# THE SUITABILITY OF SOME CALIFORNIA-GROWN EUCALYPTS FOR PAPER PULP.

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# THE SUITABILITY OF SOME CALIFORNIA-GROWN EUCALYPTS FOR PAPER PULP.

Pulp and paper men in recent years have taken much interest in the development of new species to take the place of the rapidly disappearing supplies of the softwoods which are at present so necessary to the industry. In 1922, the latest year for which figures are available, seventy-seven percent of the wood used for pulp in the United States was either spruce, fir or hemlock[1]. As much as fifty-five percent of the pulpwood was from a single group of conifers, the spruces. With this concentration on a small number of species, it is not surprising that it is now becoming increasingly important to find ways in which other woods can be used economically in place of the conifers. The western hemlock, now used so extensively in the Pacific Northwest, was formerly held to be unsuitable for pulp manufacture and is a good example of the adaptation of a new species. Douglas Fir is another wood which is just now beginning to be used. A recent bulletin[2] issued by the U. S. Dep't of Agriculture gives the results of tests made at the Forest Products Laboratory in Madison, Wisconsin, on some ninety-four American woods. The pulping tests were made by the four commercial processes now in general use. A large percentage of the woods were those known as hardwoods. The pulp and paper industry in 1922 used 790,000 cords of hardwoods and about 4,750,000 cords of softwoods.

One of the most interesting groups of hardwoods is that which includes the genus eucalyptus. There are over 300 species of eucalypts, all of them native to Australia or Tasmania. Many of them are noteworthy for their rapid growth and for the great size they often attain. About 65 or 70 species have been planted in California[3]. Because they grow so fast and their wood is usually of such a beautiful texture, much has been expected of these trees in the past. Between 1900 and 1910 many plantations were set out in California, and companies were organized to exploit the timber. The difficulty of seasoning the wood, especially that of the species selected for most of the plantations, was so great that the only use found for most of the trees was as fuel or, in some localities, as windbreaks. Most of the plantations where the trees grew successfully have been left standing because the wood was not valuable enough even as firewood to pay for cutting the trees. In some places the leaves of the trees have been used in the production of eucalyptus oil, but the oil from California species is a poor grade because of its high pinēne content. On the whole, it seems that the wrong species have been planted for use either as timber or in the production of the oil.

The possibility of using the trees for paper pulp has lately seemed to be worth investigating. As would be expected, this possibility has been much considered in Australia and in Tasmania. Experiments have been conducted on pulp manufacture in other countries where the eucalypts have been found to be a fast growing species.

The purpose of the work described in this paper was to determine pulping characteristics of the principle species of eucalyptus grown in California. The species selected were those which have shown themselves to be capable of rapid growth under conditions prevailing in large sections of the state. One species, the so-called Blue Gum, is found in nearly all parts of California. It is also an extensively planted species in other countries such as Portugal[4], France, and North Africa[5]. It is better to speak of the Blue Gum found in California as eucalyptus globulus as there are other species which are known in some localities as blue gums. The other species selected were eucalyptus corynocalyx or Sugar Gum, and eucalyptus viminalis or Manna Gum. (See Appendix) It was originally intended that only the Sulphate process should be used in pulping the different woods, but later developments made it necessary to change to other processes.

## PREVIOUS WORK

As the trees are indigenous only to Australia and Tasmania, where they are found in great quamtity, it is natural that most of the previous work should have been done in these two places. Starting within the last twelve or thirteen years, an impetus having been given by the shortage of paper-making materials during the war, systematic investigations were made of some of the principal eucalypts[5]. The small amount of work done before that time had not been in agreement. For example, in 1911, the California "Blue Gum" was found by "exhaustive research work" to be an excellent material for paper pulp. Another investigator, Mr H. E. Surface, when asked to report on the eucalypts by the government of Tasmania in 1915, found that of three species tested, - E. regnans, E. globulus, and E. obliqua, - obliqua was the best for paper pulp, and that none were suitable for pulping by the Sulfite process or the Mechanical process. All produced a good grade of pulp by the Soda process[7].

In 1916 a committee was appointed by the government of New South Wales to inquire into the suitability of some of the Australian woods for paper pulp. About sixty species were investigated in the laboratory by the Soda process, among them many eucalypts, and it was found that of the different groups of eucalyptus species the "Ash" group "had characters distinctly promising for woodpulp production." Unfortunately, the "Ash" group is very poorly represented in California, all of the large eucalyptus stands being composed of the so-called "Gums". This latter group was found to be "hardly suitable for paper-pulp production, as the shortness and brittleness of their fibres, difficulty in bleaching and felting, militated somewhat against their usefulness for the purpose". In 1918 the committee sent some logs of E. Dalrympleana, a typical member of the "Ash" group, to the Forest Products Laboratory at Montreal, Canada, to be tested on a semi-commercial scale. The work was not completed, but it was found, among other facts, that the fibres averaged 1.11 mm. in length. One of the logs was later used by Messrs. W. Clifford and B.C. Hope of this country for semi-commercial tests at Canton,

N. C., by both the Soda and Sulphate processes. Both processes produced a very good grade of pulp, the yield by the latter process being 47.8 percent of the dry weight of wood used. Two of the members of the New South Wales committee, R. T. Baker and H. G. Smith, published the report from which the information in this paragraph is taken[8]. They are also the authors of a valuable work entitled "A Research on the Eucalypts and their Essential Oils"[9].

In 1920 the Institute of Science and Industry at Melbourne began a survey of the paper-making qualities of Australian woods. Results of work by the Soda process were published in 1923[10]. The immature wood was found to be better than old timber. The species found to be most suitable were E. regnans, E. delagatensis, E. sieberiana, E. obliqua, and E. globulus. The last-named is the only one of the species tested that has been extensively planted in California. Semi-commercial scale pulping tests by the Soda process were made and confirmed the results of the laboratory tests. Mill scale paper-making experiments showed that, by slightly modifying the standard methods of beating the pulp, paper containing from 60 to 70 percent eucalyptus pulp could be made to give higher bursting and tensile strength tests than paper made entirely from similarly treated spruce Sulphite pulp. Spruce is the wood from which a large percentage of the world's supply of Sulphite pulp is now made. The finish of the eucalyptus paper was as good as that of the spruce sulphite paper and the opacity was superior. The report of the work of the Institute of Science and Industry was published in a bulletin printed on paper containing 60 percent of Soda pulp from Australian eucalypts, 30 percent of imported chemical pulp, and 10 percent of waste paper.

An investigation into the pulping of eucalypts by the Sulphite process was begun by the Australian Institute of Science and Industry in 1924. Newsprint paper ordinarily contains from 20 to 30 percent of unbleached Sulphite pulp, added because of the strength it gives the paper. Pulp produced by cooking the wood in a liquor containing free sulphurous acid and calcium bisulphite is of a lighter color than either Sulphate or Soda pulp, tho' it is at the same time weaker than the former. Later some experiments were started on the production of groundwood pulp from the eucalypts. Groundwood pulp is cheaper than chemical pulp and is produced, as its name implies, by grinding the wood to pulp by pressing pieces about two feet in length against the wet face of a large, revolving grindstone. The long axis of the log is parallel to the axis of the stone. Between 80 and 70 percent of the "furnish" of newsprint paper is groundwood pulp. Results of the work on production of groundwood and of some of the work by the sulphite process were published by Mr. L. R. Benjamin in 1927.[11] The species investigated were E. regnans, E. obliqua, E. delagatensis, E. globulus, and E. sieberiana of which, again, only the globulus is a California species. From the results described it is evident that the problem of whether these eucalypts are suitable for the manufacture of newsprint is almost entirely economic. Many paper-making tests were made using different proportions of eucalyptus sulphite pulp, eucalyptus groundwood, and spruce sulphite pulp. Paper made entirely of eucalyptus sulphite was much stronger than even the high quality English newsprint but did not have a very good finish. Pulp mixtures of 70 percent eucalyptus sulphite and 30 percent eucalyptus groundwood yielded paper giving better bursting and tearing tests than English newsprint. The opacity of the paper was higher than standard newsprint, the untinted color was superior, and, after sizing, the paper had approximately the same ink absorbency.

The work with some of these immature eucalyptus species indicated that the sulphite pulp could be produced in Australia at a cost that was much lower than the price of sulphite pulp in other countries. Production of groundwood from the eucalypts was estimated to be cheaper than from other trees, but only because of the lower cost of the pulpwood.

Some work on the pulping of two eucalyptus species by the Sulphite, Soda, Sulphate and Groundwood processes was done by Miller at the Forest Products Laboratory of the U. S. Department of Agriculture at Madison, Wisconsin. The species were E. saligna and E. tereticornis, both of them members of the group of "Gums", and the wood used was from trees grown in the state of Sao Paulo, Brazil. The latter species is plentiful in California. Results with the Soda and Sulphate processes were favorable, and the Sulphite process applied to E. saligna gave a good yield of a satisfactory grade of pulp. The Sulphite process with E. tereticornis and the mechanical (groundwood) process with both species did not give good results. Some work was also done by Miller for the Paulista Railway Company in Brazil, but the results are not known. The Paulista Company is reported to have built a 50-ton per day plant in Brazil. In their investigation of Moroccan woods, Messrs. Dupont and Soum [12] included work on eucalyptus globulus. The blue gum and several other species of eucalyptus have been planted in various parts of North Africa as shade trees along the roads, along railroad lines, and in plantations. Besides giving an analysis of the wood, which was in very poor agreement with the results quoted by Schorger [13] from the work of Mahood and Cable [14], conditions were given under which it was found possible to produce a 48.5 percent yield of a satisfactory grade of easy bleaching pulp by the Soda process.

The eucalypts are classified into groups such as the "Gums", "Peppermints", and the "Ash" group. However, the variation within the groups is often very great, as the results of my own work have clearly shown. Tho' all three species tested are "Gums", their pulping characteristics are widely different. The table worked out by Baker and Smith [15] of the evolution of the species of eucalypts from the genus Angophora shows the three species occurring in widely separated branches. Work on the pulping of species belonging in the group of "Gums" was done only on a laboratory scale by Baker and Smith as it was early shown that the "Ash" group was generally better suited to the purpose.[16] This group is poorly represented in California. The most hardy of the species have never been tried in this State.

Eucalyptus globulus is a tree which grows rapidly and reaches great size in its native habitat. Eighty percent of the groves in California are of this species.[17] The tests made on the Blue Gum by the Soda process make it a useful standard for comparing the results obtained from other species by the same process, and from the same and other species by different processes. On land which is suitable, from an economic standpoint, for the growth of the tree, the average yearly increase per acre is between two and five cords. E. corynocalyx, the second species tested, is a tree which is very drought resistant,- this and its susceptability to injury by frost explain the fact that it is found chiefly in Southern California. Groves of this tree, the Sugar Gum, make up 4 percent of the Eucalyptus plantations of the state. The average growth per year is 1.22 cords. The tree is, like the Blue Gum, tall and straight. Supplies of these two species were obtained from the groves of the Murphy Oil Company at East Whittier.[18] The logs were cut from trees about sixteen or seventeen years old and measured from 11 to 12.5 inches in diameter in the case of the Blue Gum, and between 10 and 11 inches in the case of the Sugar Gum. The third species selected, E. viminalis (See Appendix) or Manna Gum, is one which is second only to the Blue Gum in its rate of growth. In California it has proven to be frost resistant and grows well even in the northern part of the state. Of the last two species, the sugar gum is more plentiful. Four percent of the plantations of the state are Sugar Gum; less than one percent of the stand in the state is Manna Gum. The wood of the Manna Gum used in these tests was obtained from a tree growing in a plantation on the south side of Victory Boulevard, just west of Burbank, Calif. The diameter of the tree was six inches at 4 feet from the ground.

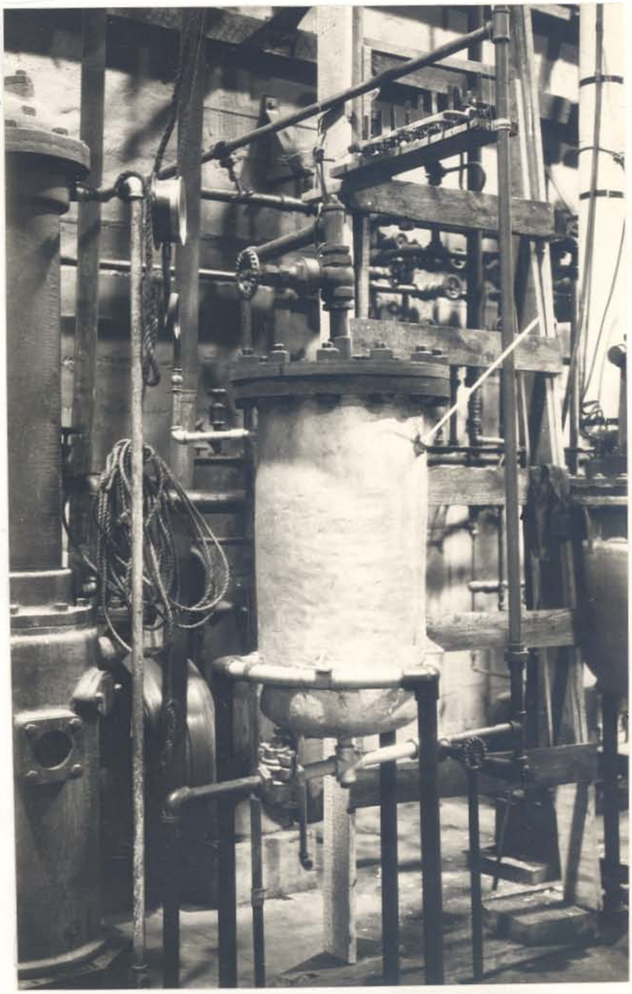
## EXPERIMENTAL.

In the greater part of the work already done to determine the pulping characteristics of the different species of eucalyptus, the species used have been those, with the exception of eucalyptus globulus, which are not plentiful in California. Most of the work appears to have been done using the Soda process. Accordingly it seemed to be desirable to experiment with the most common California species by some other standard process, such as the Sulphate process. In carrying out the work the chief result sought was to secure data on the yields obtainable on a semi-works scale, and also to determine the quality of the pulp, the ease of pulping and other factors important in a consideration of the suitability of the wood for paper pulp.

For preparing the wood for the digester no chipper was available as the nearest pulp mill was more than 500 miles distant. The difficulty was surmounted by cutting the logs into discs whose thickness was equal to the length of chip desired. The discs were then split by hand into chips measuring 5/8 inch with the grain, 1/8 inch thick, and of any width between 1/2 and 2 inches. The process can be visualized from Fig. 1 which shows the discs and the chips made from them, as well as the small hand mold used for making the test

Fig. 1. - Illustrates steps in the process of reducing the wood to chips. The discs first cut from the log and the chips split from them are shown, as well as some of the pulp and a sheet of the paper made on the small hand mold, the two parts of which are shown disconnected.

Fig. 2. - The digester in which the tests were made. Steam entered thru the pipe shown extending across the top of the photograph and down the right hand side to the bottom connection. The drain pipe extends to the left from the bottom connection.



sheets. It was found to be more satisfactory to split the discs by hand, as the toughness and hardness of the wood caused any light-weight mechanical contrivance to go to pieces very quickly. A hickory mallet and a light, sharp hand-axe were the most satisfactory tools. In preparing the samples of E. ~~viminalis~~ tereticornis a different method was used. The log of this wood was cut into 1/8 inch boards and these were then sawed at right angles to the grain. In this way pieces were obtained that were 1/8 inch thick, 5/8 inches long with the grain, and of any width up to the diameter of the log. The chips produced by both methods were rather more uniform than the average run of chips obtainable in commercial practice. Knots were not intentionally removed, but the fact that the wood around the knots usually broke off in larger pieces caused many of the knots to be removed in screening out oversize pieces. The wood was probably, therefore, freer from knots than would be possible under ordinary mill conditions. Dust and undersize pieces were screened out in a square mesh, half-inch screen. Bark was completely removed from the logs before the chipping operation was started. The bark is very easily stripped off with all three of these species. By the time they were used in the digester, the moisture content of E. globulus and E. corynocalyx was from 18 to 20 percent. That of

E. ~~viminalis~~ tereticornis was over 42 percent as the wood was used very shortly after being chipped. The logs of the first two species were from trees felled in December, 1927, and cooking operations with them were not begun until March, 1928.

Using a two-foot section of 10 inch, 250 pound pipe, a digester was constructed at a reasonable cost by welding a flange to one end of the pipe and a curved bottom plate to the other. In the side of the digester, near the top, a section of 1/2 inch pipe was welded in at a slant for a thermometer well and a small plate welded over the lower, inside end to close it. A section of 3/8 inch pipe was welded in on the opposite side near the top for the steam guage. The 3/8 inch pipe was flush with the inside of the digester at one end, and the projecting end was supportéd by a triangular steel plate. Much of this detail can be seen from Fig. 2 . In the center of the steel plate which was bolted to the top flange as a lid to the digester was welded a short length of one inch pipe. The pipe was threaded at both ends for attaching a relief valve and, on the inside, a fitting to reduce loss of liquor thru the relief line. The combined steam inlet and drain was placed in the center of the bottom plate. This was a 3/4 inch pipe with the end inside the digester capped as shown in

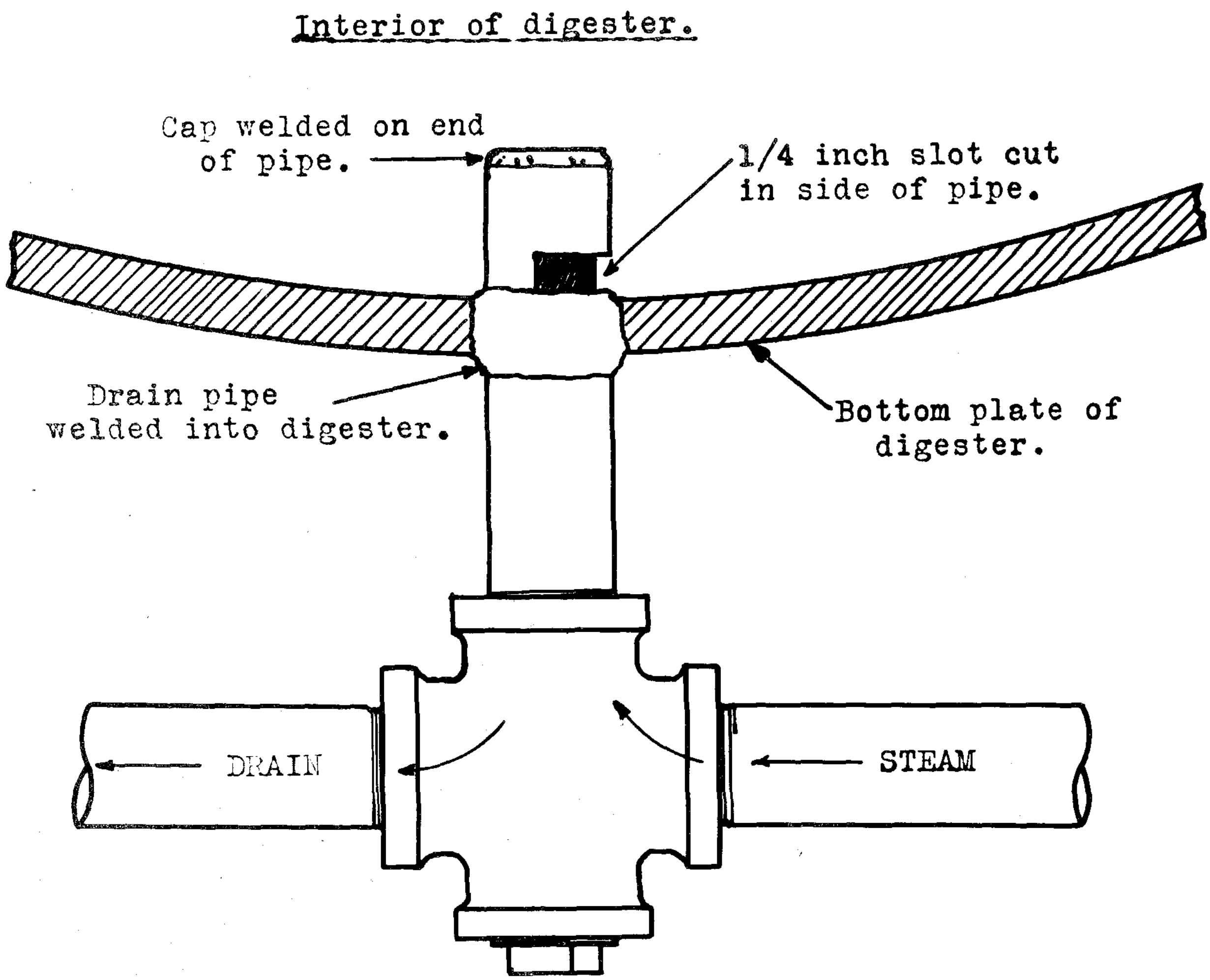



Fig. 3. - Detail of the bottom connection on the digester.

the sketch. (Fig. 3) Draining liquor from the digester after a cook was never a difficult operation with this arrangement. The body of the digester was well lagged with magnesia pipe covering, the thickness of the insulation being about an inch and a half, and the lagging was painted with aluminum paint. The large amount of condensation always found in such small size apparatus when direct steam heating is used was thus cut down to within reasonable limits.

The Sulphate process is one in which the cooking liquor consists principally of sodium hydroxide and sodium sulfide in solution. The name is derived from the fact that salt cake (sodium sulphate) is used in one part of the liquor-making process to replace the caustic which has been lost in the pulping process. The liquor is used repeatedly, being evaporated, burned, the solids dissolved again, and then causticized after it has been separated from the pulp. The combination of sodium sulfide and hydroxide gives a cooking liquor which is not so severe in its effect on the fibre. Consequently, the yield is higher and the strength of the fibres is greater than when the sodium hydroxide is used alone. When easy bleaching pulp is being prepared, the non-cellulosic portions of the wood are as thoroly removed as with the Soda process, in which sodium hydroxide is the active agent.

The pulp is chiefly used where strength, not a light color, is required. For the preparation of Kraft pulp the wood is undercooked so that the maximum strength is obtained. The strongest papers are made from this pulp. It is of a brown color, and bleaching is not economical. In making the liquors for this research, processes were used that are very different from those used in commercial practice. The latter methods are not suitable for small scale work. The liquor obtained had essentially the same composition. At first the liquor was made by dissolving sulfur in caustic solution under pressure and at a temperature of about 134°C. This method was tho't to give too much sodium thiosulfate for the amount of sodium sulfide produced, and was abandoned in favor of a simpler method in which hydrogen sulfide gas was dissolved in a caustic soda solution until the desired ratio of sulfide to total caustic had been obtained. The total caustic was considered to be the sum of the sodium hydroxide present plus the sodium hydroxide equivalent of the sodium sulfide. Some liquor was made up by dissolving crystals of pure sodium sulfide in the caustic soda solution.

The chips for the cook were weighed and just enough were used to fill the digester to within fifteen or sixteen inches of the lid. This distance was provided so that the loss of liquor thru the top valve while relieving would not be too great. The total volume of the charge was thus usually near 2.8 gallons, or about 0.37 cubic feet. The weight of oven dry wood, usually from 4 to 5 pounds, was computed on the basis of moisture determinations made every other day or oftener. The weight of total caustic was based on the weight of oven dry wood, and for kraft pulp amounted to between 20 and 23 percent of the wood in the charge. Easy bleaching pulp was produced by using 30 percent total caustic. Enough water was added to insure nearly covering the chips at the beginning of the cook. When chips and liquor had been measured in, the lid was bolted on and steam run directly into the charge to heat it and bring the pressure to the desired point. During the steaming period the pressure was kept at between 40 and 45 lbs guage, allowing uniform penetration of the wood by the liquor before the actual cooking began. After steaming for the proper length of time, the pressure was raised to the cooking point. In the alkaline processes, cooking (solution of lignin) does not begin until the temperature is 150°C or higher. During the cook the relief valve on the top was held slightly open to allow escape of gases and to improve circulation. Good circulation is essential to a high quality of pulp, but it is easily obtained in small digestors. On completion of the cook, pressure was relieved as quickly as possible. It is probable that the fact that the dewign of the digewter did not permit the contents to be "blown" out as with large digesters had something to do with the chips of even the easily pulped E. globulus wood holding their original shape fairly well until removed and washed. Liquor was drained from the digester and the contents washed thru the relief valve on top before the lid was taken off. The digester always drained quickly. When the pulp was removed, it was placed in a box with a 14 mesh screen for a bottom and then washed thru onto a 75 mesh screen. An ordinary garden hose nozzle accomplished the washing satisfactorily. The 75 mesh screen formed the bottom of a second, shallower box that exactly fitted the upper box with the 14 mesh screen. The amount of material left on the coarse screen was negligible with the pulp from E. globulus. The screened pulp, after being dewatered in a small centrifuge, was weighed and a representative sample removed. From the oven dry weight of the sample the yield of dry pulp was calculated. The yield of pulp from cook number 14 and those following was determined by weighing the pulp as it came from the digester and computing the oven dry weight from a representative sample which was very carefully taken as the digester was emptied of pulp. The oven dry weight of the screenings left after washing was subtracted from the total weight to give the weight of screened pulp. The yield of Cook No. 14 was also found in the same way as with the preceding cooks, in order to check the accuracy of the method first used. It was found that the later method showed a yield of 53 percent, while the figure given when the pulp was weighed after screening was 4 percent lower or only 49 percent. The loss in screening was probably similar in the other cooks, so that from 2 to 5 percent should be added to the yield figures for the first ten cooks.

Results of the cooks are given in Table II. The difference in the ease with which the three species are pulped is striking. Eucalyptus globulus wood is very easily converted into pulp. When cooking it by the sulphate process, it was found necessary to reduce the cooking time to about a third of that usually needed for coniferous woods. The total caustic was also less than the ordinary figure for woods such as spruce and hemlock. It is probable that even in Cook No. 4 the resulting pulp was too "soft" to be called a Kraft pulp,- in other words, the cooking time or the liquor concentration should have been still further reduced. With E. corynocalyx exactly the opposite was true. Even under the conditions of Cook No. 18, the severest conditions of any cook made, the resulting pulp was raw and full of tiny, black specks. Tho' better than any of the other cooks of this wood, the color of number 18 was not satisfactory. E. viminalis was a little more difficultly pulped than E. globulus. The pulp was darker than that of the blue gum and did not have the same reddish coloration.

Objections to the disagreeable odors produced when pulping wood by the sulphate process made it necessary to change to other methods when only eight cooks had been completed. Four cooks were made by the Soda process,- one of them using the so-called Modified Soda process; and eight cooks were made by a method which will be referred to as the Hypo process. Two unsuccessful attempts were made to cook E. ~~viminalis~~ tereticornis wood by a modification of the Keebra process.

The cooking liquor used in the Soda process is an aqueous solution of sodium hydroxide. The process is used commercially for the pulping of hardwoods. The pulp is usually bleached and possesses qualities which make it valuable for the manufacture of printing papers. It does not have the strength of Sulphate pulp,-the valuable qualities of the pulp are its softness and its ability to hold loading materials well. As has been mentioned, the majority of the tests on the suitability of the eucalypts for paper manufacture have been made using the Soda process. The procedure used when making the four Soda cooks was very similar to that described for the Sulphate cooks, except that the required amount of caustic was weighed out for each cook. About a gallon of water was used to dissolve the caustic (one-half gallon in Cook No. 15), and the solution was poured over the chips in the digester. The length of the steaming period, the pressure used, and the method of determining the yield were as described for the Sulphate process. Results of the four Soda cooks are noted in Table II. E. corynocalyx yielded about the same quality pulp by this process as by the Sulphate process. As Cook No. 12 did not produce any pulp and Cook No. 15 was made to determine the effect of the sodium thiosulfate used in No. 14, it was not possible to compare the quality of correctly cooked Soda pulp from E. globulus with either Sulphate or Hypo pulp from the same species. The comparison, however, is hardly necessary as the general qualities of Sulphate and Soda pulps are well known, and in addition E. globulus has been the subject of more investigations, (nearly all of them by the Soda process), than perhaps any other eucalyptus species.

Cook No. 10 was made by the Modified Soda process, a process recently developed for use with woods which are not easily converted into a good quality of pulp by the standard methods. The modification is applicable to any of the alkaline processes and was originally used by the author in making Kraft(a)pulp from Douglas Fir. Instead of using just enough cooking liquor to effect solution of the non-cellulosic materials in the wood, at least twice that amount was poured over the chips. Enough water was used to nearly cover the chips at the beginning of the cook. Condensation, of course, quickly increased the quantity of liquor so that the chips were more than covered by the time the cooking temperature had been reached. Pressure was brought to 95 lbs. per square inch within 8 minutes after starting cook No. 10 and was kept at that point for

(a) (In the preparation of Kraft pulp, wood is under-cooked by the Sulphate process in order to give pulp of maximum strength. When cooked to yield pulp that can be more easily bleached, Sulphate pulp is designated as Easy Bleaching.)

25 minutes, and the pressure then relieved very quickly. As soon as the pressure in the digester was equal to atmospheric, the drain line was opened and all the liquor drained off. Next the drain and the relief lines were closed and steam again let in until the pressure was as high as was possible with the type of boiler being used. The pressure during this steaming period was between 100 and 103 lbs. in all of the tests made by the modified processes. At the end of the steaming period, pressure was relieved and the pulp washed and treated as at the completion of cooks made by the ordinary Soda or Sulfate processes. The first cooking period allowed the chips to be thoroly penetrated by the liquor. Enough liquor was retained in the wood to dissolve out the noncellulosic material during the steaming period. In addition to the Modified Soda cook, (Cook No. 10), two Modified Hypo cooks were made. The only difference between the two modified processes is in the liquor used, otherwise the procedure is identical.

The commercial use of the modification of the alkaline processes which has just been described is very limited at present. Many changes are made in the procedure outlined in adapting it for use on a large scale. The usefulness of the process in this research lay in the fact that it obviated the difficulties encountered because of the large amount of condensation in the small sized digester that was used. In cooking wood like E. corynocalyx by the ordinary method a good grade of pulp could not be obtained when the chips were in the digester a total time of four hours, yet if more time for digestion had been allowed, the dilution of the liquor would have decreased the pulping action until it practically ceased. The effect of a longer digestion period is obtained when one of the modified processes is used.

The Hypo process referred to above is one in which the cooking liquor consists of an aqueous solution of sodium hydroxide and sodium thiosulfate. The pulp from this process is very similar to Sulphate pulp. The purpose of the sodium thiosulfate is the same as that of the sodium sulfid in the latter process; but, as would be expected from a consideration of the nature of sodium thiosulfate, the molal percentage of thiosulfate is twice that of the sulfid required. The process has probably never been used commercially,- its advantage to this work being the possibility of getting a pulp very similar to Sulphate pulp without having the same objectionable odors. The liquors were made up by dissolving Hypo cyystals in water and mixing the solution with a solution of caustic soda. This method is, of course, too costly for use in the industry, but the liquor obtained is nearly the same as that produced in a modification of the Sulphate process, (Paper Trade Journal, Vol. 85, Aug.4, 1927, Page 62), in which, instead of burning the black ash with salt cake, sulfur is introduced by mixing it with the lime sludge just before calcining. Once the liquor is prepared the balance of the process conforms exactly with the Sulphate process. Six ordinary Hypo cooks and two Modified Hypo cooks were made. Unfortunately, the odors from the Hypo process, tho' not as bad as those from the Sulphate process, were found to be objectionable enough so that it was not possible to continue the work until some method of quickly removing all waste liquor had been devised. In fact, lack of proper facilities for disposing of waste liquors was the most serious obstacle in the way of properly completing this work. When making the Modified Hypo cooks, gases were not relieved from the top of the digester during the cooking or impregnating period. In this way a high steam pressure could be used without having a correspondingly high temperature, and it was possible to get good penetration without much solution of non-cellulosic material. As will be seen by referring to Table II., the only satisfactory results from E. corynocalyx were given by Cook No. 18 when the Modified Hypo process was used, indicating that severe treatment by the standard Sulphate or Kraft process would yield a fair grade of pulp. In pulping the wood commercially much higher pressures would be used and a good grade of pulp could probably be produced in 3 or 4 hours. Unfortunately, the equipment used in this work was of the wrong design for working with a wood like E. corynocalyx. Excellent results were obtained when the Hypo process was applied to E. globulus and E. ~~viminalis~~ tereticornis. Cook No. 20 of E. ~~viminalis~~ tereticornis was made by the Modified Hypo process because an easy bleaching pulp was desired, but in a larger digester in which condensation was less an easy bleaching pulp could have been produced from this wood by the standard Sulphate process merely by cooking somehwat longer and using 30 to 33 percent total alkali.

Lafge samples of the pulp from all of the different cooks were kept in numbered, paper containers and in gallon size tins with tight-fitting lids.

The most important points to consider when determining the quality of pulp are (1.) the strength possessed by paper made from it, and (2.) the amount of bleaching solution required to completely bleach the pulp. It is also valuable to study the fibres microscopically; and it is important from an economic standpoint to know how much pulp a given amount of wood will yield. An attempt was made to answer the first point by sending samples of the pulp from some of the cooks to the testing laboratory of a Pacific Coast paper company which volunteered to make test sheets of paper from the pulp and test the strength according to standard methods. The results of the tests have not yet been received. To answer the second point, a series of bleach consumption tests were made on the pulp from six of the cooks. The method followed in these tests was one recommended by the Joint Executive Committee on Vocational Education, representing the Technical Sections of both the Canadian and the American Pulp and Paper organizations.

A weighed quantity of from 4 to 5 grams of the air dry pulp was macerated in a mortar with a definite quantity of water. The mass was poured into a wide mouth, glass stoppered bottle and slightly more than the amount of standardized bleach solution which the sample of pulp seemed to require was added. The contents were kept at a temperature of from 35 to 40°C for three hours and shaken at frequent intervals. The contents of the bottle were then poured over a Büchner filter, washed, and the filtrate titrated with standard sodium thiosulfate solution.

("Manufacture of Pulp and Paper" Vol.III, Section 8, page 46- 2nd Ed.) Results of the tests are given in Table 11. The figures indicate the percentage of available chlorine required, based on the original, air dry weight of the pulp. The bleach consumption of the pulp from Cook No. 18, the lightest colored pulp obtained from E. corynocalyx in any of the cooks, is seen to be much higher than that of the pulp from either of the other two woods. The figures for the easy bleaching pulp from E. globulus, Cook No. 5, are very good, and can be favorably compared to the bleach requirements of the Sulphite pulp usually obtained from woods like spruce and hemlock. The Sulphite pulp from the latter woods is used in the manufacture of news-print without being bleached. The light color of the pulp from E. globulus is a point very much in its favor. E. ~~viminalis~~ tereticornis, too, yields a pulp having a color which, tho' not as light as that of E. globulus pulp, can still be considered as excellent. A sample of Kraft pulp from red cedar, a wood from which a good, light-colored Kraft pulp is made, is included with the samples of pulp from the different eucalyptus species. The E. globulus pulp is seen to be of a much lighter color than the pulp from red cedar, while the pulp of E. viminalis is a trifle darker. The strength of the sample sheet of red cedar pulp should not be compared with that of the eucalyptus pulp, as the former was made in a standard sheet machine in the correct manner to develop its strength. The sheets of eucalyptus pulp were made on a hand mold by the crudest of methods, as will be described in a later paragraph.

The accompanying photomicrographs (Figs. 4 to 9) were all made at a magnification of 96 diameters for the purpose of comparing them with the photomicrographs of other eucalyptus species reproduced in "Australian Wood Fibres". (Baker and Smith. See Bibliography.) Figures 4 and 5 are E. globulus fibres from Cooks Nos. 4 and 5 respectively. The length of the fibres appears to vary between 0.8 and 1.2 mm. The short, thick ray cells are very much in evidence, a characteristic feature of the pulp from hardwoods. Figure 4 also shows two of the cells from the vessels. The ray cells and the cells from the vessels do not give any strength to the pulp, in fact, they weaken it. Fortunately, the ratio of width to length is very small in the case of the tracheids and the wood fibres, thus giving the pulp good "felting" qualities. The interlacing of these longer fibres gives paper its strength. Figures 6 and 7 show the fibres of E. corynocalyx to be on the average very slightly shorter than those of E. globulus, but with a smaller percentage of ray cells. This pulp should be stronger than E. globulus pulp or E. ~~viminalis~~ tereticornis pulp, as the latter also shows a large

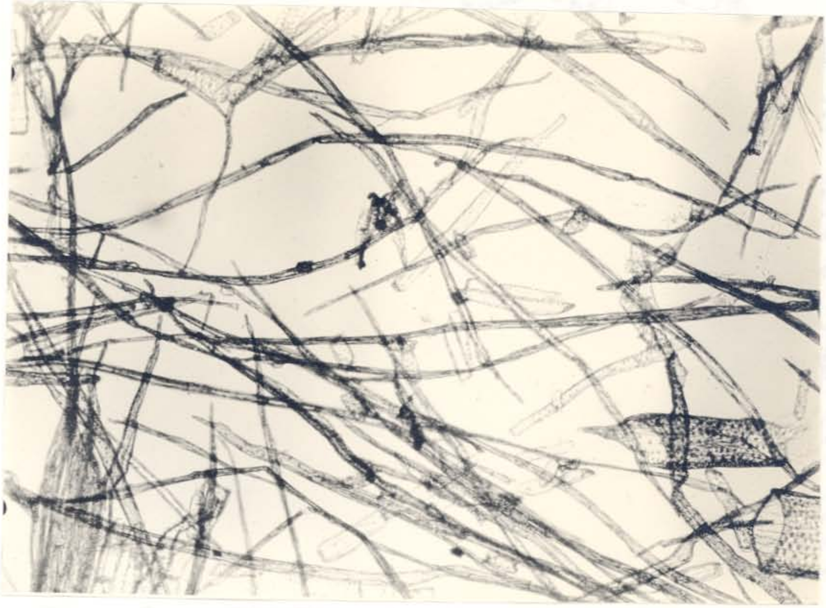


Fig. 4. - Kraft pulp from E. globulus. (Blue Gum.) Cook No. 4. The large, thick cells in the lower, right-hand corner are cells from the vessels. These and the short ray cells contribute no strength to the pulp. Magnification 96 diameters as in Figs. 5, 6, 7, 8 and 9.

Fig. 5. - Easy bleaching Sulphate pulp from E. globulus. Cook No. 5.

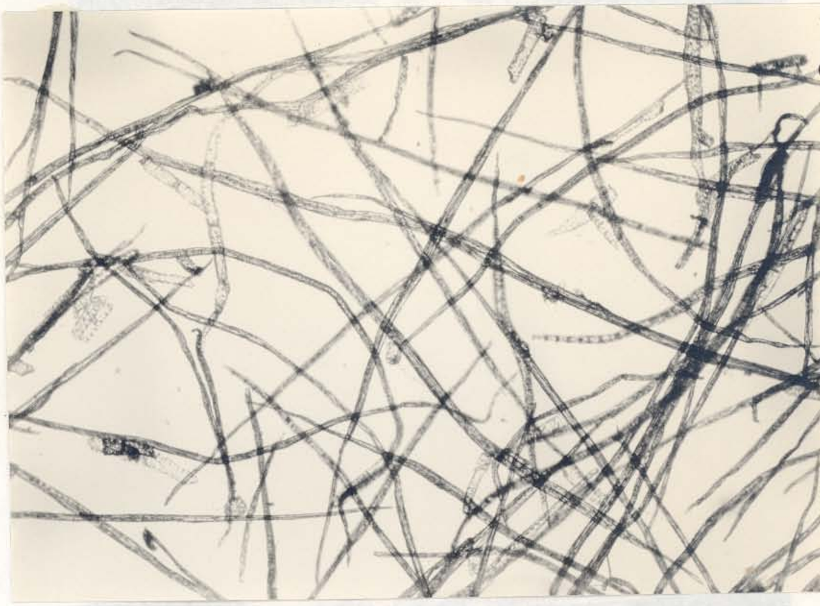


Fig. 6. - Kraft pulp from E. corynocalyx, Cook No. 8. Note the smaller number of short, ray cells as compared to Figs. 4, 5, and 8.

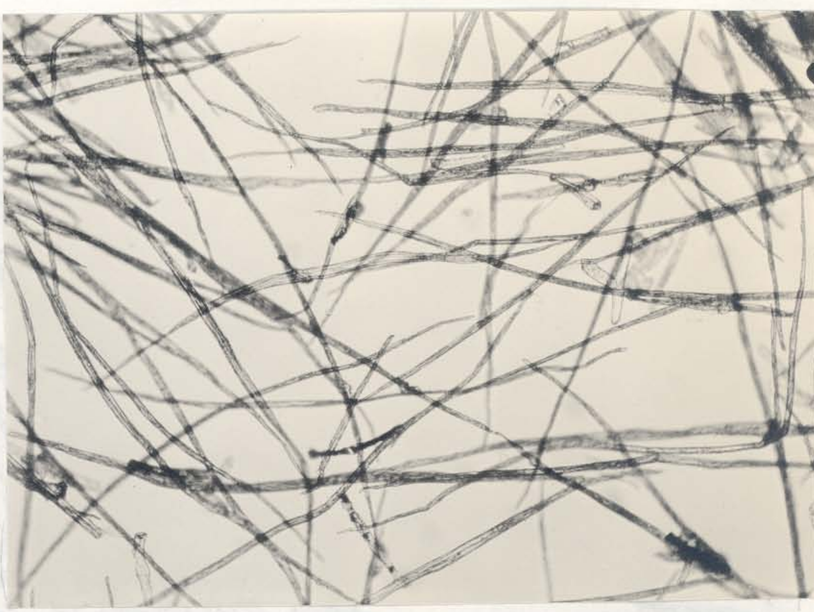


Fig. 7. - Pulp made from E. corynocalyx by the Modified Soda process. Cook No. 10.

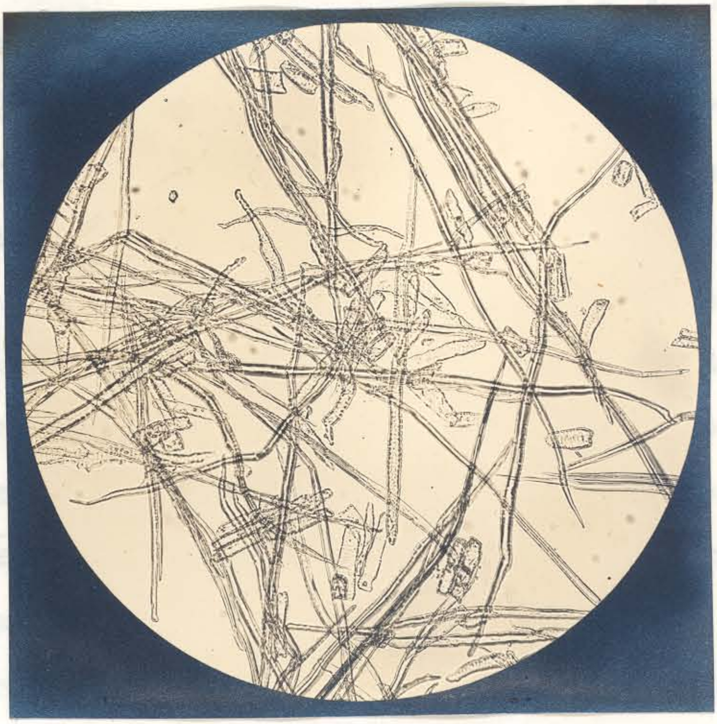


Fig. 8.-E. viminalis pulp from Cook No. 19. (Hypo Process.)

Fig. 9. - Kraft pulp made from red cedar. Shown here enlarged the same as the other photomicrographs for comparison.

percentage of the short ray cells (However, refer to the Appendix.). The fibres of E. viminalis, shown in figure 8, appear to be shorter than those of either of the other two species. As nearly as can be judged the fibres are 0.7 mm and longer, with the tracheids, (those showing a large number of pits,) even shorter than 0.5 mm. Accordingly, of the three pulps, E. corynocalyx would be expected to have the greatest strength, with E. globulus next and E. ~~viminalis~~ tereticornis last. All of the fibres are shorter than those shown in Fig. 9. These are the fibres in the pulp of red cedar cooked by the Kraft process, and are tracheids some 3 or 4 mm. in length. As indicated by the shape of the fibres, the pulp from Red Cedar is exceedingly strong. This photomicrograph, made to the same magnification as the others, is shown here for purposes of comparison. It can be seen that, altho' the red cedar fibres are much longer than the eucalyptus fibres, they are also much wider; and, in fact, the ratio of width to length, or the felting power, appears to be even smaller in the case of the eucalyptus fibres. Thus it seems that by proper treatment of the pulp from the three species tested, a reasonably strong grade of paper could be obtained.

After all, the proof of the pulp lies in the paper that can be made from it. The small hand mold, of which the two parts- deckel and frame- are

~~are~~ shown in Fig. 1, was used to make a few test sheets of paper. Beating the pulp is essential in order to develop any strength, and as no ball mill or other method of beating the pulp was available, the paper produced in these tests should not be expected to have much strength. No sizing materials were used to stiffen the paper, the felts were too coarse for the purpose, and the vat used was too shallow to give a well formed sheet. In addition, the operator had not acquired the proper technique, and when the hand mold was being removed from the vat, in forming the sheet, could not give the "shake" as it should be given. Unless the "shake" is done properly, the paper will not have any strength. The best authorities state that at least five years practice is needed before the technique of the "shake" is mastered. In spite of all these difficulties, the test sheets of paper, as can be seen from the samples included in this report, are fairly strong. What can be done when the pulp is properly treated is shown by the small sample of Australian paper. This paper was clipped from Bulletin 25 of the Institute of Science and Industry of Australia (see bibliography) and contains 60 percent of Soda pulp from species similar to the three tested in this work. The sample also contains 30 percent of spruce Sulphite pulp and 10 percent waste paper. Pulp produced by the Sulphate or Hypo processes is much stronger than Soda pulp, and correct treatment of the pulp produced in this work should yield a paper stronger than the Australian sample submitted without the addition of any pulp from other woods.

## SUMMARY.

The object of this work was to obtain data on the pulping characteristics of the three Eucalyptus species planted most extensively in California. Information was particularly desired on the quality of pulp that could be obtained by some standard process other than the Soda process. Because it was necessary to abandon the standard Sulphate process and change to processes which have not been thoroly tested in commercial work, the data is not as complete as it should be. The first point, however, has been covered sufficiently to warrant some definite conclusions.

The wood of eucalyptus globulus is very easily reduced to a pulp having a remarkably light color, as can be seen by comparison of the sample sheet of pulp from Cook No. 2 with the sample of red cedar pulp submitted. The strength of the pulp is decreased by the large number of short ray cells, and the fibres are shorter than those from a typical conifer. An advantage from the standpoint of strength is the fact that, as with the other two species tested, the ratio of length of the fibres to width is high.- The pulp produced by the Hypo process is a little redder than that produced by the standard Sulphate process. The yield of pulp from E. globulus is high.

The combination of light color and high yield put eucalyptus globulus wood in a very favorable light, especially when it is remembered that this is the most extensively planted and one of the fastest growing species of eucalypts in California. That the shortness of fibre is not a serious difficulty has been demonstrated by the recent work conducted for the Institute of Science andIndustry of Australia.

Somewhat less favorable are the results of the work with E. ~~viminalis~~ tereticornis. The pulp from this wood is a little darker than the sample of red cedar pulp and much darker than the pulp of E. globulus. The color is, however, good. Whether it would be lighter if cooked by the standard Kraft process is a difficult question to answer without experimental evidence. Judging from the photomicrographs, the strength of this pulp is close to that of E. globulus; the difference, if any, would probably favor the latter. E. ~~viminalis~~ Tereticornis wood is easily pulped, but again not so much so as E. globulus. This species of eucalyptus is about as fast growing as E. globulus or blue gum, and is more resistant to frost. It has not been as extensively planted as some of the other species, but has done well wherever the soil conditions were reasonably good. (See Bulletin 380 of the College of Agriculture at Berkeley, Calif. for details.)

Results with the wood of E. corynocalyx or sugar gum are not at all promising. The wood is not easy to reduce to pulp, and the color of the pulp obtained is poor. Photomicrographs of the fibre indicate a possibility of greater strength than with the other two species, but this is, after all, only a conjecture and can not be proven until actual tests of strength have been made. Further study of the species is not recommended. The tree is less frost resistant than blue gum or manna gum and is not grown extensively except in Southern California.

In conclusion, therefore, it may be said that the wood of the blue gum is entirely suitable for the manufacture of paper pulp by the Sulphate or Soda processes, or even by such modifications as the so-called Hypo process. The wood of E. ~~viminalis~~ tereticornis or ~~Manna~~ Red gum is less desirable, but still entirely worthy of investigation. Further effort spent on pulping sugar gum by any of the alkaline processes would probably be wasted. Tests should be made of the possibility of pulping this wood by the standard Sulphite process.

Dec. 1, 1928

APPENDIX

Additions and Corrections to Thesis Submitted on August 30.

Although some seventy species of eucalypts have been planted in California, about ninety-nine percent of the stand consists of the four species known commonly as Blue Gum, Gray and Red Gums, and Sugar Gum. As stated in the original thesis, the approximate proportion of Blue Gum is estimated to be around 80 percent. Gray Gum,(E. tereticornis,) and Red Gum, (E. Rostrata,) are difficult to distinguish from each other. Together they form fifteen percent of the eucalyptus stand. Next to them comes Sugar Gum, (E. corynocalyx,) forming four percent of the total. Of the species making up the remaining one percent, one of the most common is Manna Gum, (E. viminalis.) As it was the purpose of this work to test the species most extensively planted in California, those originally selected for investigation were Blue Gum, Gray Gum, Sugar Gum and Manna Gum. The Gray Gum was chosen instead of the similar Red Gum because it is a taller, straighter tree and the external features of the wood made it seem a little more suitable. In general, the wood is more straight-grained than that of the Red Gum. However, by the time the digester had been completed and tests

Fig. 10 - Branches of E. tereticornis.

made on Blue Gum and Sugar Gum, it was decided that the small amount of time left would permit the testing of only one more species. Manna Gum was selected and efforts were made to obtain a sample. E. viminalis is relatively scarce in Southern California, but one of the Los Angeles County Assistant Foresters told of a grove located west of the city of Burbank. I did not at the time know enough about the different species of eucalypts to be sure that the tree cut was actually a Manna Gum, so the precaution was taken to make a fairly complete description of the tree. Several branches with leaves, flowers, and fruit were taken and photographs made of them. One of the photographs is shown here as Fig. 10. It was fortunate that the description and photographs were made, as it was later found that the tree was a Gray Gum, or E. tereticornis, and quite definitely not a specimen of E. viminalis.

The conclusion that the tree was a Gray Gum was made after discussing the description with Mr. Woodbridge Metcalf, Extension Forester at the University of California at Berkeley and an expert on the growth of the eucalypts in California. The more important points on which the conclusion was based are briefly as follows: The fruit of the tree in question is about the same size as that of both E. tereticornis and E. viminalis, but has valves more prominently exserted than is usual with the latter.

The rim is prominent and domed, a characteristic frequently found in E. tereticornis but not in E. viminalis. The peduncles are much longer than those of the latter species; and there are usually seven, rarely less and occasionally one or two more, flowers in the umbel. In the case of E. viminalis, the peduncles are short, and the number of flowers in the umbel is usually three and never more than seven. The bark of the specimen was inclined to come off in flakes while that of E. viminalis more frequently comes off in long strips. The abnormal or "sucker" leaves of this tree were broadly lanceolate like those of the tereticornis. E. viminalis has abnormal leaves which are sessile.

This work has accomplished its original purpose in that the three species tested are actually the most commonly planted eucalypts in California. E. rostrata and E. tereticornis are, of course, considered together. E. tereticornis was tested by Miller of the U. S. Forest Products Laboratory by the Sulphate process and found to be satisfactory. A photomicrograph of its fibres reproduced in "Australian Wood Fibres" is similar to the one included in this report. E. tereticornis is a tree which is more resistant to heat and drought than E. globulus. Its wood is considered good for timber in Australia. The mean annual growth of the tree in California is estimated by Metcalf[1] to be less than one cord per acre, while the

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[1] "Growth of Eucalyptus In California Plantations."

Blue Gum averages three cords, and on good soil often reaches over five cords per acre. It was unfortunate that it was not possible to test E. viminalis as the tree grows well and rapidly in a variety of conditions and is frost resistant.

It was mentioned in the original thesis that samples of the pulp from some of the different cooks had been sent to the testing laboratory of one of the Paper Companies of the Pacific Coast. No report of the test had been received up to the time the thesis was submitted, but in September a visit was made to the laboratory in question. The pulp had been tested and some surprising results obtained. Samples of paper had also been made from the three batches of pulp submitted. The procedure followed in testing pulp at this laboratory is first to determine the moisture content of the sample and then to place ~~xx~~ in a ball mill an amount of it equivalent to a certain weight of the pulp in a bone dry condition. The ball mill is filled with a definite number of rocks of standard size and a quantity of cold water is poured in with the pulp. The mill is revolved and the number of revolutions checked with a counter. At intervals of six hundred revolutions samples of pulp are removed and made into sheets of paper on a standard sheet machine. Great care is taken to always prepare the paper in exactly the same way. The sheets are put under a measured hydraulic pressure for one minute after they are formed and are then carefully dried. The test is made by placing the dried and weighed sheets in an apparatus known as a Mullen strength tester. The machine measures the force required to burst a hole in the paper. In this test the action of the ball mill is similar to that of the beating engines used in the paper mill. As it is desirable to find how much beating will be needed to develop the maximum strength of the pulp, the samples are removed at regular intervals.

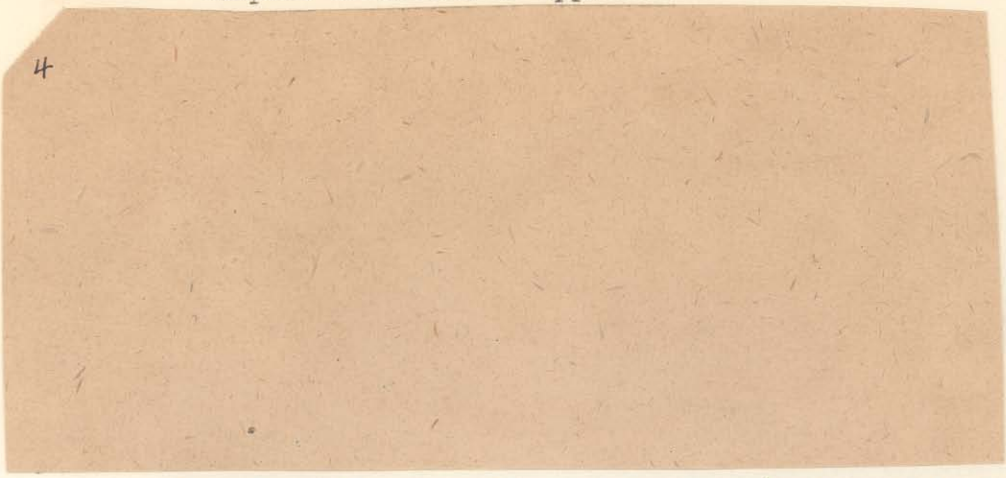
The mill where the tests were made produces kraft, sulphite, and groundwood pulp. Using hemlock wood and spruce, the strength of the kraft pulp varies between 120 and 140 percent, that of the sulphite between about 80 and 90, and the groundwood gives a test of 22 to 30. Kraft pulp is very strong and is used for wrapping papers and other purposes where strength is essential. Its color is a dark brown. The sulphite pulp is nearly white and is fairly strong. Newsprint contains 20 percent of it mixed with the groundwood for the sake of strength.

Results of the tests are given in Table III. The tests unfortunately did not include any of the pulp from E. tereticornis. Two things about the results of the test with E. globulus are remarkable. One is that it should have given such high tests as 91 percent for

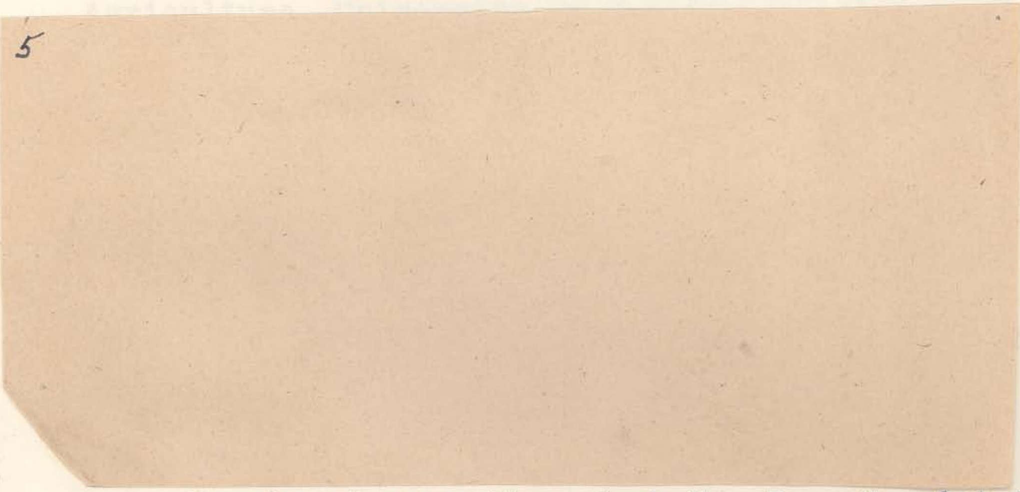
Cook No. 4 and 94 percent for Cook No. 5, and the other is that the maximum strength should have been reached in 600 revolutions in one case and 1200 in the other. The maximum strength of kraft pulp from hemlock is reached in about 6,000 revolutions. The saving in power and time in preparing such a pulp would be tremendous. The results of the tests are exactly the reverse from what was predicted from a consideration of the photomicrographs of the fibres. E. corynocalyx does not test much higher than groundwood pulp, though as it was a very hard pulp, further beating might have developed a little more strength. On the whole, the kraft pulp from E. globulus is very satisfactory. Although it is not as strong as good kraft pulp from softwoods, its strength compares favorably with that of spruce and hemlock sulphite pulp.

To complete this work a test of the strength of pulp from E. tereticornis should be made. Pulping tests on the wood of E. viminalis should prove of great value in this study of the eucalypts of California. No less desirable would be large scale tests of the ability of some members of the "Ash" group of eucalypts to grow well in plantations in different parts of the state. Species which should be thoroughly investigated are E. regnans, E. Delegatensis, E. obliqua, E. Sieberiana, and E. eugenioides. Tests should also be made with E. pilularis, E. maculata, E. saligna, E. diversicolor, and E. Dalrympleana.

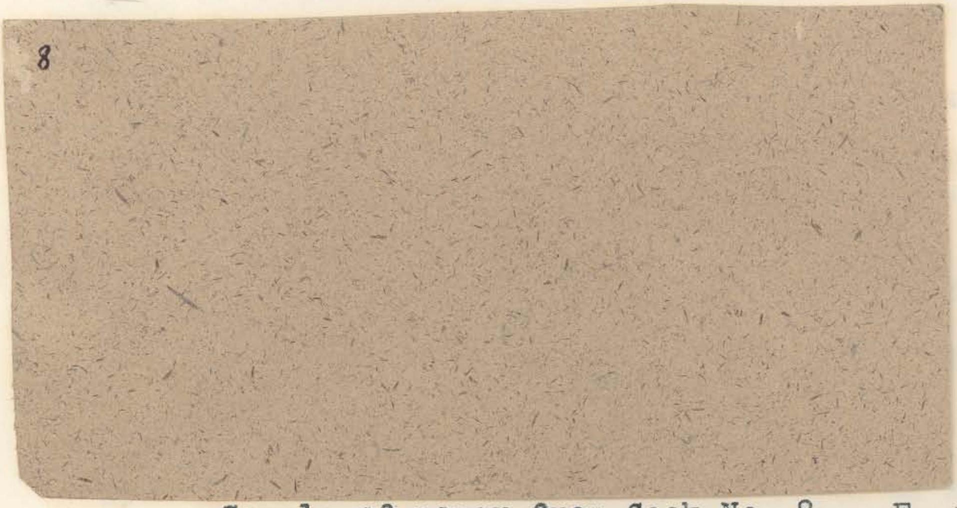
Samples Described in Appendix.




Sample of paper from Cook No. 4. E. globulus by the Kraft process.




Sample of paper from Cook No. 5. E. globulus by the Easy Bleaching Sulphate process.




Sample of paper from Cook No. 8. E. coryno-calyx by the Kraft process.

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[7] "Australian Wood Fibres." p 12 .

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17 See Bulletin 380 described under [3] .

18 See pp 23 - 24 of Bulletin 380 described under [3] .

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TABLE I.

COMPOSITION OF COOKING LIQUORS.

| Cook'g Liquor No. | NaOH lbs/ft$^3$ | $Na_2S$ lbs/ft$^3$ | Total Alkali as NaOH. lbs/ft$^3$ | Sulphidity. $100(\frac{Na_2S}{Tot.Alk.})$ | Process for making liquor. |
|---|---|---|---|---|---|
| 1-A | -- | -- | --- | about 16 pct. | Dissolved S in NaOH sol'n. |
| 2 | 8.25 | 1.66 | 9.95 | 16.7 pct. | Same as 1-A |
| 5 | 4.98 | 2.05 | 7.08 | 29.0 " | $Na_2S$ dissolved in NaOH sol'n. |
| 6 | 10.02 | 4.14 | 14.27 | 29.8 " | $H_2S$ gas dissolved in NaOH sol'n. |
| 7 | 9.3 | -- | -- | -- | Sod. thiosulfate cryst. dis'd in NaOH sol'n. |

Cooking liquor No. 7 contained 7.88 lbs per cu.ft. of sodium thiosulfate (anhydrous salt by analysis) in place of sodium sulfide. The ratio of $Na_2SO_3$ to NaOH was 0.85 .

TABLE II. - DATA ON PULPING TESTS.

| Cook No. | Species | Process | Total Alkali[1] | Sulphidity[2] | COOKING TIME[3] 1st Per. | 2nd Per. | Total | Pressure[4] (lbs) | Liquor used. (cf Tab.I) | YIELD Pulp | Screenings | Bleach Consumption. | Quality of Pulp. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | E.globulus | Sulfate (Kraft) | -- | ca.16 | 1:05 | 0:55 | 2:00 | 125 | No.1-A | -- | 0 | -- | Pulp light in color, soft. Overcooked. No screenings. |
| 2 | " | " | 23% | 16.7 | 0:40 | 2:00 | 2:40 | 110 | " 2 | -- | 0 | -- | Similar to pulp from previous cook. |
| 3 | " | " | 23 | 29.0 | 1:00 | 1:10 | 2:10 | 98 | " 5 | 50.6 | 1.2 | -- | Not overcooked so much as first two tests. |
| 4 | " | " | 20 | 29.0 | 0:40 | 0:50 | 1:30 | 98 | " 5 | 50.4 | 2.6 | 35.0 | Good. light color. Pulp still a little too much overcooked for Kraft. |
| 5 | " | Sulfate (E.B.)[5] | 30 | 29.8 | 0:35 | 2:00 | 2:35 | 98 | " 6 | 46.3 | 0 | 13 | Very light color. Good "easy bleaching" pulp. |
| 6 | E.coryno-calyx | Sulfate (Kraft) | 20 | 29.8 | 0:35 | 0:45 | 1:20 | 98 | " 6 | 30.5 | 15-25 | -- | Dark grey, raw mass. Large proportion of uncooked chips. |
| 7 | " | " | 21 | 29.8 | 1:00 | 1:00 | 2:00 | 98 | " 6 | 32.4 | 15-25 | -- | Similar to pulp from previous cook. |
| 8 | " | " | 23 | 29.8 | 1:00 | 2:00 | 3:00 | 98 | " 6 | 45.9 | 2.8 | -- | Grey, raw pulp. Color too dark. |
| 9 | " | Soda | 24 | 0 | 1:15 | 2:45 | 4:00 | 90 | " R | 46.3 | 2.8 | -- | Similar to pulp from previous cook. |
| 10 | " | Modified Soda | 50 | 0 | 0:25 | 0:41 | 1:06 | 95;103 | R | 43.5 | 1-2 | -- | Ditto. |
| | | | NaOH[6] | $Na_2S_2O_3$[7] | | | | | | | | | |
| 11 | E.globulus | "Hypo" | 15.7 | 13.3 | 0:36 | 0:40 | 1:16 | 98 | No.7 | 0 | -- | -- | No pulp. |
| 12 | " | Soda | 22 | 0 | 0:24 | 0:50 | 1:14 | 98 | R | 0 | -- | -- | " " |
| 13 | " | Hypo | 16 | 13.6 | 0:30 | 2:00 | 2:30 | 98 | No.7 | -- | -- | -- | About one percent yield of pulp. |
| 14 | " | " | 19.5 | 16.5 | 0:32 | 2:58 | 3:30 | 98 | " 7 | 53.0[8] | 0.05 | 35 + | Pulp light in color, slight red tinge. A good quality of pulp. |
| 15 | " | Soda | 19.5 | 0 | 0:31 | 2:54 | 3:25 | 98 | R | 28-30 | 22-24 | -- | A check on the pulping method of the previous cook. |
| 16 | E. coryno-calyx | Hypo | 18.7 | 15.8 | 0:30 | 3:30 | 4:00 | 98 | No.7 | 51.5 | 6.7 | -- | Pulp very dark and raw. |
| 17 | " | " | 20.7 | 17.6 | 0:30 | 4:36 | 5:06 | 98 | R | 48.4 | 2.6 | -- | Grey, raw pulp. Color too dark. |
| 18 | " | Modified Hypo. | 50 | 38.4 | 0:44 | 1:26 | 2:10 | 95-100 | R | 42.7 | 0.06 | 42.4 | Much lighter in color than previous cooks of this wood. A fair grade. |
| 19 | E.viminalis | Hypo | 22.85 | 18.0 | 0:32 | 4:00 | 4:32 | 95-100 | R | 43.8 | 0 | 36.8 | A good, soft pulp. Lighter than No.18, darker than No.14 . |
| 20 | " | Modified Hypo. | 49.8 | 42.3 | 0:46 | 1:32 | 2:18 | 95;101 | R | 37.7 | 0 | 30.0 | Similar to previous cook, but lighter in color. |

1 Total Alkali, as NaOH, given as a percent of the wt. of oven dry wood.

2 Sulphidity = 100 x $Na_2S$/Total Alkali .

3 For ordinary cooks, the 1st period is the steaming time, the 2nd period is the cooking time. For modified cooks, the time with liquor and the steaming period are given.

4 The pressure during the cooking period is given. For modified cooks, the pressure during both periods is given.

5 E.B. = Easy bleaching.

6 This column gives NaOH, not total alkali, as a percent of the wt. of oven dry wood:

7 The balance of this column gives $Na_2S_2O_3$ as a percent of the weight of oven dry wood. (Sodium thiosulfate, less water of hydration.)

8 More accurate method for determining yield used with No.14 and those following. Figures for previous cooks 2 to 5 percent low. See text for description of methods.

R in "Liquor used" column indicates that the required amount of chemicals were weighed out for each cook.

TABLE III.

Results of Tests on Strength of Eucalyptus Pulp.

| Cook No. | Species | Process | Mullen Strength Test. Revs. in Mill | Mullen test |
|---|---|---|---|---|
| 4 | E. globulus | Kraft | 600 | 91 % |
| | | ("Hard" | 1200 | 82 |
| | | Sulphate | 1800 | 60 |
| | | Pulp.) | 2400 | 53 |
| | | | 3000 | 38 |
| 5 | E. globulus | E. B. | 0 | 49 |
| | | ("Soft" | 600 | 75 |
| | | Sulphate | 1200 | 94 |
| | | Pulp.) | 1800 | 67 |
| 8 | E.corynocal-yx. | Kraft | 0 | 18 |
| | | | 600 | 34 |
| | | | 1200 | 36 |

Sulphate pulp from E. globulus. (Cook No. 2)

All of these samples, (excluding, of course, the Australian paper,) were prepared from unbeaten, unsized pulp. Strength is not to be considered, - the samples are shown to illustrate the color and texture of the pulp from the different woods.

Bleached sulphate pulp from E. globulus. (Cook No. 2)

Australian Eucalyptus Paper.

Hypo pulp from E. corynocalyx.

Cook No. 17.

Unscreened Kraft Pulp
from red cedar.

Hypo pulp from E. viminalis.

Cook No. 19