnish*	0·19	225
8	March 15, 1928 ..	90	Hard brush	0·17	350
		Total	furnish*	0·21	230

* This sample comprised the total beater furnish of insignis-pine sulphite, tawa sulphite, and tawa groundwood, just prior to emptying the beater. All other tests are upon tawa sulphite only.

TABLE 25.—MILL TRIAL NO. 1: BEATER FURNISH AND STRENGTH DATA—PAPER MACHINE RUNS AT GREAT WESTERN PAPER CO. MILL, LADYSMITH, WISCONSIN.

Machine-run No. and Date	Kind of Paper.	Beater Furnish.																Strength Data.						
		Beater-run No.	Insignis-pine Sulphite.					Tawa Sulphite.					Tawa Groundwood.				Weight per Ream.	Thickness.	Tearing Factor.	Bursting Factor.	Tensile Breaking-length.	Number of Double Folds.	Stretch.
			Per Cent. of Furnish.	Cook No.	Wet Pulp.	Per Cent. Oven-dry.	Oven-dry Pulp.	Per Cent. of Furnish.	Cook No.	Wet Pulp.	Per Cent. Oven-dry.	Oven-dry Pulp.	Per Cent. of Furnish.	Wet Pulp.	Per Cent. Oven-dry.	Oven-dry Pulp.							
1928.					lb.		lb.			lb.		lb.		lb.		lb.	lb.	In.	Grm./lb./ream.	Pts./lb./ream.	Metres.		Per Cent.
1	News	1	15	1	380	35·7	136	50	3	1,240	36·3	450	35	1,060	29·7	315	39·6*	..	0·66	0·26	..	..	..
Feb. 9..	,,	2	15	1	380	35·7	136	50	3	1,240	36·3	450	35	1,060	29·7	315	40·0*	..	0·70	0·30	..	..	..
	,,	3	21	1	580	35·7	207	46	2	1,240	36·3	450	33	1,060	29·7	315	45·0*	..	0·67	0·26	..	..	..
	,,	4	21	1	580	35·7	207	46	4	1,240	36·3	450	33	1,060	29·7	315	38·0*	..	0·71	0·28	..	..	..
2	,,	1	25	1	630	39·5	249	57	2	1,450	38·5	558	18	595	29·0	173	38·1	0·0033	0·79	0·26	2,633	3	1·8
Feb. 13..	,,	2	21	1	510	39·5	202	57	2	1,450	38·5	558	22	740	29·0	215	41·2	0·0042	0·77	0·24	2,759	2	1·7
	,,	3	16	1	380	39·5	150	58	4	1,450	38·5	558	26	890	29·0	258	35·0	0·0037	0·72	0·23	2,617	2	1·4

* Tests made at mill.

TABLE 26.—MILL TRIALS NOS. 2 AND 3: BEATER FURNISH AND STRENGTH DATA—PAPER MACHINE RUNS AT CONSOLIDATED WATER-POWER AND PAPER CO., WISCONSIN RAPIDS, WISCONSIN.

Machine-run No. and Date.	Beater-run No.	Kind of Paper.	Insignis-pine Sulphite.						Tawa Sulphite.								Tawa Groundwood.				
			Per Cent. of Total Furnish.	Cook No.	Wet Pulp.	Per Cent. Oven-dry.	Oven-dry Pulp.	Time beaten.	Per Cent. of Total Furnish.	Cook No.	Wet Pulp.	Per Cent. Oven-dry.	Oven-dry Pulp.	Time beaten alone.	Freeness.	Total Beating-time.	Per Cent. of Total Furnish.	Wet Pulp.	Per Cent. Oven-dry.	Oven-Dry Pulp.	Time beaten.
1928.					lb.		lb.	Hours.			lb.		lb.	Hours.	c.c.	Hours.		lb.		lb.	Hours.
1	1	News	20	1	963	37·4	360	0·50	50	2 and 4	2,412	37·6	900	5·75	340	6·25	30	1,701	31·7	540	0·50
March 13	2	„	20	1	963	37·4	360	0·50	50	2 and 4	2,412	37·6	900	4·75	320	5·25	30	1,701	31·7	540	0·50
	3	„	20	1	963	37·4	360	0·50	50	2 and 4	2,412	37·6	900	7·50	220	8·00	30	1,701	31·7	540	0·50
March 15	4	„	20	1	963	37·4	360	0·50	50	3	2,412	37·6	900	7·00	250	7·50	30	1,701	31·7	540	0·50
	5	„	20	1	963	37·4	360	0·50	50	3	2,412	36·6	900	3·25	400	3·75	30	1,701	31·7	540	0·50
	6	„	20	1	963	37·4	360	0·50	50	3	2,412	37·6	900	3·25	390	3·75	30	1,701	31·7	540	0·50
	7	„	20	1	1,177	37·4	440	1·50	50	2 and 4	2,948	37·6	1,100	..	440	1·50	30	2,079	31·7	660	1·50
	8	„	20	1	1,177	37·4	440	1·50	50	2	2,948	37·6	1,100	3·25	350	1·50	30	2,079	31·7	660	1·50
	9	„	Wet broke with 5 per cent. of pine-spruce added						..	..	..	..	..	..	..	..	..	..	..	..	..
	10	„	Wet broke with 5 per cent. of pine-spruce added						..	..	..	..	..	..	..	..	..	..	..	..	..
	11	„	Wet broke with 5 per cent. of pine-spruce added						..	..	..	..	..	..	..	..	..	..	..	..	..
	1	„	20	1	1,000	40·0	400	..	50	2, 3, 4	2,700	37·0	1,000	..	..	..	30	1,500	40·0	600	..
2	2	„	20	1 and 5	1,000	40·0	400	..	50	2, 3, 4	2,700	37·0	1,000	..	..	..	30	1,500	40·0	600	..
April 17	3	„	20	5	1,000	40·0	400	..	50	2, 3, 4	2,700	37·0	1,000	..	..	..	30	1,500	40·0	600	..
	4	„	20	5	1,000	40·0	400	..	50	2, 3, 4	2,700	37·0	1,000	..	..	..	30	1,500	40·0	600	..
	5	„	20	5	1,000	40·0	400	..	50	2, 3, 4	2,700	37·0	1,000	..	..	..	30	1,500	40·0	600	..
	6	„	20	5	1,000	40·0	400	..	50	2, 3, 4	2,700	37·0	1,000	..	..	..	30	1,500	40·0	600	..
	7	„	20	5	1,000	40·0	400	..	50	2, 3, 4	2,700	37·0	1,000	..	..	..	30	1,500	40·0	600	..
	8	„	20	5	1,000	40·0	400	..	50	2, 3, 4	2,700	37·0	1,000	..	..	..	30	1,500	40·0	600	..
	9	„	20	5	780	40·0	312	..	51	2, 3, 4	2,165	37·0	800	..	..	..	29	1,145	40·0	458	..
	10	Machine-finish	52	5	2,990	40·0	1,195	..	..	..	..	..	..	..	..	..	35	2,010	40·0	805	..
	11	Book	52	5	2,990	40·0	1,195	..	..	..	..	..	..	..	..	..	35	2,010	40·0	805	..
	12	Dry-finish	50	5	2,500	40·0	1,000	..	50	2, 3, 4	2,500	40·0	1,000	..	..	..	..	..	..	..	..
	13	Wrapping	50	5	2,500	40·0	1,000	..	50	2, 3, 4	2,500	40·0	1,000	..	..	..	..	..	..	..	..

TABLE 26.—MILL TRIALS NOS. 2 AND 3: BEATER FURNISH AND STRENGTH DATA—PAPER MACHINE RUNS AT CONSOLIDATED WATER-POWER AND PAPER CO., WISCONSIN RAPIDS, WISCONSIN—*continued*.

Machine-run No. and Date.	Beater-run No.	Kind of Paper.	Clay. Per Cent. of Total Furnish.	Clay. Weight.	Total Furnish. Oven-dry Pulp.	Total Furnish. Total Beating-time.	Total Furnish. Freeness.	Total Furnish. Bursting Factor Hand-sheets.	Reel No.	Strength Data. Weight per Ream.	Strength Data. Thickness.	Strength Data. Tearing Factor.	Strength Data. Bursting Factor.	Strength Data. Tensile Breaking-length.	Strength Data. Number of Double Folds.	Strength Data. Stretch.	Colour (Ives). Red.	Colour (Ives). Green.	Colour (Ives). Blue.	Opacity. Thickness.	Opacity. Ives.	Gloss. Ingersoll. Top.	Gloss. Ingersoll. Bottom.
1928.				lb.	lb.	Hours.	c.c.	Pts./lb./ream.		lb.	In.	Grm./lb./ream.	Pts./lb./ream.	Metres.		Per Cent.				In.			
2 March 13	1	News	..	..	1,800	6·25	..	..	..	39·2	0·0034	0·69	0·31	3,172	3	1·2	..	..	..	..	..	..	..
	2	”	..	..	1,800	5·25	..	..	..														
March 15	3	”	..	..	1,800	8·00	175	0·22	..	35·2	0·0029	0·69	0·30	2,876	3	1·1	..	..	..	..	..	..	..
	4	”	..	..	1,800	7·50	..	..	..														
	5	”	..	..	1,800	3·75	160	0·24	..	34·4	0·0032	0·65	0·29	3,137	3	1·1	..	..	..	..	..	..	..
	6	”	..	..	1,800	3·75	175	0·24	..														
	7	”	..	..	2,200	1·50	225	0·19	..	37·6	0·0034	0·68	0·28	3,164	2	1·1	..	..	..	..	..	..	..
	8	”	..	..	2,200	1·50	230	0·21	..														
	9	”	..	..	2,200	Mixed	190	0·26	..	34·0	0·0034	0·66	0·29	2,938	3	1·1	..	..	..	..	..	..	..
	10	”	..	..	2,200	only	190	0·23	..														
	11	”	..	..	2,200	Ditto	205	0·28	..														
3 April 17	1	”	..	..	2,000	0·58	235	0·15	1	35·0	0·0030	0·67	0·27	2,706	2	1·7	67	59	57	0·0030	96	25·5	29
	2	”	..	..	2,000	0·58	..	..															
	3	”	..	..	2,000	0·58	260	..	2	34·0	0·0030	0·67	0·28	2,950	3	1·7	68	60	58	0·0029	95	28	31
	4	”	..	..	2,000	0·58	255	0·22															
	5	”	..	..	2,000	0·58	225	0·17	3	34·0	0·0030	0·60	0·25	2,717	3	1·7	66	59	56	0·0028	94	30	32
	6	”	..	..	2,000	0·58	200	0·22	4	33·0	0·0025	0·59	0·31	3,043	3	1·7	67	60	57	0·0027	94	29	31
	7	”	..	..	2,000	0·58	190	0·22															
	8	”	..	..	2,000	0·58	190	0·21	5	35·0	0·0030	0·66	0·28	2,830	3	1·9	67	59	57	0·0030	96	29	31
	9	”	..	..	1,570	0·58	230	0·25															
	10	Machine finish	13	300	2,300	0·58	..	..	6	38·1	0·0031	0·76	0·35	3,480	4	1·8	70	64	59	0·0030	95	29	31·5
	11	Book	13	300	2,300	0·58	250	0·26															
	12	Dry finish	..	..	2,000	0·58	500	0·19	7	39·1	0·0033	0·97	0·36	3,660	7	1·6	77	67	62	0·0034	91	29	27
	13	Wrapping	..	..	2,000	0·58	500	0·18															
Standard news containing 26 per cent. spruce or hemlock sulphite and 80 per cent. spruce groundwood (average figures).										32·0	0·0032	0·74	0·28	2,980	3·9	1·9	67	62	59	0·0032	..	..	..

APPENDICES.

APPENDIX I.—SHIPMENT AND FOREST DESCRIPTIONS.

SHIPMENT DESCRIPTION.

TREES COLLECTED FOR INVESTIGATIONAL PURPOSES.

Shipment No.	Species.	Quantity.	Age.	Total Height.	Diameter. B.H.	Locality.
		Cords.	Years.	Ft.	In.	
101	Corsican Pine (*Pinus laricio*) ..	1	23	57	7·7	Whakarewarewa.*
102	Austrian Pine (*Pinus austriaca*) ..	1	23	45	8·3	Whakarewarewa.*
103	European larch (*Larix europea*)	1	22	65	7·2	Whakarewarewa.*
104	Insignis-pine (*Pinus radiata*) ..	3	12	60	7·3	Whakarewarewa.*
105	Rimu (*Dacrydium cupressinum*) ..	2	..	..	12·0	Mamaku.†
105A	Rimu slabs	1	..	..	..	Mamaku.‡
106	Tawa (*Beilschmiedia tawa*) ..	3	..	..	10·0	Mamaku.†
		Cub. ft. I.B.				
111	Insignis pine (*Pinus radiata*) ..	927	30	90	18·0	Swanson.§
112	Tawa (*Beilschmiedia tawa*) ..	2,090	..	70	16·0	Mamaku.†

* See "Forest Description," below. † See "Forest Description" below. ‡ From G. A. Gamman and Co. operation. § See "Forest Description," page 51.

FOREST DESCRIPTION. (1926)

THE EXOTIC SOFTWOODS COLLECTED FOR PULPING TESTS.

Whakarewarewa.

Locality.—Whakarewarewa, Rotorua Forest Conservation Region.

Situation and Altitude.—Situation: Near Rotorua. Altitude: About 1,000 ft. above sea-level.

Climate.—Rainfall: Mean annual, 55·11 in. Temperature: Annual mean, 54·8° F. Sunshine: Mean, 2,055 hours.

Stand.—Block: 22. Compartments: 1, 2, 3. Areas: 132 acres, 108 acres, 305 acres 2 roods 16 perches. Species: *Pinus radiata.* Spacing: 6 ft. by 3 ft. Age: Eleven years. Density: Overstocked. Crown cover: Very complete. Average height: 48 ft. Average D.B.H.: 5·75 in. Stand per acre (to 3 in. top): 5,462 cub. ft. (Total stand: 1—720,984 cub. ft; 2—589,896 cub. ft; 3—1,665,910 cub. ft.). Diameter growth: Five rings per inch. Height growth: 36 in. Remarks: Planted 3 ft. apart in rows and 6 ft. between the rows in order to suppress the heavy fern. Windfalls and double leaders common.

Block: 1. Compartment: 2. Area: 51 acres and 32 perches. Species: *P. austriaca, Sequoia sempervirens* (a few). Spacing: 4 ft. Age: Twenty-two years. Density: Overstocked. Crown cover: Very complete. Average height: *P. aust.*, 35 ft.; *S. semp.*, 45 ft. Average D.B.H.: *P. aust.*, 6·5 in.; *S. semp.*, 10 in. Stand per acre (to 3 in. top): 3,744 cub. ft. (Total stand: 190,944 cub. ft.). Diameter growth: *P. aust.*, 8 rings per inch; *S. semp.*, 3 rings per inch. Height growth: *P. aust.*, 18 in.; *S. semp.*, 20 in. Soil: Pumice. Site: 1. Aspect: Level, but gentle slope to north-west.

Block: 2. Compartment: 1. Area: 22 acres. Species: *P. austriaca*, 66 per cent.; *P. Laricio*, 34 per cent. Spacing: 4 ft. Age: Twenty-two years. Density: Overstocked. Crown cover: Very complete. Average height: 35 ft. Average D.B.H.: 6 in. Stand per acre (to 3 in. top): 5,586 cub. ft. (Total stand, 122,892 cub. ft.). Diameter growth: Seven rings per inch. Height growth: 18 in. Soil: Pumice. Site: 1. Aspect: Level, but gentle slope to north-west.

Block: 4. Compartment: 1. Area: 66 acres 1 rood 24 perches. Species: *Larix europea, Pseudotsuga taxifolia.* Spacing: 4 ft. Age: Twenty-one years. Density: Overstocked. Crown cover: Very complete. Average height: 50 ft. Average D.B.H.: 5·6 in. Stand per acre (to 3 in. top): Larch, 1,'41 cub. ft.; Douglas Fir, 367 cub. ft. (Total stand: Larch, 128,591 cub. ft.; Douglas Fir, 24,313 cub. ft.). Diameter growth: Larch, nine rings per inch; Douglas, three rings per inch. Height growth: *L.*, 20 in.; *D.*, 25 in. Soil: Pumice. Site: 1. Aspect: North-west. Remarks: Larch thinned. Douglas good on strip 2 chains wide on south boundary, rest poor and small. Sample plot No. 2.

TAWA AND RIMU COLLECTED FOR PULPING TESTS.

Mamaku.

Locality.—Mamaku, Rotorua Forest Conservation Region.

Situation and Altitude.—Situation: Six miles from Mamaku Railway-station. Altitude: About 2,000 ft. above sea-level.

General Topography.—Type: Plateau. Drainage: Good. Exposure: Fairly exposed. Prevailing wind: South-west.

Soil.—Formation: Rhyolite rock underlying. Soil: Pumice with light loam. Drainage: Good.

Climate.—Rain: About 60 in. per annum. Climate: Mild in summer, cold and bleak in winter. Unseasonable frosts.

Stand.—Type: Rimu-tawa type. Composition: 80 per cent. rimu and tawa, rimu varying from 50 to 30 per cent., and tawa from 30 to 50 per cent., with associated species including miro, matai, rata, rewarewa, hinau, and beech comprising the remaining 20 per cent. Density: Total merchantable stand about 12,500 ft. board measure per acre. Origin: Probably rich in taxads. Diameter development: Only few rimu-trees per acre with average diameter breast-high of about 40 in.; tawa-trees are more numerous, but merchantable specimens average only about 20 in. diameter breast-high. Regeneration: Rimu poor, tawa good.

Insignis-pine Pulping Timber.

Swanson, December, 1927.

Locality.—Section 14 and south part old Swanson Kauri-gum Reserve (Birdwood Settlement), Block XIII, Waitemata S.D., Auckland Forest Conservation Region.

Situation and Altitude.—Situation: One to two miles from Swanson Railway-station; nine miles west of Auckland City. Altitude: 150 ft.

Boundaries and Area.—Small stand 1½ acres, and scattered trees.

General Topography.—Rolling foothills of Waitakere Range. Drainage: Good to creeks, thence to upper Waitemata Harbour. Slope: Gentle to medium. Aspect: Westerly. Exposure: Moderately sheltered by hills. Prevailing winds: Westerly.

Soil.—Clay.

Climate.—Rain: About 45 in. per annum. Climate: Mild.

Forest-floor.—Litter: Pine-needles, 3 in. Humus: Fresh, shallow. Ground floor: Nil in plantation, grass and fern under scattered trees. Underbrush: Nil in plantation, manuka under scattered trees. Reproduction: Nil in plantation, manuka fairly plentiful in adjacent scrub and fern.

Stand.—Type: Insignis pine, large poles and tall trees. Composition: Plantation pure insignis; some *P. pinaster* with scattered trees. Origin: Plantation planted about thirty years ago; remainder self-sown. Density of crown cover (plantation): 95 per cent. Age: Plantation, thirty years; scattered trees, twelve to eighteen years. Diameter development: Plantation average, D.B.H., 18 in.; suppressed trees felled, 9 in.; scattered trees—average 11 in., one tree 24 in. Height development: Plantation average height, 90 ft.; suppressed trees felled, 60 ft.; scattered trees—average 50 ft., one tree 70 ft. Form of trees: Good trees tall, with little taper and small lateral branches. Condition: Dominant and co-dominant trees vigorous, one or two scattered trees fire-scorched, but only living trees were felled. History of stand: Plantation planted about 1897; this was the first thinning; scattered trees self-sown from adjacent pines. Merchantable condition of trees: Merchantable for sawing into box-timber, but owner of plantation is holding for a few years. Site class: 1.

APPENDIX II.—METHODS USED IN THE CHEMICAL ANALYSIS OF WOODS AND PULPS.

Sampling.

The logs, as received, were sawn into 4 ft. lengths and peeled. Two of these 4 ft. logs were selected at random from each species, sawn into 1 ft. lengths, and quartered longitudinally. Two boards, approximately ⅜ in. thick, representing each part of the log, were cut lengthwise from these quarters in much the same manner as wood is quarter-sawn. These small boards were then reduced to sawdust by means of a special type of circular saw, previously described by Schorger.* The sawdust was quartered and ground to pass a 60-mesh standard sieve. The portion remaining on an 80-mesh sieve was used for analysis; that passing through the 80-mesh sieve was discarded.

Cellulose.

Cross and Bevan† in 1880 found that ligno-celluloses when treated first with dilute NaOH solution, then with chlorine gas and dilute sodium-sulphite solution, yielded a white product resembling cotton cellulose. Schorger* showed that higher yields of cellulose were obtained by omitting the initial treatment of the wood with 1 per cent. sodium-hydroxide solution. In both the above methods the chlorination treatments are long, ranging from thirty minutes for the first chlorination to fifteen minutes for the last. Ritter‡ has shown that these chlorination periods may be shortened to three minutes for the first chlorination, and that even in this short period the same quantities of lignin and substances other than cellulose are removed. The cellulose thus isolated is in as pure a form as when treated with chlorine gas for the longer periods. Roe§ has described a method for the determination of the amount of chlorine absorbed by unbleached sulphite pulps. Dore‖ chlorinated his samples directly in the crucible, and devised a special apparatus for that purpose. By application of the principles of these latter methods to the modified methods of Schorger and of Ritter for cellulose

* A. W. Schorger, J. Ind. & Eng. Chem., 9 No. 6, 556 (1917).

† Cross and Bevan, J. Chem. Soc., 38, 666A (1880); Chemical News, 42, 77–91 (1880); J. Chem. Soc., 55, 199 (1889).

‡ G. J. Ritter, J. Ind. & Eng. Chem., 16, 947 (Sept., 1924).

§ R. B. Roe, J. Ind. & Eng. Chem., 16, 8, 808 (1924).

‖ W. H. Dore, J. Ind. & Eng. Chem., 12, 264 (1920).

estimation in wood and wood-pulps, it is possible to determine the amount of chlorine required for the isolation of the cellulose. The data thus obtained, especially in the case of pulps, furnishes a measure of their relative bleachability.

Method of Estimation.

Approximately 2 grammes of air-dry wood or pulp are weighed in a tared alundum crucible, placed in a weighing-bottle, and dried in the oven for two hours and a half at 105° C. The crucible is placed alongside the bottle during drying, after which it is again placed in the bottle, stoppered, cooled in a desiccator, and reweighed to obtain the weight of oven-dry material.

In the case of wood the crucible, with contents, are extracted three to four hours in a Soxhlet extractor with a mixture of 67 per cent. of benzene and 33 per cent. alcohol. This extraction may be dispensed with in the case of pulps. After evaporating the solvent the sawdust is thoroughly washed with hot water, using the suction-pump. The moist material is then transferred to a Jena glass crucible (size 35 c.c., No. 3, porosity 5 to 7), which is equipped with a fritted-glass bottom. Suction is applied first at the bottom of the crucible until the excess moisture is removed, and then at the top. This removes the water from the fritted-glass plate and evenly distributes the remaining moisture through the entire sample. The crucible is water-jacketed and connected between the gas burette and Hemphel gas-pipette of the Roe* apparatus by means of two rubber stoppers, through which passes a capillary glass tubing. A measured quantity of chlorine gas is passed from the burette up through the material in the crucible and over into the Hemphel gas-pipette as fast as possible. During the first chlorination samples of wood absorb approximately 230 c.c. of the chlorine gas at room-temperature and atmospheric pressure; this necessitates refilling the burette, which may be done quickly, as it is connected to a chlorine-tank with a three-way stop-cock. The first chlorination treatment requires from three to four minutes, after which the crucible is removed from the apparatus and the material washed with approximately 50 c.c. of distilled water, and successively with 50 c.c. of approximately 3-per-cent. SO_2 water, 50 c.c. water, then 50 c.c. of freshly prepared 2-per-cent. normal sodium-sulphite solution. The material is transferred to a 250 c.c. Pyrex beaker, using a pointed glass rod, the last traces of material being washed out of the crucible with 100 c.c. of a 2-per-cent. sodium-sulphite solution. The beaker is covered with a watch-glass and placed in a boiling-water bath for thirty minutes. The fibres are again transferred to the glass crucible and washed with about 250 c.c. of hot distilled water. The above procedure is never sufficient to remove all the lignin, so that the treatment with chlorine and subsequent treatments as outlined above are repeated until the fibres are practically a uniform white or show only a very faint tinge of pink upon addition of the sodium-sulphite solution. The second and following treatments with chlorine should not require more than two or three minutes.†

After all the lignin has been removed the fibrous residue is thoroughly washed in an alundum crucible (porosity 98) successively with hot water, dilute acetic acid, 500 c.c. hot water, 50 c.c. of 95-per-cent. alcohol, and finally with 50 c.c. of ether. It is then dried for two hours at 105° C., again placed in the original stoppered weighing-bottle, cooled in a desiccator, and weighed as cellulose.

CHLORINE-CONSUMPTION.

This value is a measure of the total chlorine gas required in the isolation of the cellulose, and in the case of pulps indicates their relative bleachabilities. The percentage of chlorine consumed is obtained by summing up all the values of the several chlorination treatments after correcting the results to 0° C. and 760 mm. pressure, taking into consideration the vapour-pressure of chlorine gas at the chlorination temperature over calcium-chloride‡ solution saturated with chlorine gas, using the following formula:—

$$Vo = \frac{V_t (P - a)}{760 (1 + 0{\cdot}00367t)}$$

where Vo = volume under standard conditions of temperature and pressure, a = vapour-pressure of chlorine gas over calcium-chloride solution saturated with chlorine gas, and t is the temperature of chlorination.

t° C.	A.	t° C.	760 (1 + 0·00367t).
24·5	17·3	24·5	828·36
25	18	25	829·76
26	19·4	26	832·57
27	20·8	27	835·40
28	22]	28	838·12
29	23·5	29	840·96
30	25	30	843·66
31	26·4	31	846·48
32	29	32	849·30
		33	852·04
		34	854·90
		35	857·67

The weight of 1 c.c. of chlorine gas at standard temperature and pressure = 0·0031675 grm.

$$\text{Percentage chlorine consumed} = \frac{Vo \times 0{\cdot}0031675 \times 100}{\text{Oven-dry weight of sample.}}$$

* R. B. Roe, *loc. cit.* The Roe apparatus consists of a water-jacketed gas-burette, a chlorination-chamber, and a Hemphel gas-pipette used as a reservoir.

† Prolonged-action chlorine gas, together with the hydrochloric acid formed in the secondary reactions, hydrolyzes the cellulose, gives low yields, and causes varying amounts of alpha cellulose.—Paper Trade J., 76, No. 8, 47 (22nd February, 1923).

‡ Calcium-chloride solution for gas-burette and Hemphel gas-pipette: Saturate a solution with calcium chloride at room temperature and bubble chlorine gas in until saturated and filter for use.

Alpha, Beta, and Gamma Cellulose.

The determination of alpha, beta, and gamma cellulose* in cellulose obtained from wood by the chlorination method or directly on pulps, is a measure of the resistance of the cellulose or pulp to the action of 17·5-per-cent. sodium-hydroxide solution, known as Mercer's solution. In cases where the alpha-cellulose content of a cellulose or pulp alone is desired, or when the alpha cellulose is not difficult to filter and wash, the gravimetric method may be used. However, when data on all three constituents is desired the work may be facilitated by using the volumetric method of Bray and Andrews.†

Gravimetric Method for Alpha Cellulose.

One gramme of oven-dry cellulose obtained by the above method, or of the sample of pulp, is weighed into a beaker, triturated with 25 c.c. of mercerizing liquid (17·5-per-cent. sodium-hydroxide solution)‡ until the mass is homogeneous, and allowed to stand for thirty minutes. The contents of the beaker are filtered by suction through either a tared alundum crucible (porosity R.A. 98), a Gooch crucible, or a fritted-glass Jena crucible (No. 3, porosity 5 to 7). After the insoluble cellulose or alpha cellulose is sucked practically dry, it is loosened with a glass rod, washed with 4-per-cent. sodium-hydroxide solution (50 c.c.), and then with cold distilled water (approximately 300 c.c.). The alpha cellulose is next treated with approximately 75 c.c., hot dilute (10 per cent.) acetic acid, again washed with hot distilled water (300 c.c.), dried at 105° C., cooled in a desiccator, and weighed as alpha cellulose.§

Lignin.

The lignin,‖ or non-carbohydrate content of wood-substance or pulp, is obtained by a modification of the method of Ost and Wilkening¶ employed in the hydrolysis of cellulose.

Approximately 2 grm. of air-dry wood (sawdust passed through a 60- and held on an 80-mesh wire sieve), or shredded pulp, are weighed into a tared alundum crucible (porosity R.A. 98). The crucible is dried in the oven for two hours at 105° C., cooled, and weighed in a stoppered weighing-bottle. It is then extracted with ether in a Soxhlet apparatus for three to four hours as described under the ether-soluble determination. In the case of pulps the extraction operation may be dispensed with, and the samples may be weighed and dried in weighing-bottles directly. The dried material is transferred from the crucibles to weighing-bottles, divided into fine particles, and treated with 40 c.c. of 72-per-cent.** (± 0·1 per cent.) sulphuric acid by weight, the strength of which has been previously determined by titration with a standard sodium-hydroxide solution. The hydrolysis is allowed to proceed for sixteen hours at room-temperature, with frequent stirring at the beginning of the operation. The resulting solution is transferred to a 2-litre Erlenmeyer flask and diluted to 1,570 c.c. with distilled water which makes a concentration of H_2SO_4 exactly 3 per cent., covered with a watch-glass, and boiled for two hours, adding distilled water from time to time to keep the volume constant. The suspended particles of lignin are then filtered on the tared alundum crucible used in the beginning of the determination, washed thoroughly with hot distilled water (500 c.c.), dried for two hours and a half at 105° C., cooled in a desiccator, and weighed as lignin.

Ether-soluble Material.

This determination is a measure of the waxes, fats, resins, &c. Approximately 2 grm. of the sawdust or shredded pulp are weighed in a tared alundum crucible (porosity R.A. 98) and stoppered weighing-bottle. The crucible containing the material is placed alongside the bottle and heated for two hours or to constant weight at 105° C. The crucible is placed in the stoppered bottle, cooled in a desiccator over concentrated H_2SO_4, and weighed as oven-dry material. The crucible is placed in a Soxhlet apparatus, and the sawdust is extracted with ethyl ether for three to four hours, dried at 105° C., cooled, and weighed. The extracted sawdust or pulp may be used for the lignin determination. The amount of material extracted may be determined either by weighing the residue after evaporation of the solvent, or by determining the loss in weight of sawdust due to extraction. The latter procedure was followed in these tests.

Alcohol-benzene - soluble Material.

In addition to the substances removed by ethyl ether, possibly some of the so-called wood-gums are dissolved by extraction with a mixture of 67 per cent. benzene and 33 per cent. alcohol. The

* Cross and Bevan, "Researches on Cellulose," III (1905–10), 23; "Papermaking" (1916), 97. Schwalbe, "Chemie der Cellulose" (1911), 637; Jentjen Zeit Kunstoffe, 1, 165 (1911); Mag. Jahr., 57, 426 (1911); Zts. Aug. Chem., 24, 1341 (1911). Opfermann, "Die Chemische Untersuchung Pflanzliche Rohstoffe und der daraus abschiedenen Zellstoffe," translated by C. J. West), Paper 8, 19 (1921). Bronnert, Die Chem. Under ect. Berlin (1920). Schwalbe and Sieber, "Die Chemische Betriebs-Kintrolle in der Zellstoffe and Papier Industrie," 151. Bray and Andrews, J. Ind. & Eng. Chem., 15, No. 4, 377 (April, 1923); Cellulose Chemie 4, 115 (1923); Zelstoff und Papier, 3, 5, 109 (May, 1923); Papermakers' Monthly J., London, 61, 6 (1923). Sherrard and Blanco, J. Ind. & Eng. Chem., 14, 64 (1922). Th. Beutzen, Paper Trade J. 83, No. 22, 48 (1926).

† Bray and Andrews, *loc. cit.*

‡ Add 825 c.c. of distilled water to 175 grm. of C.P. sodium hydroxide; cool and titrate a sample with normal sulphuric acid to methyl orange and phenolphthalein end points. In this manner the solution may be adjusted so that the actual NaOH content is 17·5 per cent.

§ In all cases the crucibles were placed in stoppered weighing-bottles when cooled in a desiccator containing H_2SO_4 or when weighed.

‖ Klason, Paper Industry, 4, 262 (May, 1922); *ibid.*

¶ Cross and Bevan, "Researches on Cellulose," III, 39 (1905–10); Chemiker Zeit., 461 (1910).

** Becker, Papier-fabr., xvii, 1325. P. Klason, Svenk. Pap. Tid., 129 (1916).

procedure in this determination is the same as that described in the preparation of the sample for the estimation of cellulose.

The amount of material extracted is determined by weighing the residue remaining after evaporation of the solvent in the air-oven at 105° C.

One-per-cent. Alkali-soluble Material.

Two grammes of air-dry sawdust (through 60- and on 80-mesh sieve), or shredded pulp, are weighed in a weighing-bottle, dried two hours and a half at 105° C., and again weighed. In the case of woods containing volatile oils it is necessary to determine the moisture separately by the Xylol method, and to use air-dry wood only for this determination. The sample is placed in a 250 c.c. beaker and 100 c.c. of 1-per-cent. sodium-hydroxide solution* added. The beaker is covered with a watch-glass and placed in boiling distilled water for exactly one hour, the height of the water in the bath being maintained level with the solution in the beaker by means of a constant level flask. The contents of the beaker are occasionally stirred with a glass rod. The undissolved material is then collected in a tared alundum crucible, washed thoroughly with hot distilled water, dilute (10 per cent.) acetic acid, and water successively, dried in an air-oven at 105° C., cooled in a dessicator, and weighed. The difference is the portion soluble in alkali.

Alkali-soluble corrected for Water-soluble or Ether-soluble.

This value is obtained by subtracting the percentage of hot water or of ether-soluble material from that of the 1-per-cent. alkali-soluble material.

Pentosans.

The estimation of the pentosans—namely, xylan and araban—occurring in wood is based on the quantitative determination of furfural formed by the action of hydrochloric acid on the material.

Two grammes of oven-dry wood or pulp are placed in a 250 c.c. flask† provided with a separatory funnel, and attached to a condenser ; 100 c.c. of 12-per-cent. hydrochloric acid (sp. gr. 1·06) are added, and the contents of the flask are distilled at the rate of 30 c.c. in ten minutes. The distillate is passed through a small filter before entering the receiver. As soon as 30 c.c. of the distillate are collected, 30 c.c. of the hydrochloric acid are added to the distillation-flask, and the distillation is continued in this manner until 360 c.c. of distillate are collected. To the total distillate are added 40 c.c. of filtered phloroglucine solution that has been prepared at least a week previously by heating 11 grm. of cp. phloroglucine in a beaker with 300 c.c. of 12-per-cent. hydrochloric acid, and, after solution has taken place, making up to 1,500 c.c. with 12-per-cent. hydrochloric-acid solution.

After addition of the phloroglucine the solution soon turns greenish-black. After standing sixteen hours‡ the furfural phloroglucide will have settled to the bottom of the beaker. If a drop of the supernatent liquid gives a pink colour with aniline acetate paper§ the precipitation of the furfural is incomplete. A further amount of phloroglucine is then added and the beaker allowed to stand overnight as before. 40 c.c. of the phloroglucine solution is usually sufficient.

The furfural phloroglucide is filtered, using a tared Gooch crucible having a thick asbestos mat, and washed with exactly 150 c.c. of distilled water. The crucible is then dried for three hours at 105° C., cooled over sulphuric acid, and weighed in a weighing-bottle. From the weight of the furfural phloroglucide so obtained the amount of total pentosans in the wood is calculated either from the tables of Krober and Tollens‖, which has a range for weights of phloroglucide between 0·030 grm. and 0·300 grm., or from the following formulæ¶ :—

For weight of phloroglucide a under 0·030 grm : Pentosans $= (a + 0{\cdot}0052) \times 0{\cdot}8949$.

For weight of phloroglucide a ranging between 0·030 grm. and 0·300 grm. : Pentosans $= (a + 0{\cdot}0052) \times 0{\cdot}8866$.

For weight of phloroglucide a exceeding 0·300 grm. : Pentosans $= (a + 0{\cdot}0052) \times 0{\cdot}8824$.

Pentosans in the Cellulose.

The method of estimation of the pentosans remaining in the isolated cellulose is the same as that described above for the total pentosans.

Pentosans not in the Cellulose.

These bodies disappear with the lignin during the process of cellulose isolation. This value is obtained by subtracting the value for the pentosans in the cellulose from that of the total pentosan content of the wood after all results have been calculated to the oven-dry weight basis of the wood.

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* The strength of the sodium-hydroxide solution is previously determined by titration with standard sulphuric acid, using phenolphthalein and methyl orange as indicators, so that correction for carbonates may be made in adjusting the solution to exactly 1 per cent. NaOH.

† The flasks are easily made by fusing an outlet-tube and separating-funnel to the tubes of the ordinary all-glass wash-bottles.

‡ Boddener and Tollens (J. Landw., 58, 232–7) have found that if the distillate containing the phloroglucine is heated to 80° to 95° C. and then allowed to stand for two hours the precipitate of furfural phloroglucide may be filtered off without waiting for the solution to stand overnight. The latter method, however, is preferable in order to use the tables for calculation.

§ The aniline-acetate paper is conveniently prepared by dipping strips of filter-paper into aniline acetate. The latter is prepared by adding acetic acid to water, drop by drop, to a mixture of equal parts of aniline and water until a clear solution is obtained.

‖ Abderhalden's "Handbuch der Biochemischen Arbeitsmethoden," vol. ii, 137, 154.

¶ Browne, P., "Handbook of Sugar Analysis," 452.

APPENDIX III.—LABORATORY EQUIPMENT FOR PULP AND PAPER MAKING.

Chip-screening.

For screening chips on a semi-commercial scale an ordinary contractor's sand-screen is used. The area of the screen was 21 in. by 42 in., made of heavy wire of $\frac{5}{16}$ in. mesh. The chips are raked by hand over the screen set in a horizontal position, allowing the sawdust and dirt to fall through. The large pieces and slivers are picked out. Common galvanized-iron garbage-cans holding approximately 50 lb. of chips are used for retaining the chips. Bone-dry weight determinations are made from average samples of the chips taken as they are raked into each can, and the bone-dry weights are computed using the bone-dry factor. All calculations of chemical and yield are based on the bone-dry weight of the chips.

Alkaline and Semi-chemical Digester and Equipment.

The digester used is of a tumbling type, well lagged, and of a size capable of holding 100 lb. of oven-dry spruce chips. The digester is constructed in two sections, the lower section having a steam jacket which was used to reduce excessive condensation during the steaming rise period. The digester is equipped with a cooling-coil in the relief-line for liquor-sampling. All connections to the digester pass through the trunnions. The digester is equipped with a thermometer and a pressure-gauge, and is revolved, by means of motor, at a speed of one revolution every six minutes. A 2 in. blow-line is used for blowing.

The cooking-liquor tanks are located above the digester, so that the liquor can be run into it by gravity if so desired.

The digester blow-pit consists of a wooden tank 4 ft. in diameter and 7 ft. in height. The pit is fitted with a false bottom made of Monel-metal plate perforated with holes $\frac{3}{32}$ in. in diameter. The blow-line from the digester enters the blow-pit about 2 ft. above the false bottom. At the point of entering, it is tangent to the sides, so that on blowing the digester the centrifugal motion given to the contents completely separates the pulp from the steam, which can then escape through an opening on the middle of the top of the blow-pit without carrying away the pulp. The pulp can be washed with water from a hose or a spray, both of which are attached to the pit. The pit is provided with a drain controlled by a quick-opening valve. The waste liquor is filtered through a Fourdrinier wire before going to the drain.

Sulphite Digester and Equipment.

This digester is of the stationary type. It is made of steel, and lined with an acid-resistant earthenware lining cemented to the steel shell by a litharge and glycerine cement. The capacity is 100 lb. of oven-dry chips. This digester is also built in two sections, the lower section containing an indirect-steam coil made of lead, and used for auxiliary heating of the digester during cooking, in order to minimize condensation of the direct steam, (which is admitted at the bottom of the digester). The indirect steam may also be used alone in making so-called Mitscherlich sulphite cooks. The digester is equipped with a bronze cover containing a pressure-gauge and relief-lines, and temperatures are measured by a mercury thermometer and by a recording thermometer placed at the centre and top of the digester respectively. A side relief is provided in addition to the top relief in the cover, and a recording pressure-gauge is used to measure steam-pressures.

The liquor-tanks are located on the floor above the digester, and are two in number. The acid is made by passing SO_2 gas (from cylinders) into a suspension of calcium hydrate. The relief gases are also passed into the liquor-tanks to assist in building up the liquor.

The blow-pit is the same as used for alkaline cooks, excepting that an acid-resistant earthenware bottom is provided, perforated to permit easy drainage of the pulp. (See Plate 11).

Hydraulic Press.

The hydraulic press used for pressing the pulp from the pit preparatory to sampling is made to accommodate a basket 18 in. in diameter and 15 in. deep. The basket is made of 12-gauge iron, with $\frac{3}{32}$ in. perforations. A 10 oz. duck bag, 18 in. in diameter and 18 in. high, is fitted inside the basket, and the pulp is loaded into it. The bag answers two purposes—it protects the pulp from rust-stains, and prevents the loss of fibre.

Pulp-screen and Wet Machine.

The pulp-screen used was a four-plate diaphragm screen. The plates have 0·020 cut slits. The screen is connected to a stock-chest and a 20 in. wet machine. The crude pulp is pumped from the chest to the screen, run over the wet machine, and collected in a basket.

Marx Beater.

The beater is of the single-roll type, rated at 50 lb. capacity, having a roll 24 in. in diameter by 18 in. face and a bed-plate of the elbow type. The roll is fitted with steel fly-bars each $\frac{3}{8}$ in. thick. The bed-plate is fitted with steel bevelled fly-bars each $\frac{1}{3}\frac{5}{2}$ in. thick. The roll has a device to counter-balance its weight. The tub of the beater is of concrete construction, with a trough of special cross-section, designed for rapid circulation of the stock. The beater is driven at 300–310 r.p.m., corresponding to a peripheral speed of 1,950 ft. to 2,000 ft. per minute. (See Plate 12.)

Paper-machine.

The experimental machine is practically a duplicate of the commercial Fourdrinier machine, consisting of two presses, nine driers, and a stack of calenders. The sheet obtainable is of 12 in. trim. The paper is wound on a reel, and can be obtained calendered or uncalendered. The paper taken from the reel is cut into sizes suitable for both records and paper tests. (See Plate 14.)

Rod Mill.

The experimental rod mill is 3 ft. in diameter, 5 ft. long (inside measure), and rubber-lined. The charge of steel rods consists of fifty-two rods varying from $1\frac{1}{2}$ in. to $2\frac{1}{2}$ in. in diameter, 4 ft. 10 in. long, and weighs 3,720 lb. The beating action results from tumbling of the rods by the rotation of the mill. The mill is driven by a 15 horse-power motor at a speed of 28 r.p.m. The mill in these experiments was operated in batch runs. Commercially, however, the mill is operated continually. (See Plate 13.)

Yield Determinations.

In the case in which the pulp is screened and run over the wet machine, the screenings are collected, dried in the oven, and weighed. The screened pulp is thickened and run into a sheet on the wet machine, the total quantity being weighed. Samples of the sheet are obtained throughout the wet-machine run and these combined (average) samples oven-dried and weighed. The yield may be calculated from these data.

In the case of semi-chemical or very raw pulps the pulp is washed thoroughly and drained, then pressed in the hydraulic press. It is opened up in a shredder, weighed, and sampled for moisture. The oven-dry weight and yield can be calculated from moisture-determination figures.

APPENDIX IV.—COLOUR-ANALYSIS BY MEANS OF THE IVES TINT-PHOTOMETER.

General.

The Ives tint-photometer is used for a numerical evaluation of the colour of pulps and papers. This instrument, and its use for this purpose, has been described in detail in the technical papers of the Technical Association of the Pulp and Paper Industry, page 123, Series X, 1927. It measures the amount of light of certain wave-lengths as reflected from the sample by comparison with a standard white surface. Readings are taken only in the red, green, and purple-blue portions of the spectrum, as these three colours are sufficient to characterize the colour of the sample. The results are definite and reproducible, and may be interpreted in terms of ordinary visual impressions.

Apparatus.

The Ives photometer consists essentially of a source of white light, a standard white surface, a clamp for holding the sample for analysis, an optical system for comparing the intensity of light diffusely reflected from standard and sample, and three colour-filters. The light-source is a standard daylight lamp. The standard white is a block of magnesia. The sample, which must be of the same size and shape as the standard surface, is held in a special clamp which ensures a smooth, level surface, and in the same plane as the standard. It must be of sufficient thickness to prevent any transmission of light from the sample-holder through the sample. The colour-filters, which have been carefully standardized, transmit pure light of the following wave-lengths (in millimicrons): 638 (red), 535 (green), and 475 (purple-blue). Light from the two surfaces enters the instrument through slits fitted with sliding shutters. The shutter admitting reflected light from the standard is operated by a lever, which works over a scale graduated in 100 units; the other is operated by a micrometer screw which is set permanently. The field viewed in the eyepiece is divided, half being illuminated by light from the standard, the other half by light from the sample.

Operation.

The instrument is set in adjustment by matching two standard surfaces and regulating the set-screw of the object-slit so that the match is perfect when the standard slit is open to 100 on the scale. A sample and the standard are then placed in their proper positions, and the lever moved until the intensity of illumination is the same for both halves of the field. The scale-reading then gives the parts of light reflected by the sample in terms of the standard white. Readings are made with each of the three colour-filters. Three or more readings are made with each filter, depending upon the degree of accuracy desired. The setting is a matter of matching intensity only, not tint, and the method is purely objective, thus avoiding to a considerable extent errors due to individual differences in colour sense.

Interpretation of Results.

Conversion of the results of an analysis into terms of visual impressions will be briefly explained and illustrated. It is based upon the theory of colour and the special construction of the instrument.

The three filters transmit light of the so-called primary additive colours. When light of these three colours is mixed in proper proportions, white light results. Since the readings are referred to a white surface as a standard, equal parts of red (R), green (G), and purple-blue (B) as measured would give white light. Furthermore, equal parts of two primary colours give secondary colours, and these may be still further combined, if necessary. Thus red and purple-blue give magenta; green and purple-blue, peacock-blue; red and green, yellow; yellow and red, orange. These are all the combinations commonly needed for analysis. With a paper in which all the readings are the same (say, R, 70; G, 70; B, 70) we can say that the paper contains 70 per cent. white, and 100 — 70 = 30 per cent. theoretical black; it is then a rather light grey. In a paper giving different readings for the three colours another fact is needed. The total brightness or luminosity of white light is due mainly to the green part of the spectrum. Hence in determining the real luminosity of a coloured sample it is necessary to multiply the percentage of each colour present by an appropriate factor to determine the proportion of the total luminosity supplied by each, and then add these products. This sum, the luminosity, subtracted from 100, gives the theoretical percentage of black in the colour. The proportional factors for the three primary colours have been determined, and are as follows: 0·19 for red, 0·71 for green, and 0·10 for purple-blue. To find the partial luminosity due to any secondary colour it is simply necessary to multiply the amount of each primary colour in it by the proper luminosity factor and add the results. To illustrate the treatment with a coloured paper, we may take one with the following readings:—

	Red.	Green.	Blue.		
	85	75	60		
Deduct	60 +	60 +	60		= 60 white.
Leaving	25	15	0		
and	15 +	15		= 15 yellow	
Leaving	10	0		so finally	
	10			+ 10	= 10 orange
	0			5	= 5 yellow.

when all the primary colours have been used.

To determine the luminosity:—

$60 \times 0{\cdot}19 + 60 \times 0{\cdot}71 + 60 \times 0{\cdot}10 = 60$ from white

$20 \times 0{\cdot}19 + 10 \times 0{\cdot}71 = 10{\cdot}9$ from orange

(since orange contains a double proportion of red)

$5 \times 0{\cdot}19 + 5 \times 0{\cdot}71 = 4{\cdot}5$ from yellow

and as a check,—

$85 \times 0{\cdot}19 + 75 \times 0{\cdot}71 + 60 \times 0{\cdot}10 = 75{\cdot}4$ total luminosity

and from the last value we find 100 — 75·4 = 24·6 theoretical black.

Thus our sample has 60 parts white, a primary hue of orange, and a secondary hue of yellow (primary and secondary on the basis of actual amounts present), with luminosities of 60, 10·9, and 4·5; this is a rather strong tint of orange. The black serves to darken or deaden the colours.

In this way a rough mental image of colour can readily be formed, even without computation. The lowest of the three readings obtained determines the amount of white; the highest, the primary hue; and the relative values show the strength or saturation of that hue.

APPENDIX V.—METHODS OF ANALYSIS OF SULPHITE ACID AND LIQUOR.

Method of Analysis of Sulphite Acid and Liquor.

Total SO_2.

A 2 c.c. sample of acid is diluted to 150 c.c. with H_2O in a 500 c.c. Erlenmeyer flask. Starch indicator is added, and the sample is titrated with N/16 iodine solution. 1 c.c. N/16 iodine is equivalent to $\frac{1}{10}$ per cent. total SO_2.

Free SO_2.

Two cubic centimetres of the acid is diluted to 150 c.c. in an Erlenmeyer flask. Phenolphthalein is added, and the solution is titrated with 1 c.c. N/16 NaOH solution to a faint permanent pink. 1 cc. N/16 NaOH is equivalent to $\frac{1}{10}$ per cent. free SO_2.

Combined SO_2.

The per cent. SO_2 present as combined SO_2 (in the form of $CaSO_3$) is obtained by the difference between the per cent. total and per cent. free SO_2.

Sander Method for Analysis of Acid and Liquor.

A 2 c.c sample is diluted to 75 c.c. with water in a 500 c.c. Erlenmeyer flask. Methyl orange or bromphenol blue is added, and the solution titrated to neutrality with N/8 NaOH solution. An excess of saturated mercuric-chloride solution is added, and the solution again titrated to neutrality.

Total SO_2.

The second titration × 0·4 gives the per cent. total SO_2.

Combined SO_2.

The difference between the second and first titration × 0·2 gives the per cent. combined SO_2.

Free SO_2.

This is obtained by difference between the per cent. total and per cent. combined SO_2.

Loosely combined SO_2.

A portion of the SO_2 combined with the dissolved ligneous materials in sulphite liquor is but very loosely combined, presumably with aldehyde groups, and may be hydrolyzed off with NaOH. This is the basis of the quantitative estimation of SO_2 in this form. The method follows: After the titration of sulphite liquor for total SO_2 by iodine, the blue colour is destroyed by a drop of N/16 $Na_2S_2O_3$ (sodium thiosulphate). An excess, 10 c.c. of 15-per-cent. NaOH is added, and the solution allowed to stand for twenty minutes, the solution then being made slightly acid with HCl, and again titrated with N/16 iodine. This titration gives the per cent. SO_2 present as loosely combined SO_2, each cubic centimetre of iodine being equivalent to 0·1 per cent. SO_2.

DETERMINATION OF TOTAL SO_2.

A method for the determination of SO_2 in all forms, or the total SO_2 content of sulphite cooking-liquor, as worked out by Miller and Swanson, Forest Products Laboratory, is as follows: A 2 c.c. sample of the liquor is run into a 1 c.c. portion of 15-per-cent. NaOH in a 35 mm. porcelain crucible. This is then absorbed in about 4 grm. Eschka mixture, and the crucible and contents dried at 105° C. The crucible is then placed in a Shimer crucible and heated in a stream of oxygen, at a dull red for one hour. The oxygen and sulphur gases pass through a ret-hot zone in the silica tube attached to the Shimer crucible, and out through an outlet-tube into a Drexel flask containing 5 c.c. of 15-per-cent. NaOH and 10 c.c. saturated bromine water in 100 c.c. distilled water. After the combustion the porcelain crucible and contents are placed in a 600 c.c. beaker and allowed to cool. Then the contents of the Drexel flask are added, the flask being washed with hot water three times, the washings being added to the beaker-contents. The beaker is placed on a hotplate, and allowed to digest for half an hour. Then the contents are filtered into a 600 c.c. beaker, the residue and crucible being washed six times with hot water. The filtrate, about 400 c.c., is made slightly acid with HCl, the excess bromine boiled off, and 10 c.c. of 10-per-cent. $BaCl_2$ solution pipetted into the solution. The $BaSO_4$, precipitated, after digestion for one hour on a water bath, is separated by filtration into a weighed Gooch. After washing the precipitate several times with hot water the crucible and contents are dried and ignited, cooled, and weighed. From the weight of $BaSO_4$ obtained, the per cent. SO_2 is found thus:—

$$\text{Wt. } BaSO_4 \times 0{\cdot}27443 \times 50 = \text{per cent. } SO_2.$$

or

$$\text{Wt. } BaSO_4 \times 0{\cdot}1372 = \text{per cent. } SO_2.$$

SOLUBLE SULPHATES IN SULPHITE LIQUOR.

In 250 c.c. Soxhlet flasks are placed about 55 c.c. of distilled water and 25 c.c. of 25-per-cent. hydrochloric acid (approximately equivalent to 16 c.c. of ordinary concentrated acid). The flasks are clamped in position under the condensers, and 25 c.c. of waste sulphite liquor, or raw sulphite acid, as the case may be, are pipetted into the two Soxhlet flasks, the second being corked immediately and connected to the generator. The condenser-stoppers are coated with collodion in order to ensure tight connections. The flasks containing the iodine solution and standard sodium thiosulphate are connected to the condenser-outlet. Carbon dioxide is then passed through for about five minutes until all the air is displaced from the apparatus, thus obtaining an atmosphere of carbon dioxide in which very little or no oxidation of SO_2 to SO_3 takes place. At this stage the solutions in the Soxhlet flasks are slowly heated until they boil gently, and the boiling is continued until the experiment is finished. Any liquor vapourizing during heating is condensed back into the flask, thus maintaining almost constant concentration of the solution. The SO_2 evolved is swept out by the carbon dioxide, is cooled on escaping, and is finally absorbed in the iodine solution. At the end of the experiment the excess iodine is titrated with sodium thiosulphate of equivalent strength, using starch solution as an indicator. From the amount of iodine reduced by the evolved SO_2 the quantity of the latter is calculated. The end point of the reaction occurs when the iodine solution is no longer decolorized, or, better still, by bubbling the escaping gas through a very weak iodine solution in a pill-plate in case the amount of SO_2 given off is not being determined. Ordinarily it takes from forty-five minutes to one hour to completely remove the SO_2, this time varying according to the amount of SO_2 present, the rate at which the CO_2 is passed through the solution, and also according to the rate of heating of the latter. When all the SO_2 is expelled the Soxhlet flasks are disconnected, and the sulphate-free precipitate formed is filtered off. The filter is thoroughly washed with hot water, and the clear filtrate is neutralized with NH_4OH and made slightly acid with HCl. It is diluted to approximately 400 c.c., brought to a boil, and 10 c.c. of N/2 $BaCl_2$ are very slowly added. Boiling is continued until the $BaSO_4$ precipitated becomes granular, and is then kept hot for from four to six hours longer. The $BaSO_4$ is then filtered and thoroughly washed with hot water until free from chloride. It is carefully ignited, allowed to cool, and then weighed.

LIME AS CaO IN SULPHITE LIQUOR.

A 10 c.c. sample of the liquor* is pipetted into a 250 c.c. beaker, and is treated with 5 c.c. concentrated H_2SO_4 and 10 c.c. concentrated HNO_3, and heated until sulphur trioxide (white) fumes appear. If the organic matter is not destroyed, more HNO_3 is added, and heat applied, until the solution appears clear. Then the solution is allowed to cool, is diluted to 150 c.c. and treated with

* Raw or finished acid may be treated as follows: Heat 10 c.c. in 250 c.c. beaker as above, but add 10 c.c. concentrated HCl instead of HNO_3 and H_2SO_4; boil to expel SO_2, and proceed as above.

an excess (50–60 c.c.) of 3-per-cent. solution of oxalic acid. The solution is heated and made ammoniacal. The precipitate formed is separated by filtration, and then washed a number of times with hot water. The precipitate and filter-paper are placed in the original beaker, 150 c.c. water and 10 c.c. of 1 : 1 H_2SO_4 added. The whole is heated to 90° C., and titrated with N/10 potassium permanganate.

Calculations :—

1 c.c. KM_nO_4 = 0·00028 grm. CaO.
Per cent. CaO = 10 × wt. CaO in grammes.
Per cent. SO_2 = combined as $CaSO_3$ with CaO = per cent. CaO × 1·14.

Standard Solutions.

N/10 Hydrochloric Acid.

Dilute 9 c.c. concentrated hydrochloric acid (sp. gr. 1·18, 1·19, 35–36 per cent. HCl) to 1 litre. Standardize as follows: Weigh accurately two 0·2–0·25 grm. samples of pure dry sodium carbonate into 400 c.c. beakers. Dissolve in water; titrate with acid to be standardized, using methyl-orange indicator. 1 c.c. N/10 HCl is equivalent to 0·005304 grm. sodium carbonate.

N/8 Sodium Hydroxide.

Weight 5·2 grm. commercial caustic soda, dissolve, and dilute to 1 litre. Standardize against N/10 hydrochloric acid, using methyl-orange indicator. Reduce the N/10 hydrochloric acid used to N/8 basis by multiplying the HCl titration by 0·8, and calculate the strength of the sodium hydroxide.

N/10 Potassium Permanganate.

Dissolve 3·2 grm. potassium permanganate in 200 c.c. warm water in a beaker. When in solution, cool and transfer to a litre flask and make up to volume. Allow to stand for one week. Filter through asbestos to remove manganese dioxide. Standardize as follows: In a 400 c.c. beaker dissolve 0·25–0·30 grm. pure dry sodium oxalate weighed accurately in 200–250 c.c. hot water (80°–90°); add 10 c.c. of 1 : 4 H_2SO_4; titrate with potassium-permanganate solution, stirring the liquid vigorously and continuously. The KM_nO_4 must not be added more rapidly than 10–15 c.c. per minute. The last cubic centimetre should be added dropwise, allowing each drop to decolorize before adding the next. One-tenth gramme of sodium oxalate is equivalent to 14·91 c.c. N/10 KM_nO_4.

N/16 Iodine.

Dissolve 7·94 grm., weighed roughly, in a litre flask containing a solution of 12–14 grm. potassium iodide in 25 c.c. water. The flask is closed and shaken until the iodine is completely dissolved, then the solution is made up to the mark.

Optional Method (F.P.L.).

Stock solution: Dissolve 550 grm. iodine in a solution of 950 grm. KI in 500 c.c. water. Dilute to 2 litres when all dissolved. Standard iodine: Dilute 200 c.c. of stock solution to 7 litres. This makes a N/16 solution very closely. Standardize as follows: The iodine solution may be standardized directly against either N/10 sodium thiosulphate or sodium arsenite.

N/10 Sodium Arsenite.

Weigh 4·95 grm. pure dry arsenious oxide into a 400 c.c. beaker containing 10 grm. pure sodium bicarbonate in 200 c.c. water. Boil until completely dissolved, add 10 grm. sodium bicarbonate, cool and dilute to 1 litre. If pure arsenious oxide is used, this may be considered accurately tenth normal. Or it may be standardized against accurately standardized iodine.

Optional Solution (F.P.L.).

Weigh accurately 4·95 grm. pure resublimed arsenious oxide, dissolve by warming gently in 400 c.c. beaker in 150 c.c. water and 15 c.c. concentrated H_2SO_4, cool, and dilute to 1 litre. To use, run acid into a saturated solution of sodium bicarbonate, and run solution to be standardized (iodine) into this solution.

N/10 Sodium Thiosulphate.

Dissolve 24·83 grm. pure crystallized sodium thiosulphate ($5H_2O$) in water which has been completely freed from air by boiling; the solution is diluted to 1 litre with cold air-free water. Allow to stand one week before standardizing. Standardize as follows: Into an Erlenmeyer flask containing 100–150 c.c. water, run 25–40 c.c. accurately N/10 potassium permanganate. Add an excess of potassium iodide, " acidify " with 25 c.c. acetic acid (25 c.c.), and titrate the liberated iodine with sodium-thiosulphate solution. Determine normality by comparison with potassium permanganate.

Indicators.

Methyl Orange.—Dissolve 1 grm. methyl orange in water and dilute to 1 litre.

Tetrabromophenol Sulphonphthalein (Bromophenol-blue).—Dissolve ½ grm. in 100 c.c. of 95-per-cent. alcohol. Use two to three drops.

Phenolphthalein.—Dissolve 1 grm. phenolphthalein in 100 c.c. 95-per-cent. alcohol.

Starch Indicator.—Make a paste of 5 grm. soluble starch with cold water; add to a litre of boiling water; boil two to three minutes; add 8 c.c. of a 10-per-cent. solution of potassium iodide saturated with mercuric iodide.

APPENDIX VI.—METHODS FOR DETERMINATION OF BLEACHABILITY OF PULPS.

General.

The method consists of bleaching several samples of the pulp under standard conditions with varying quantities or ratios of bleaching agent. The bleach-consumption of the sample most nearly matching a previously selected standard white is taken as the bleach-requirement or bleachability of the pulp.

Sampling.

Any method is suitable which ensures an average representative pulp sample.

Moisture Determination.

The moisture content can be determined by drying a weighed sample of the pulp either by use of an electrically heated centrifuge, such as the Williams, or by making a machine sheet and rapidly drying same on a steam-plate, followed by several minutes in an electric oven.

Analytical Sample.

The equivalent of 25 grm. to 30 grm. oven-dry pulp should be used for each determination. It should be screened to remove shives, lumps, &c.

Analysis of Bleach Liquor.

Mohr's modification of Penot's method is used. The available chlorine is determined by adding N/5 sodium arsenite to a bleach-liquor sample until all bleach is neutralized, as indicated by starch-iodine solution, the end point being accurately determined by back titration with iodine. The available chlorine can then be calculated by use of the following formula :—

$$\frac{\text{No. cc. of N/5 } Na_3AsO_3}{\text{No. c.c. in sample}} \times 2{\cdot}028 = \text{per cent. by weight of 35 per cent. bleaching-powder in the liquid.}$$

Bleaching.

The wet equivalent of 30 grm. oven-dry pulp is placed in a glass battery jar and mixed with sufficient water to give a consistence of about two per cent. Several such samples are prepared and different bleach ratios employed. The jars are placed in a water bath heated to 105° F. and the pulp agitated mechanically. The quantity of bleach liquor necessary to give the desired bleach ratio is added to each and the bleaching continued until all available or bleaching chlorine has been consumed by the pulp, as shown by a starch-iodine test. The quantity of bleach liquor required to produce a given bleach-ratio may be calculated by means of the following formula :—

$$\frac{\text{Grm. oven-dry pulp}}{\text{Per cent. standard bleaching-powder in liquor.}} \times \text{per cent. bleach ratio} = \text{amount of liquor (by weight).}$$

Washing.

After the bleach is exhausted, the pulps are washed well with water, made into hand or machine sheets, and dried.

Colour.

The bleach-requirement or degree of bleaching is measured by comparison of the bleached sheets with the standard, the bleach ratio of the sample matching most nearly being selected as the proper ratio to use on the pulp. If more accuracy is desired the colour can be measured with a photometer or spectrometer.

APPENDIX VII.—BALL-MILL METHOD OF DETERMINING MAXIMUM STRENGTH OF PULPS.

The Ball Mill.

The ball mill used at the Forest Products Laboratory is a double domestic-jar mill listed as 4 gallon capacity, made by the Abbe Engineering Co., New York City. It consists of two porcelain jars, each approximately 15 in. in length by 12 in. in diameter (outside measure), and 1 in. thick. Each jar is covered by a wrought-iron jacket. The volume of each is approximately 16,000 c.c. A thick porcelain cover fitted with a rubber gasket, and held in place by a screw clamp, fits tightly over the open end, making a watertight compartment.

The Pebbles.

The pebbles used are of a good quartz and granite formation, as nearly round as it is possible to find them, and approximately 25 mm. in diameter. Approximately 5,000 grm. of pebbles, displacing 1,780 c.c. of water at 22° C., are used in each mill. The charge is checked after each 15,000 revolutions of the mill, and new pebbles are added to replace the weight and volume lost due to wearing away. From 2 to 3 grm. are lost between each inspection.

Preparation of the Pulp.

Approximately 600 grm. of air-dry pulp are needed for each run. The pulp is first run through a coarse screen (No. 18 or 20). When the pulp is in a dry condition it will screen much faster if soaked in warm water for a short time before screening. The screened pulp is caught in small "box screens" and put in a coarse cloth bag. As much water as possible is pressed out in a wine-press. The pressed pulp is shredded, thoroughly mixed, and a representative moisture sample taken. The rest of the pulp is packed in one or two battery - jars and covered tightly to prevent change in moisture content. The moisture sample should be left in the oven overnight to ensure complete drying.

After the percentage of moisture in the pulp has been determined, an amount equivalent to 100 grm. of air-dry pulp is weighed out for each batch and placed in a battery-jar of 3-litre capacity. 2,000 c.c. of filtered tap-water, 22° to 25° C., is added to each jar, allowance being made for the moisture in the pulp, and the mixture kneaded with the fingers to ensure thorough breaking of all lumps. Usually five such batches are enough, although six or seven are sometimes necessary, depending upon the time required to reach a maximum bursting test.

Preparation of the Ball Mill.

If the room-temperature is greater than 25° C. or less than 20° C. it is advisable to run the mill a short time containing the stones and about 3 litres of water at the desired temperature, in order that the first batch may be run at the required temperature. With a variation of 2° or 3° in temperature the difference in the results of the tests is negligible.

The speed of the mill must be checked, and adjusted to 66 r.p.m. This is easily done with the aid of the counter fastened to one end of the shaft.

Beating Procedure.

Usually two different cooks are beaten at the same time, although one may be run with the same degree of accuracy. Time is saved by beating one cook in each jar.

One of the battery-jars containing the mixture of pulp and water previously prepared is dumped into one of the jars of the mill, together with the proper amount of pebbles. The other jar is loaded in the same manner. The covers are clamped on, and the mill set in motion. Successive batches are run for increasing periods up to 80 and sometimes to 160 minutes, depending upon the quality of pulp. Sufficient batches are beaten at 10- or 20-minute intervals to show that the maximum bursting-strength has been reached. Ordinarily batches are beaten for 20, 40, 60, 80, and 100 minutes, requiring 1,320, 2,640, 3,960, 5,280, and 6,600 revolutions respectively. The batches are best timed by the number of revolutions, this method being the most accurate.

Making the Hand-sheets.

When the batch has run the required number of revolutions, the charge, consisting of pulp, pebbles, and water, is dumped from the pebble mill into a 10-quart pail, and the mill rinsed carefully with a hose, so that none of the fibres remain in the mill or are lost. The charge is dumped i to a strainer which has been placed in the stone vat from which stock for the hand-sheets is dipped. The strainer is made of very heavy ½ in.-mesh wire. The pulp is thoroughly washed from the pebbles and strainer into the stone vat, which is filled with water up to the 20-litre mark.

From the dilute suspension of pulp in the stone vat, six sheets are made by dipping 500 c.c. for each sheet in a copper measure. The sample is emptied into one of two 1-gallon measures. The measure is filled with water and the mixture poured back and forth from one measure to the other five or six times. The mixture is then poured into the deckle-box of the sheet machine quickly, and distributed evenly by moving the measure back, forth, and criss-cross. The drain-valve is immediately opened wide. The suction is allowed to continue for five seconds after the water is out of the deckle-box. The deckle-box is then turned back on its hinge, and the plate bearing the wire and sheet removed, turned over on a pile of moist felts, and pressed down. The plate and wire are lifted from one edge, leaving the sheet on the felt.

Drying the Sheets and preparing them for Testing.

The test sheets are hung up on the felts in the drying-room and air-dried. The drying procedure is hastened by directing a current of air upon them by means of an electric fan. As soon as the sheets are thoroughly air-dried they are pressed in the letter-press for five to ten minutes to flatten them out. They are then trimmed on a paper-cutter to 5 in. by 7 in., and placed on the conditioning-rack in the humidity-room, with a relative humidity of 65 per cent. for two hours before testing. In that time they reach equilbrium, and are ready to be tested under the standard conditions of 65 per cent. relative humidity and a temperature of 72° F. From the six sheets the four best are selected and used for bursting and tearing strengths. One of the remaining sheets is used for folding and tensile tests, and the other sheet is filed with the test data.

B[illegible]sting-strength Test.

The Ashcroft tester is used for determining the bursting-strength. The four sheets are weighed on a balance to $\frac{1}{10}$ grm., cut diagonally, and eight tests made along the diagonal edges of each sheet, making a total of thirty-two tests for each batch. This enables one to obtain a fair average value for the test. The pounds per ream can be computed as follows :—

$$\frac{\text{Sq. in. ream of 500 sheets 24 in. by 36 in.} \times \text{No. of grm. in 4 sheets}}{\text{Sq. in. in 4 hand-sheets (5 in. by 7 in.} \times \text{No. of grm. in 1 lb.}} = \text{lb./rm. of 500 sheets 24 in. by 36 in.}$$

Weight of four sheets × 6·8 = lb./rm. of 500 sheets 24 in. by 36 in. By dividing the average test by the lb./rm. we got the pts./lb./rm., which is a standard measure of the bursting-strength of paper.

In some cases, where the sheets are greatly hydrated, they may shrink so much that it is impossible to cut the sheet 5 in. by 7 in. The sheet is then cut 4 in. by 6 in., and the ream-weight calculated by multiplying the weight of the four sheets in grammes by 9·99.

Calibration of the Ashcroft Tester.

The Ashcroft tester should be checked at least once in two weeks against a similar instrument that has been calibrated by the manufacturer. If the tester does not check properly, it should be sent to the manufacturer for calibration, and the other instrument used for routine work. If the two testers are used alternately in this manner a properly calibrated tester will always be available.

Tearing-strength.

The other triangular halves of the sheets are used for the tearing test. The Elmendorf tearing-tester, which gives the grammes of force required to make a tear, is used. Two of the triangular sheets are cut 2½ in. wide on the gauged cutter to give five tests in the machine-direction ; the other two sheets are cut to give five tests across the machine-direction. Two sheets at a time are clamped in the machine for making the tests. A cut is made with the knife, leaving 2 in. to be torn by the machine. For best results the scale-reading should be about 15. If the tests are lower, either heavier sheets or a greater number should be used.

The zero point of the tearing-tester should be checked frequently according to the directions supplied by the manufacturer.

The grammes of force required to make the tear are computed by multiplying the average of the ten tests by the Elmendorf factor (if one sheet is used the factor is 16 ; two sheets, 8 ; four sheets, 4 ; and eight sheets, 2).

The grammes of force divided by the ream-weight calculated in the same manner used in the bursting-strength test gives the tearing-strength in grammes per pound per ream (24 × 36 — 500).

Folding and Tensile Tests.

The folding and tensile tests are made on the Schopper testing-machines. Eight strips are cut, four across and four lengthwise, from one of the remaining sheets, two of each being used for the folding tests and two of each for the tensile tests.

The strips are cut 15 mm. in width, and 100 mm. in length for the folding-tester. This machine registers the number of double folds at the rate of approximately 120 per minute, required to break the strip under a maximum tension of 1,000 grm.

For the tensile test, strips giving a length of 50 mm. between the jaws are used The scale registers the numbers of kilograms required to break the strip. The machine also registers the per cent. stretch at the point of failure.

From the kilograms required to break the strip, and the weight of the strip, the breaking-length in metres can be computed in the following manner :—

$$\frac{\text{Av. tensile str. (kg.)} \times \text{No. of strips} \times \text{length of strips in metres}}{\text{Weight of strips in grammes.}} = \text{breaking-length in metres.}$$

The data from these tests are plotted and from the curves the time required to reach the maximum and the manner in which the maximum is approached can be read at a glance. The data and curves, together with the sample sheets, are fastened together and filed.

In making the tensile test care should be taken that the strips are cut accurately to the prescribed width, parallel to or across the machine-direction, and clamped in the jaws so that the pull is straight. The lower jaw should be moved at the rate of 12 in. per minute. The tester should be calibrated occasionally.

The folding-tester should be calibrated every thirty days in the manner described in the Tappi official method of making the folding test.

APPENDIX VIII.—METHODS OF ANALYSIS OF SODA AND KRAFT COOKING-LIQUORS.

NaOH Solution.

A 50 c.c. sample of liquor is pipetted into a 500 c.c. volumetric flask, made up to 500 c.c. with distilled water, and thoroughly shaken. A 10 c.c. portion of the solution is titrated with 0·1N HCl. first to the phenolphthalein end point (reading A) and then to the methyl orange end point (reading B),

$$\{A - (B - A)\} \times 4 = \text{NaOH in grammes per litre.}$$

Na_2S SOLUTION.

A 50 c.c. sample of liquor is pipetted into a 500 c.c. volumetric flask, 50 c.c. of 10-per-cent. $BaCl_2$ solution added, the mixture made up to 500 c.c., thoroughly shaken, and allowed to settle.

A 10 c.c. portion is added to a slight excess of 0·1N iodine previously acidified with 10 c.c. of concentrated acetic acid. The excess iodine is then titrated with 0·1N sodium-thiosulphate solution, using starch as an indicator.

A = c.c. of 0·1N iodine solution ; B = c.c. of 0·1N thiosulphate solution.

$(A - B) \times 3{\cdot}9 = Na_2S$ in grammes per litre.

BLACK LIQUOR: RATIO OF COMBINED TO TOTAL ALKALI.

Free Alkali.

A 100 c.c. sample of black liquor is pipetted into a 1,000 c.c. volumetric flask, 100 c.c. of 10-per-cent. $BaCl_2$ solution added, made up to 1,000 c.c., thoroughly shaken, and allowed to settle. A 100 c.c. portion of the clear solution is titrated with 0·1N HCl to phenolphthalein end point.

Total Alkali.

A 100 c.c. sample of black liquor is pipetted into a Duriron dish, evaporated to dryness, and ashed. The ash is dissolved with distilled water and made up to 1,000 c.c. in a volumetric flask. A 100 c.c. portion is titrated with 0·1N HCl to methyl-orange end point.

x = c.c. 0·1N acid for free alkali ; y = c.c. 0·1N acid for total alkali.

$\left(100 - 100\,\frac{x}{y}\right)$ = per cent. ratio of combined to total alkali.

APPENDIX IX.—METHODS OF ANALYSIS OF COOKING-LIQUORS FOR SEMI-KRAFT PROCESS.

NaOH AND Na_2S SOLUTION.

A 50 c.c. sample of liquor is pipetted into a 500 c.c. volumetric flask, made up to the mark with distilled water, and thoroughly agitated. 50 c.c. of 10-per-cent. $BaCl_2$ solution is added to precipitate carbonates. Allow to settle. Pipette off a 10 c.c. sample of the clear liquor and add it to an excess of 0·1N iodine solution, previously acidified with acetic acid. Enough glacial acetic should be used to neutralize all the alkali and render the solution acid. The liquor containing the Na_2S must be added to the 0·1N iodine, and not *vice versa*, or low results will be obtained. Titrate the excess iodine with 0·1N thiosulphate solution, using starch as an indicator. A new 10 c.c. sample is titrated with 0·1N acid to methyl orange.

Calculations :—

Let c.c. 0·1N iodine = A ; let c.c. 0·1N thiosulphate = B ; let c.c. 0·1N acid = C.

$(A - B) \times 3{\cdot}9 = Na_2S$ in g.p.l.

$\left\{C - (A - B)\right\} \times 4{\cdot}0 = NaOH$ in g.p.l.

For analysis of black liquor see procedure under soda and kraft process.

APPENDIX X.—METHODS OF ANALYSIS OF COOKING-LIQUORS FOR SEMI-CHEMICAL PROCESS.

SEMI-CHEMICAL PROCESS.

Na_2SO_3 and $NaHCO_3$ Solution.

A 2·0 c.c. sample is titrated with 0·1N iodine, using starch as an indicator. An air-condenser is attached to the Erlenmeyer flask and the solution is boiled gently until all CO_2 is expelled. Each cubic centimetre of 0·1N iodine forms 1 c.c. of 0·1N acid, according to the equation—

$$Na_2SO_3 + 2I + H_2O = Na_2SO_4 + 2HI.$$

The acid thus liberated reacts with the $NaHCO_3$. Care must be taken that sufficient 0·1N acid is present, however, to decompose all of the $NaHCO_3$. If the original liquor is low in sulphite, sufficient 0·1N acid should be added by means of a burette before the boiling. After all the CO_2 is expelled the flask is cooled under the water-tap. An excess of 0·1N NaOH solution, which contains a small amount of $BaCl_2$, is added by either a burette or pipette. The excess NaOH is then titrated with 0·1N acid, using phenophthalein as indicator. The $NaHCO_3$ is calculated as Na_2CO_3.

Calculations :—

Let c.c. 0·1N iodine = A ; let c.c. 0·1N acid = B ; let c.c. 0·1N NaOH = C.

$A \times 3{\cdot}15 = Na_2SO_3$ in g.p.l.

$\left\{(A + B) - C\right\} \times 2{\cdot}65 = Na_2CO_3$ in g.p.l.

APPENDIX XI.—METHODS OF DETERMINING STRENGTH OF PAPER.

For paper-testing, three sheets about 24 in. long, as nearly equal in thickness and weight as possible, are selected. They are prepared for testing by seasoning on the drying-rack in the humidity-room two hours, at a relative humidity of 65 per cent. and a temperature of 72° F., which are maintained during the testing. One of the sheets is used for thickness, basis weight, and bursting tests; one for the tensile, folding, and tearing tests; and the third cut to 8 in. by 10½ in. for the sample to be saved.

Basis Weight.

A sample is cut from the first sheet corresponding to the brass template, 6$\frac{1}{16}$ in. by 14½ in., and weighed on the scale. The basis weight per ream is obtained by applying the proper correction for 500 or 480 sheets to the ream of the size 24 in. by 36 in.

Thickness.

Ten thickness readings are taken on the weighed sheet with the Randall and Stickney micrometer estimating to the nearest 0·0001 in., five along each side of the sheet. The average of the ten readings is taken as the thickness of the sheet.

Bursting-strength Test.

The bursting tests are made on the weighed sheet, using the Mullen tester, turning the handle about two revolutions per second. The bursting-strength is obtained by dividing the average of ten tests by the ream-weight (24 in. × 36 in. × 500). The gauge on the Mullen tester should be checked frequently against a standardized gauge attached to the tester.

Tensile-strength Test.

From the second sheet, five strips are cut in the machine-direction and five across the machine. The strips are 15 mm. wide, and long enough for a space of 180 mm. between the clamping-jaws of the Schopper tester. The machine registers the number of kilograms required to break the strip, and the percentage of stretch at the point of failure.

The breaking-length, or length of a strip of paper that will be broken by its weight, is computed from the kilograms required to break the strip and the weight of the strip between the jaws of the tester as follows:—

$$\frac{\text{Av. tensile str. (grm.)} \times \text{No. of strips} \times \text{length of strips (metres)}}{\text{Weight of strips (grm.)}} = \text{breaking-length (metres).}$$

Tearing-strength Test.

The Elmendorf machine, which registers the grammes of force required to make the tear, is used for the tearing test. The sheets are cut according to the gauge, and the number of sheets necessary to give a scale reading above 15 (usually either two, four, or eight sheets) are clamped in the tester. Five tests across and five in the machine direction are made. The calculation is made as follows:—

$$\frac{\text{Sum of 10 tests} \times \text{Elmendorf factor*}}{\text{No. of tests.}} = \text{grammes of force.}$$

Dividing the grammes of force by the ream-weight gives grammes per pound per ream.

Folding-strength Test.

The folding test is made on the Schopper machine, which registers the number of double folds required to break the strip, under a maximum tension of 1,000 grm. Five strips are cut across and five in the machine direction, 15 mm. wide and 100 mm. long. The results are reported in average double folds in and across the machine direction, and the average of the two.

* To reduce scale readings to force in grammes, when tearing one sheet multiply by 16, two sheets by 8, four sheets by 4, and eight by 2.

Approximate Cost of Paper.—Preparation, not given; printing (650 copies, including illustrations), £130.

By Authority: W. A. G. Skinner, Government Printer, Wellington.—1928.

Price 2s. 6d.]

PLATE I.

Cross-sections of Wood.

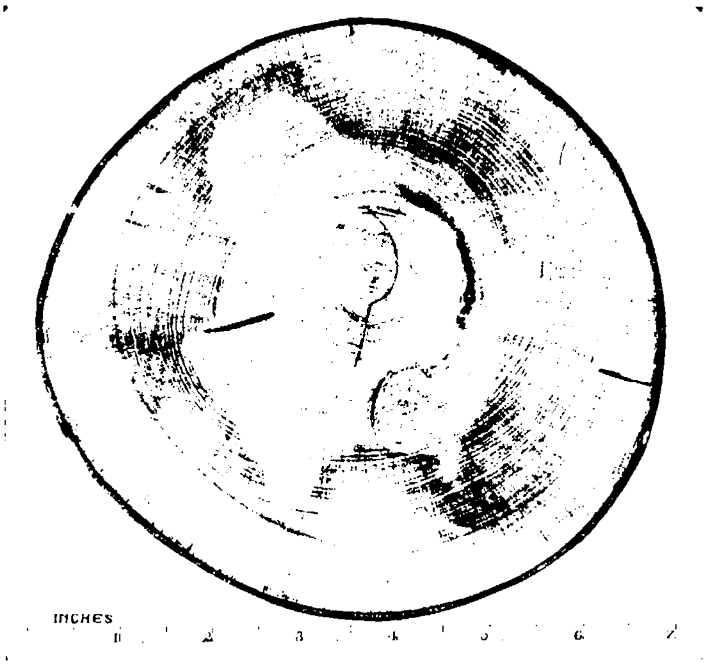


Fig. I. Cross-section of Tawa (*Beilschmiedia tawa*). The slightly darkened outer zone is an indication of slight sap stain.

Fig. II. Cross-section of Insignis Pine (*Pinus radiata*). The pith and sap stain are clearly defined.

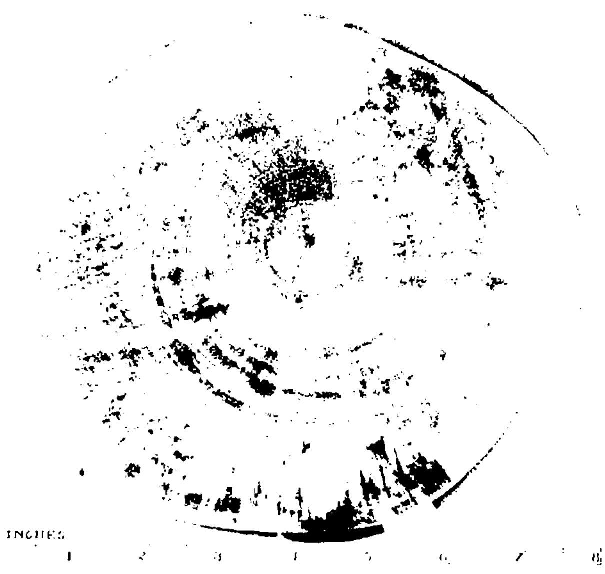


Fig. III. Cross-section of Rimu (*Dacrydium cupressinum*).

PLATE 2.

CROSS-SECTIONS OF WOOD.

FIG. I. Cross-sections of Corsican Pine. Sap-stain did not develop seriously until after three months of summer weather. The right-hand section is typical of the sap-stain at three months, the left-hand of sap-stain at five months.

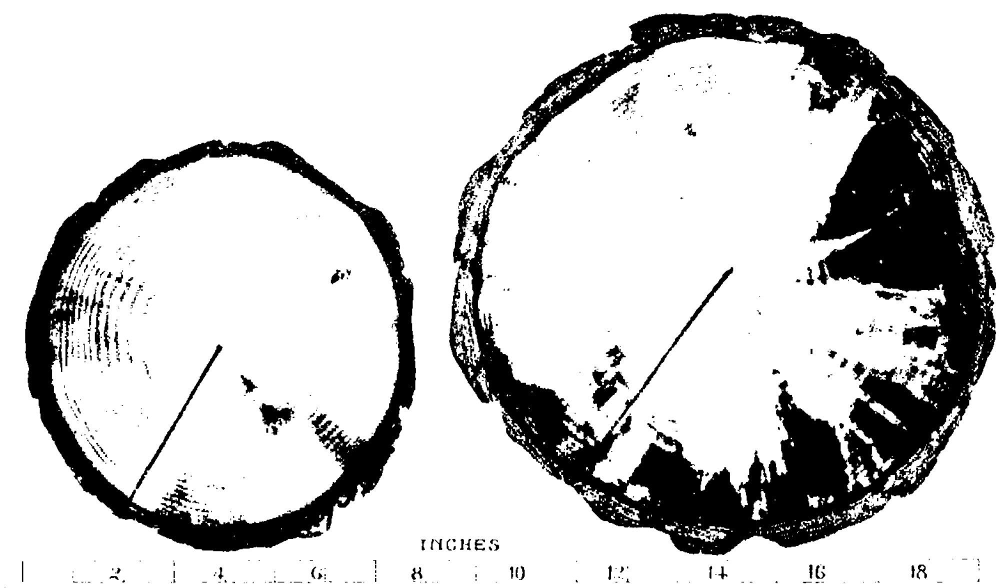


FIG. II. Cross-sections of Austrian Pine (*Pinus austriaca*). Sap-stain at three months was slight, as shown in left-hand section. After three months the sap-stain developed rapidly, as shown in the right-hand section.

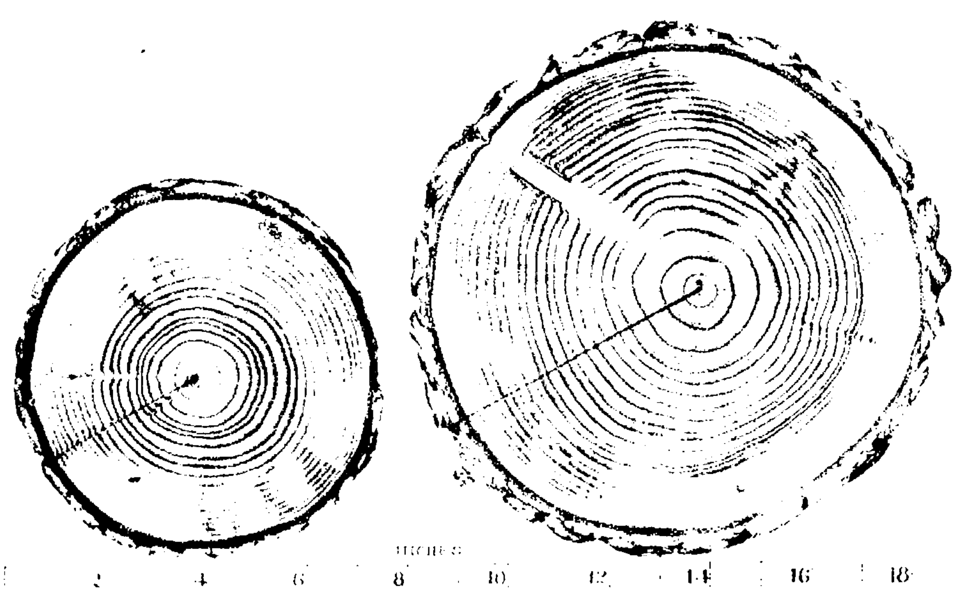


FIG. III. Cross-sections of European Larch (*Larix europea*). Slight darkenings of outer sapwood zone indicate slight sap-stain.

PLATE 3.

Experimental Wood-pulp Grinder, U.S. Forest Products Laboratory, Madison, Wisconsin

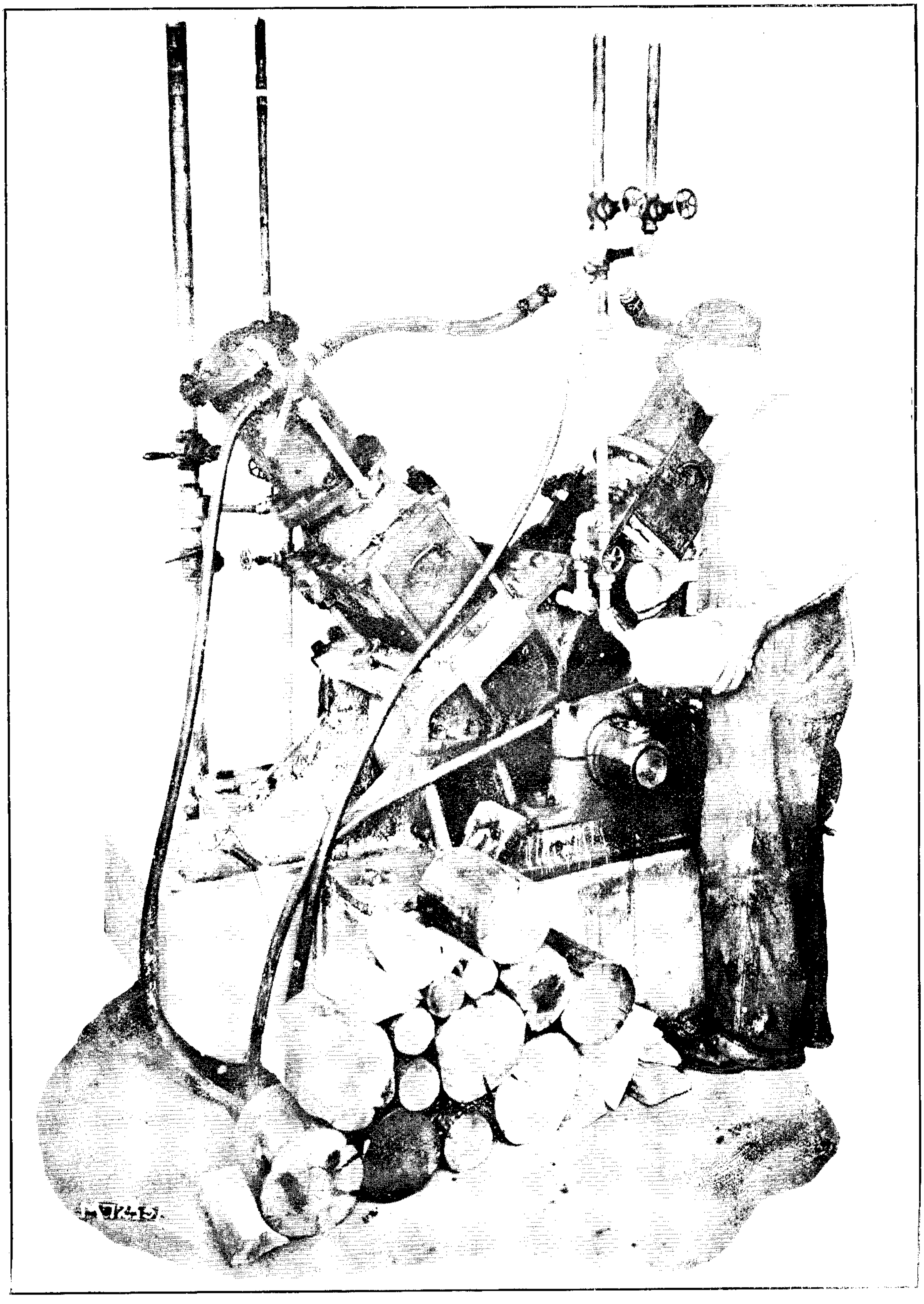


PLATE 4.

Carbon-paper Impressions of Grinder-stone Surfaces.

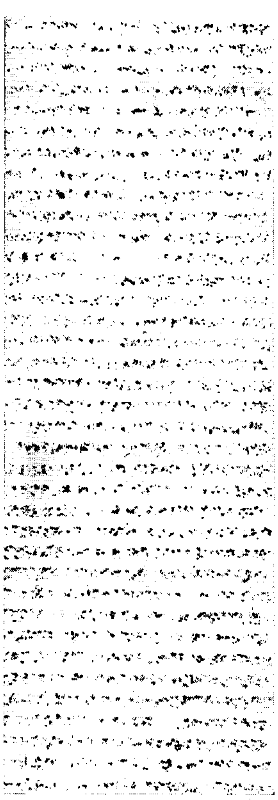


Fig. I.—Runs Nos. 1 to 5 inclusive and first part of Run No. 8. Eight-to-the-inch straight-cut burr.

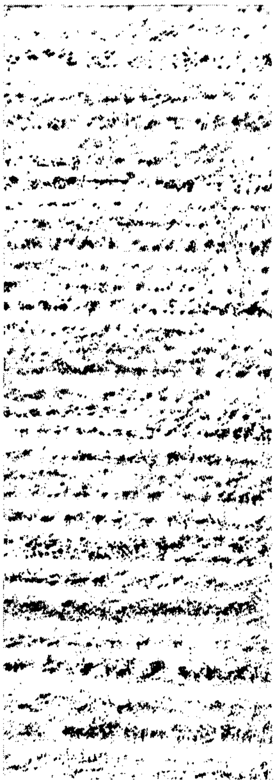


Fig. II.—Runs Nos. 6 and 7. Stone as left from Run No. 5 cut over with the three-to-the-inch straight-cut burr.

Fig. III.—Last part of Run No. 8. Three-to-the-inch straight-cut burr cut over lightly with the ten-to-the-inch spiral burr.

Fig. IV.—Run No. 9. Stone as left from Run No. 8 cut over lightly with the eight-to-the-inch straight-cut burr.

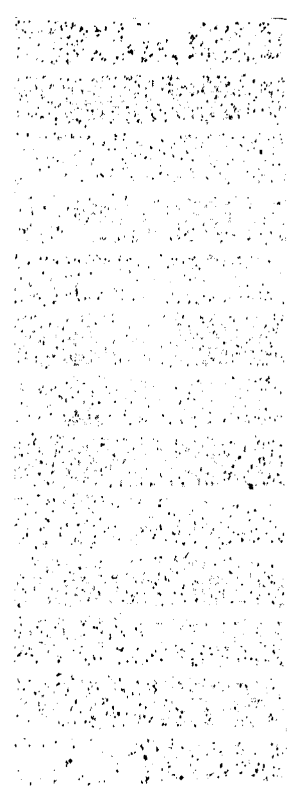


Fig. V.—Runs Nos. 10 and 11. Stone as left from Run No. 9 cut over with the ten-to-the-inch spiral burr.

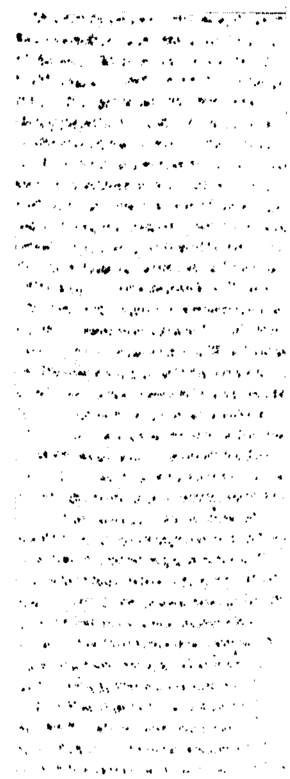


Fig. VI.—Run No. 12. Eight-to-the-inch straight-cut burr.

PLATE 5.

GROUNDWOOD PULPS. × 15.

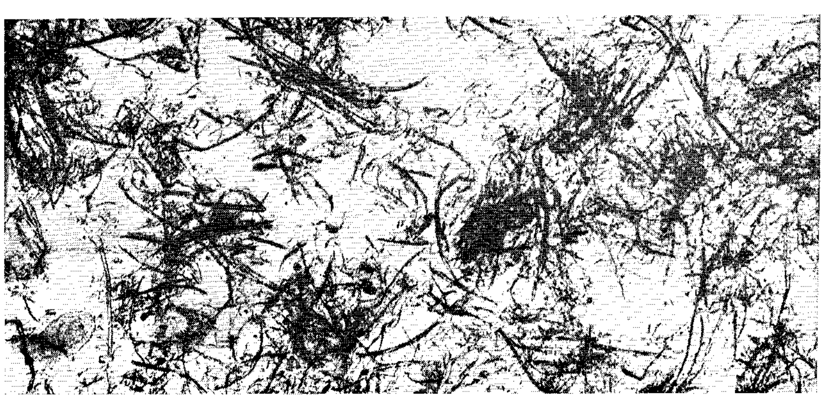


FIG. I.—Groundwood Pulp. Grinder-run No. 9 1w. Classification standard No. 1.

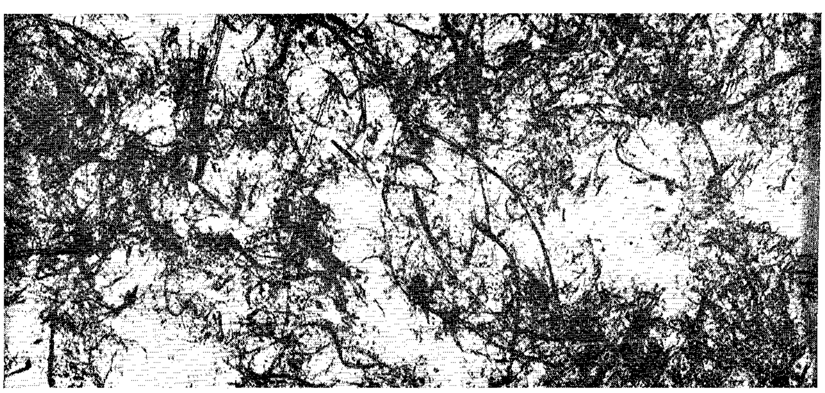


FIG. II.—Groundwood Pulp. Grinder-run No. 4. Classification standard No. 2.

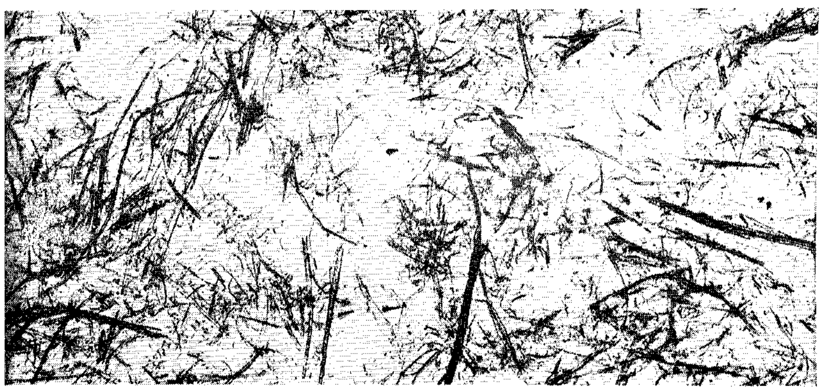


FIG. III.—Groundwood Pulp. Grinder-run No. 32. Classification standard No. 3.

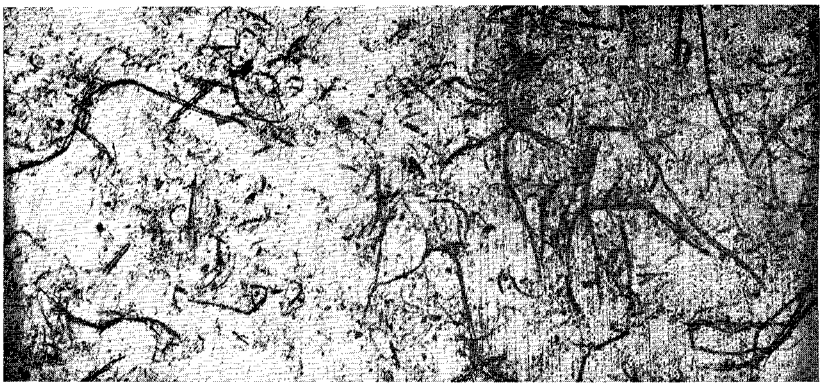


FIG. IV.—Groundwood Pulp. Grinder-run No. 15. Classification standard No. 4.

U.S. Department of Agriculture Bulletin No. 343.

PLATE 6.

GROUNDWOOD PULPS. × 15.

FIG. I.—White-spruce Groundwood Pulp. Grinder-run No. 5. Classification standard: Equal to standard No. 2.

FIG. II.—Insignis-pine Groundwood Pulp. Grinder-run No. 8. Classification standard: Between standards No. 1 and No. 2.

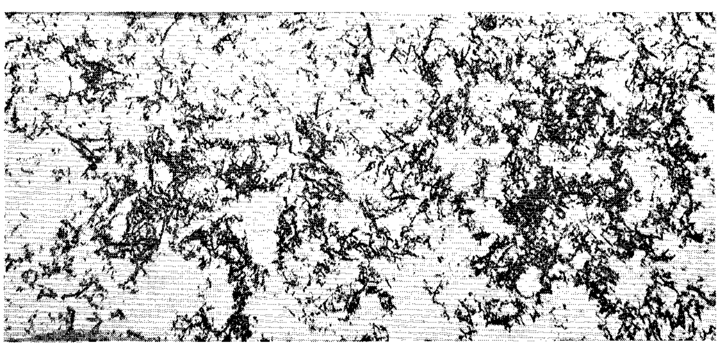


FIG. III.—Tawa Groundwood Pulp. Grinder-run No. 10. Classification: Below standard No. 4.

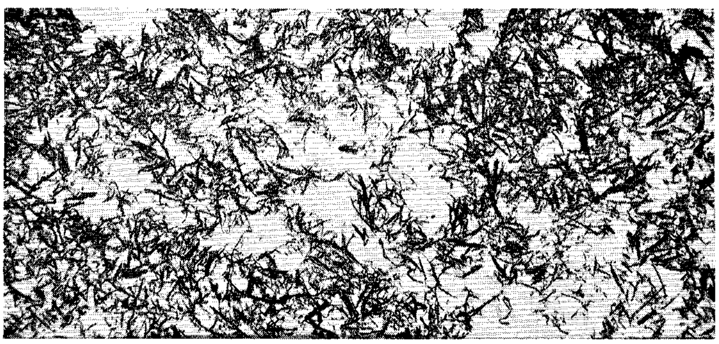


FIG. IV.—Tawa Groundwood Pulp. Grinder-run No. 15. Classification: Below standard No. 4.

FIG. V.—Tawa Groundwood Pulp. Great Western Paper Co., Ladysmith, Wisconsin. Sample taken 9th February, at 3 p.m., 105 minutes after sharpening grinder-stone.

PLATE 7.

TYPICAL TEMPERATURE AND PRESSURE SCHEDULES USED IN LABORATORY SULPHITE PULPING TESTS.

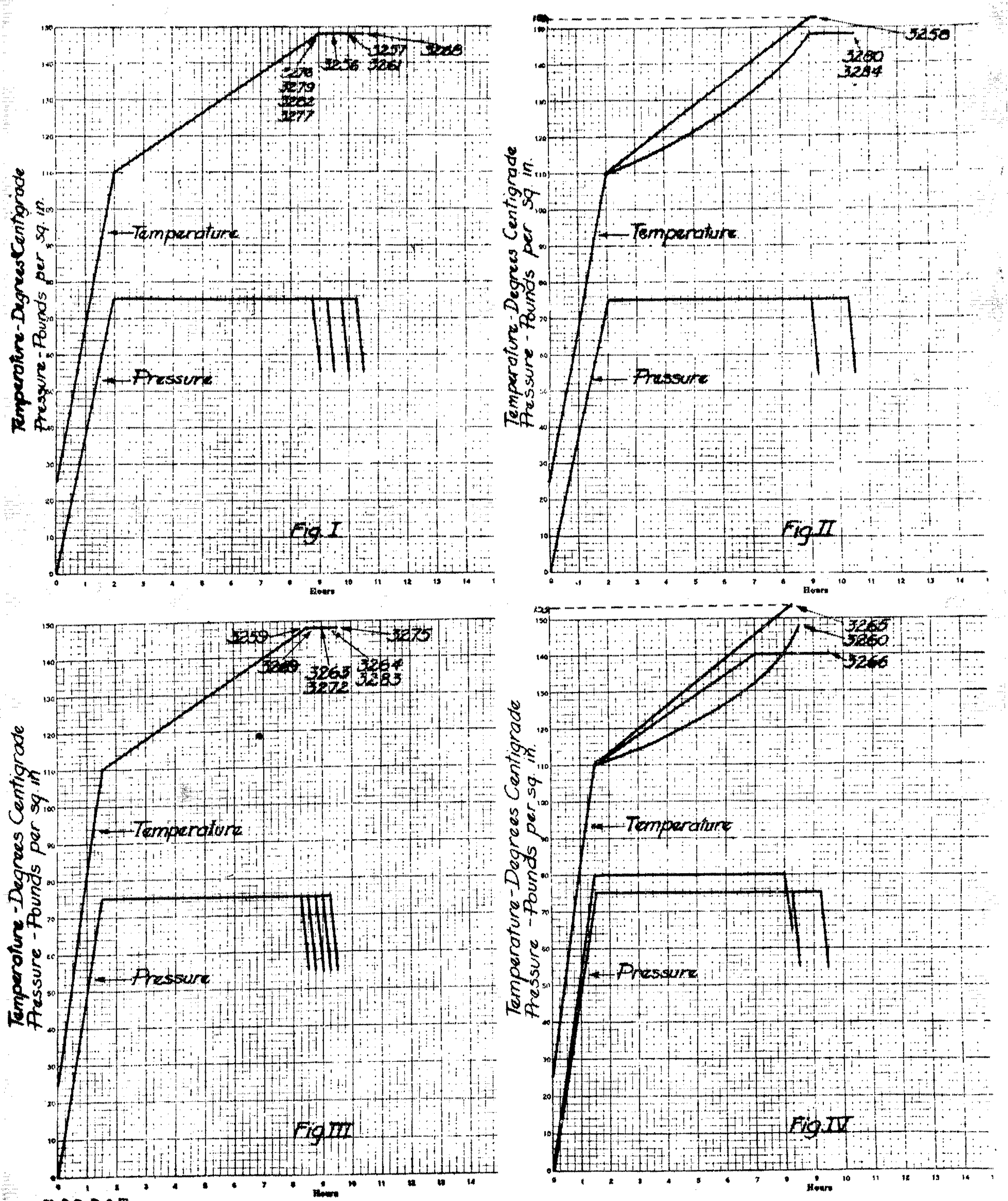
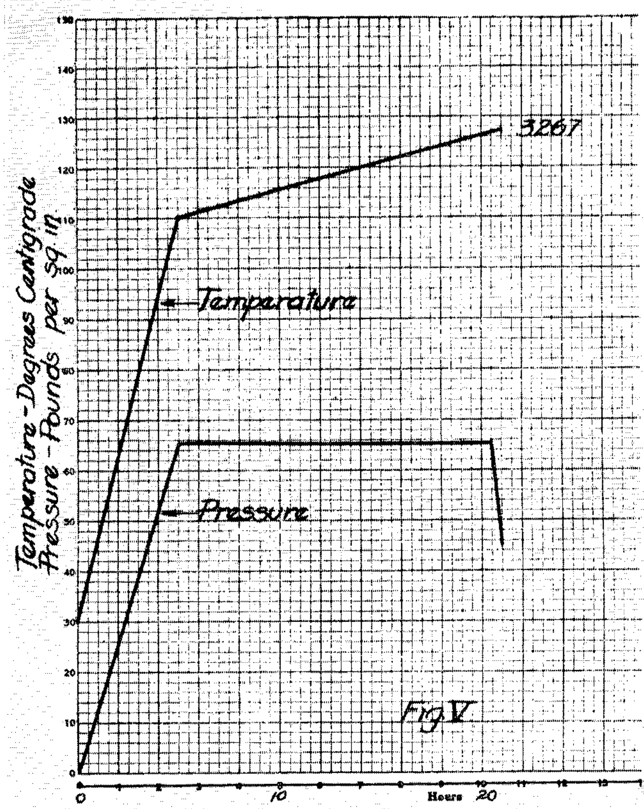
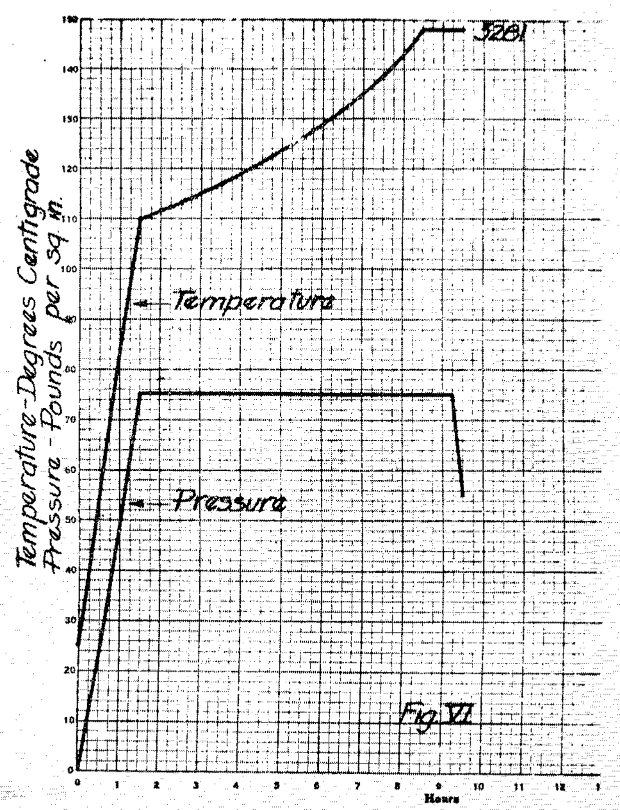
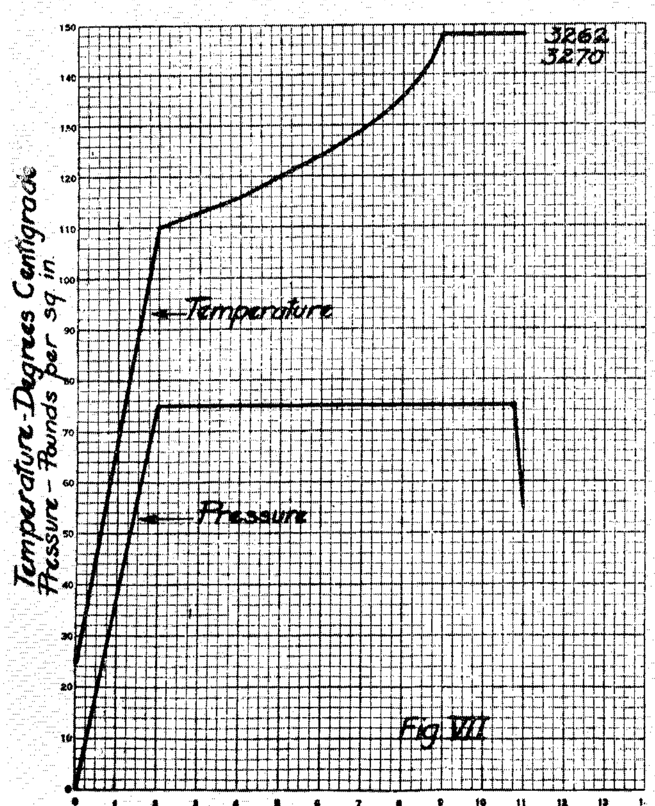


PLATE 8.

TYPICAL TEMPERATURE AND PRESSURE SCHEDULES USED IN LABORATORY SULPHITE PULPING TESTS.







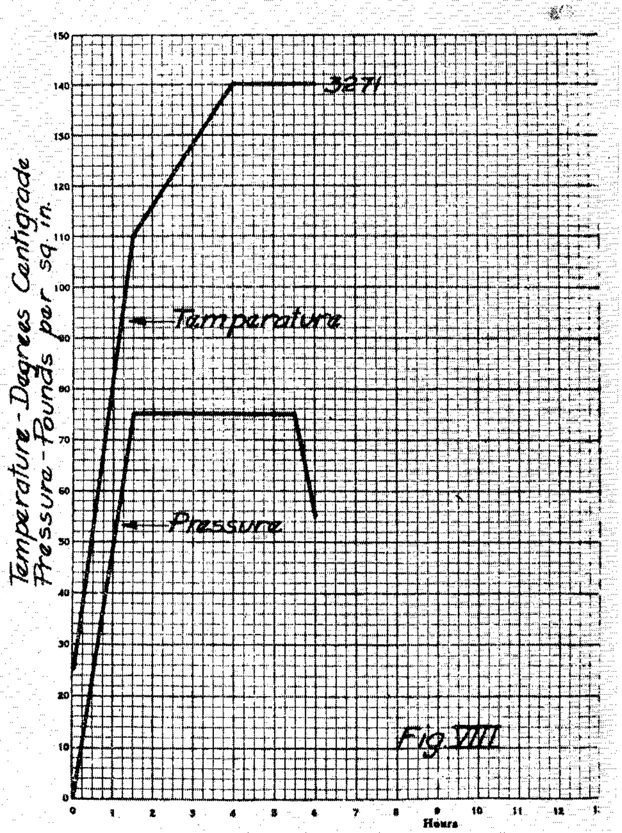


PLATE 9.

TEMPERATURE AND PRESSURE CURVES.

Commercial Pulping tests at the Great Western Paper Co., Ladysmith, Wisconsin.

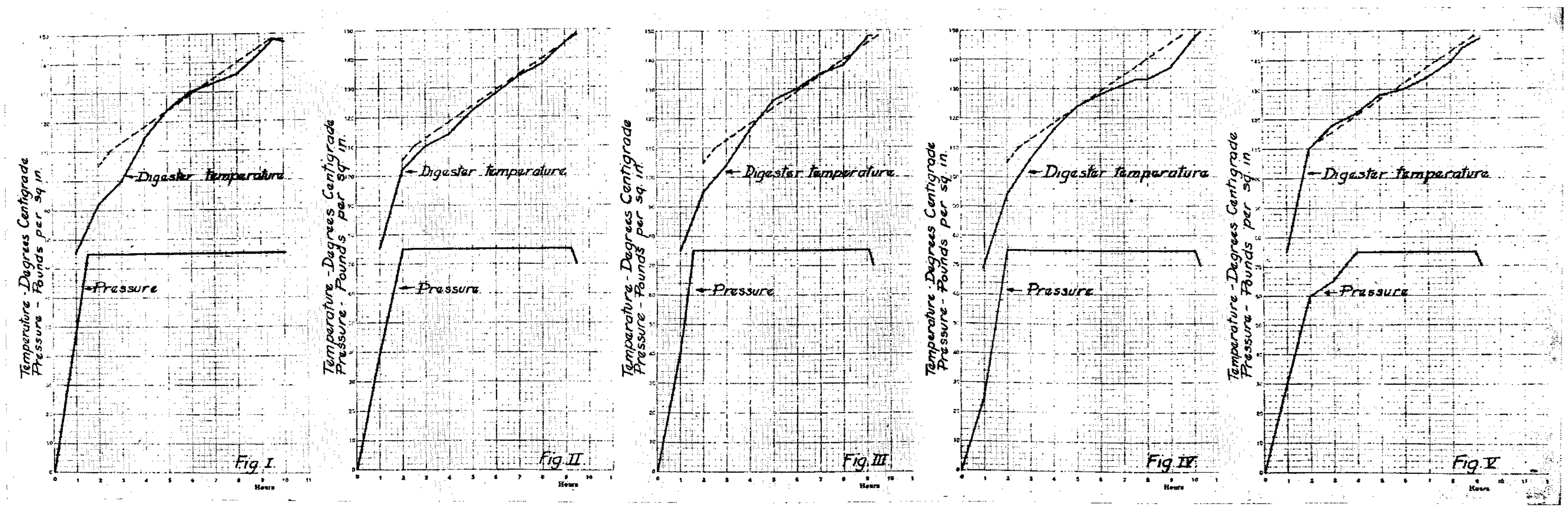


PLATE 10.

SULPHITE AND SULPHATE PULPS. × 15.

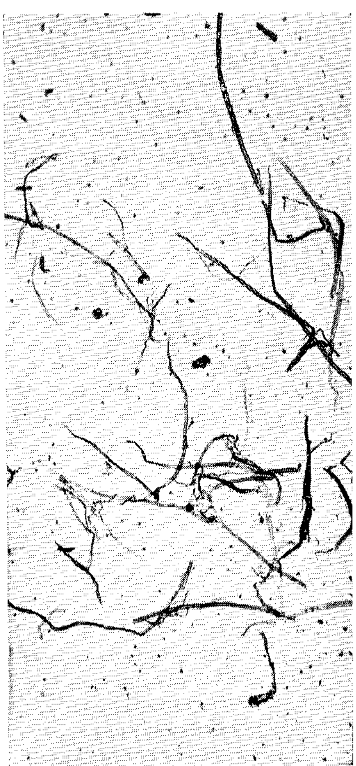


FIG. I.—Rimu Sulphite Pulp. Cook No. 3280.

FIG. II.—Tawa Sulphite Pulp. Cook No. 3273.

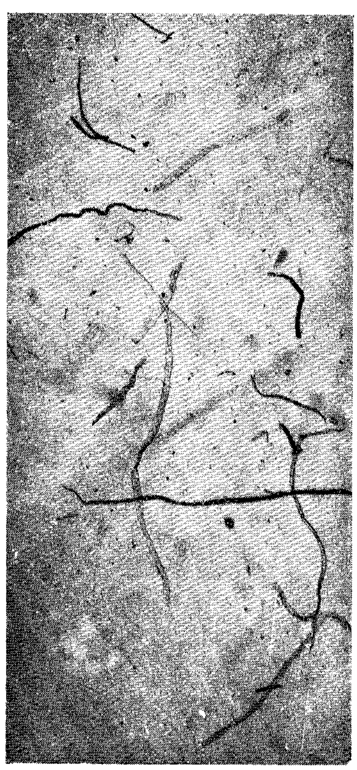


FIG. III.—European-larch Sulphite Pulp. Cook No. 3278.

FIG. IV.—Insignis-pine Sulphate Pulp. Cook No. 3269.

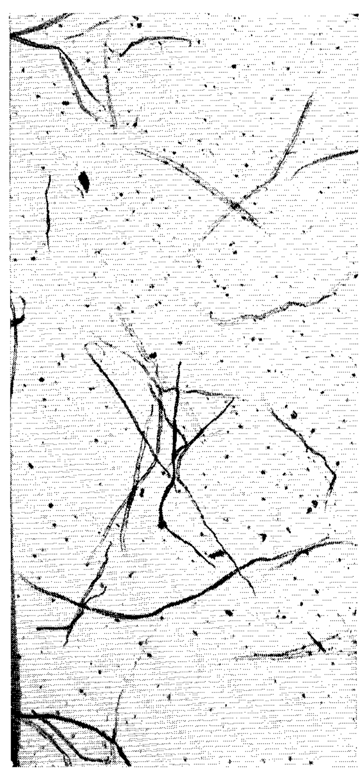


FIG. V.—Austrian-pine Sulphate Pulp. Cook No. 2236.

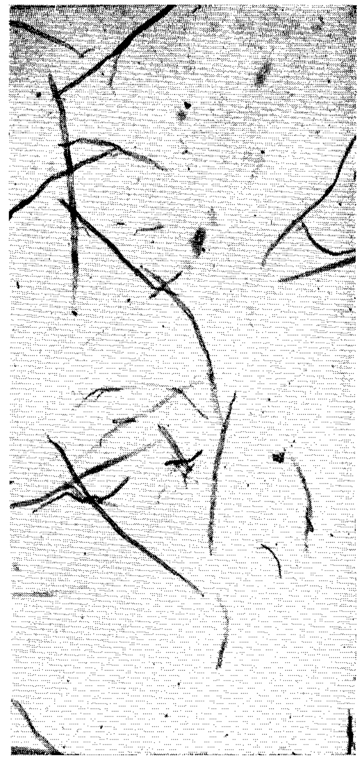


FIG. VI.—Corsican-pine Sulphate Pulp. Cook No. 2240.

PLATE 11.

DIAGRAM OF LABORATORY SULPHITE DIGESTER.

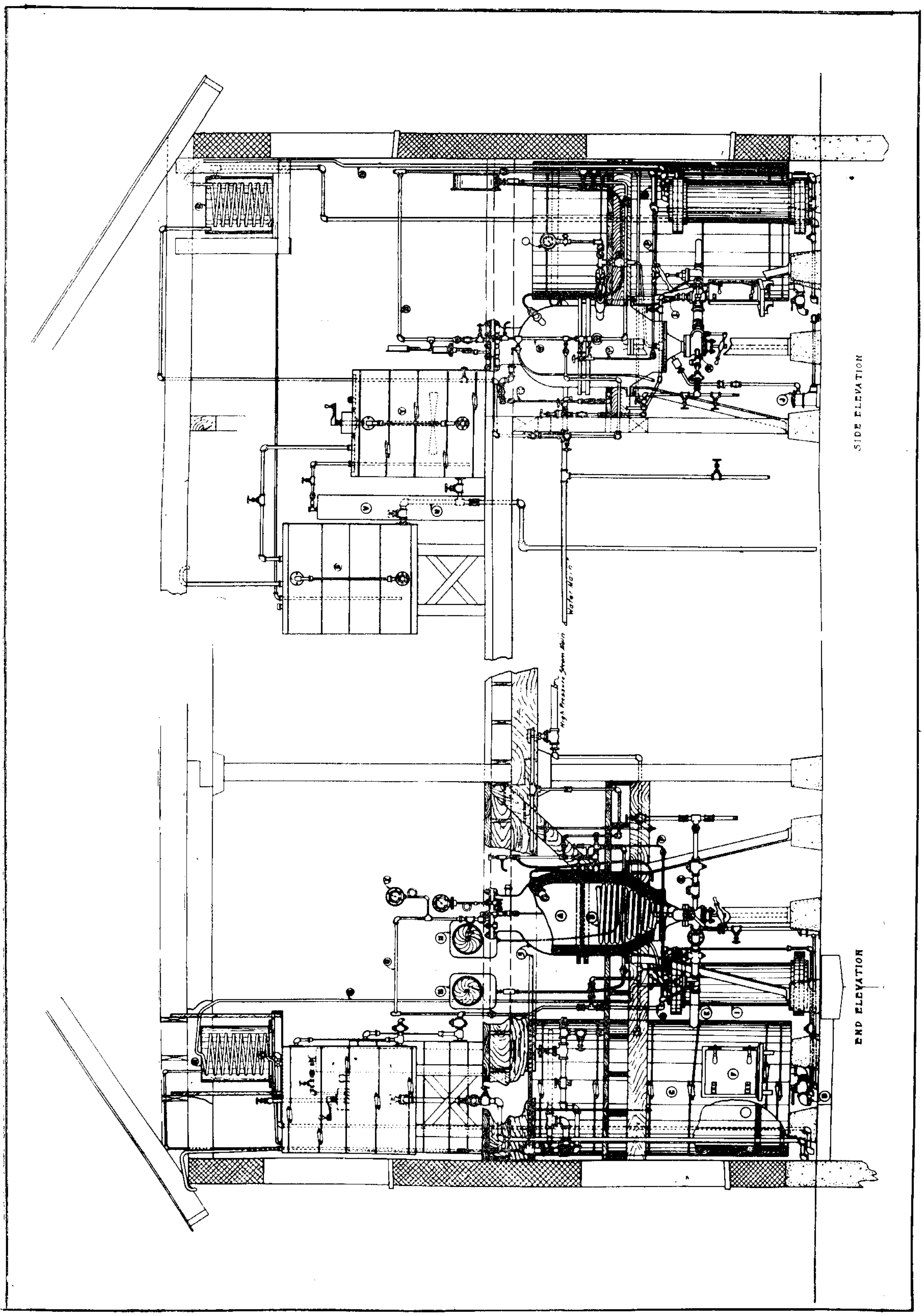


PLATE 12.

ONE OF THE LABORATORY BEATERS.

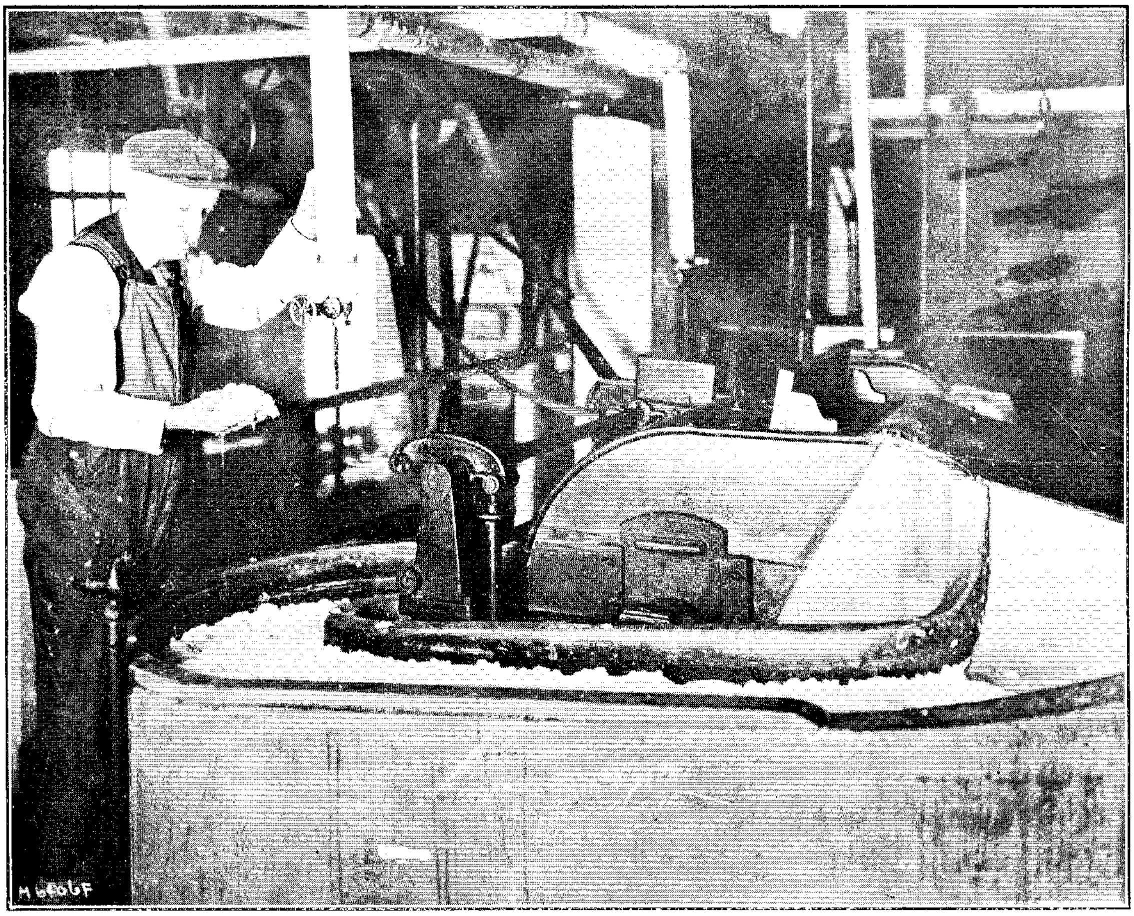


PLATE 13.

LABORATORY SEMI-COMMERCIAL ROD MILL.

The operator is changing rods.

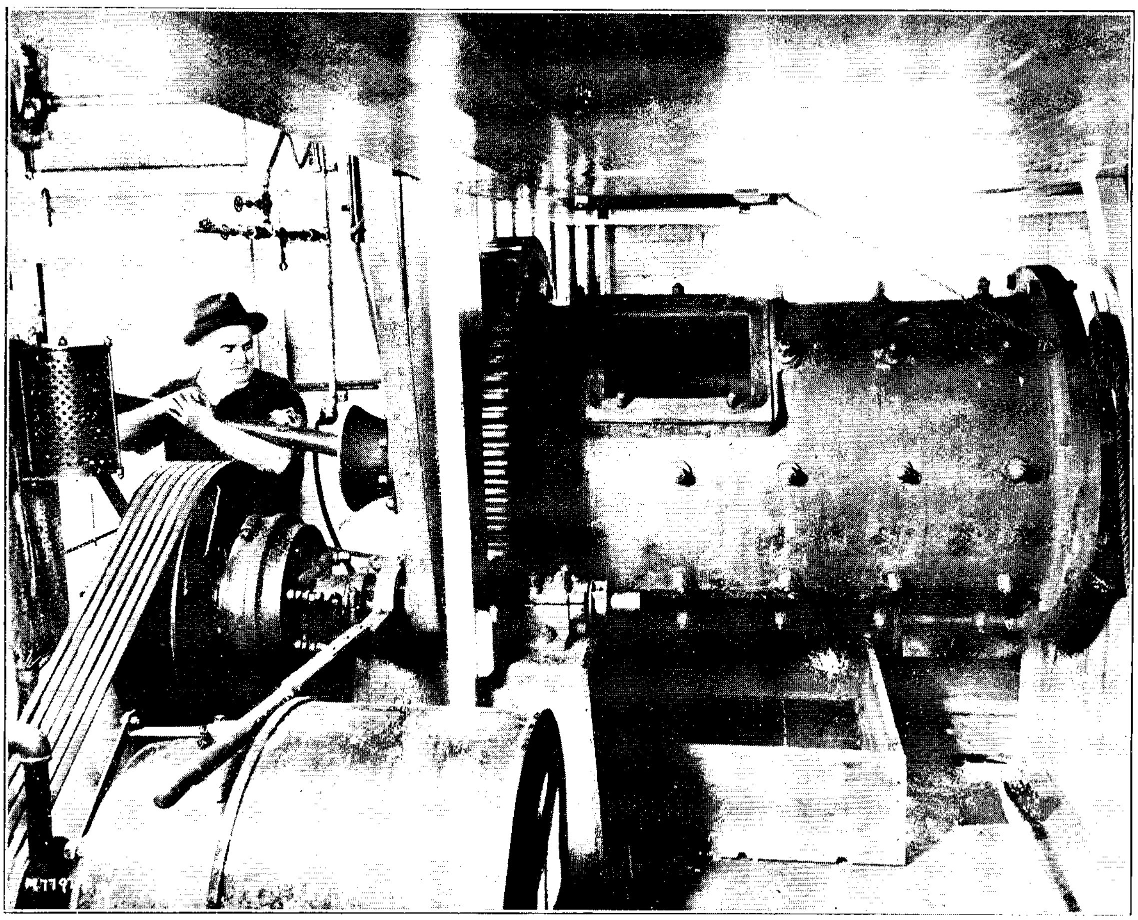


PLATE 44

LABORATORY PAPER MACHINE