SULFITE PULP PRODUCTION:
SOME FACTORS PERTINENT TO MEETING
WAR-BORN SHORTAGES

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SULFITE PULP PRODUCTION: SOME FACTORS PERTINENT TO MEETING WAR BORN SHORTAGES

By J. N. McGOVERN, Associate Technologist and G. H. McGregor, Senior Engineer

Forest Products Laboratory, Forest Service
U. S. Department of Agriculture

SUMMARY

The prospect of a serious shortage of sulfite pulp in 1944 prompted the Forest Products Laboratory to survey ways of increasing pulp production under existing conditions. It is suggested that (1) noncritical pulping species and logging, sawmill, and veneer mill wastes be utilized to the full extent of their availability; (2) advantage be taken of dense woods giving high yields per wood volume; (3) the pulping process be conducted in conformity with known principles for maximum pulp production; and (4) fiber losses from chip preparation and pulp treating and bleaching be minimized. Briefly discussed are pulping procedures applicable to species less commonly used for sulfite pulping, including aspen, cottonwood, birch, maple, gum, beech, northern pines, tamarack, western pine, larch, Douglas-fir, southern pine, western redcedar, Sitka spruce, alder, and mixed species. Sulfite process variables affecting pulp production are examined in some detail. Finally, general observations are given on methods of reducing fiber losses in the operation of wood and chip preparation, pulp washing, screening, and bleaching.

INTRODUCTION

Present trends in the sulfite pulp industry indicate a continued demand at the current high level but a decline in production, with the probability of an acute pulp scarcity in 1944. This prospective reduction in sulfite pulp production arises primarily from shortages of woods labor and logging facilities employed to produce pulpwood. Provision for sufficient woods labor is a direct and obvious way of averting the impending pulp scarcity. The threatened shortage can also, however, be lessened by utilizing species that are available but seldom used for sulfite pulping, and by operating the pulp mill so as to obtain the maximum yield of pulp from the

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available wood. These expedients are manifest and no doubt have come to the 
attention of most mill operators. Nevertheless, it is believed worth while 
under the present emergency conditions to focus attention on any ways in 
which sulfite pulp production can be improved. In this report possible pulp-
wood sources are pointed out, the general pulping procedures to be used with 
the less common species are indicated, and possible means of carrying on the 
sulfite pulping operation so as to obtain increased pulp yields are reviewed. 
The information appearing in this report can be found for the most part in 
the literature on sulfite pulping or in the experience of mill operation, 
although generally in some other connection. It is realized, too, that 
"best" practice, as judged by successful modern performance, will sometimes 
conflict with an individual mill's experience as to the best way to perform 
a particular operation.

**Seldom-Used Species**

Many sulfite mills in the United States can perhaps augment their 
dwindling supplies of spruce, balsam and grand fir, and eastern and western 
hemlock, which are generally cut at some more or less distant point, with 
locally available wood species considered heretofore as being more or less 
unsuited for sulfite pulping. Depending on the region, such supplementary 
wood supplies might consist of logging, sawmill, and veneer mill wastes and 
second-growth wood-lot material obtainable in the vicinity. This material 
would be for the most part made up of hardwoods, such as aspen, birch, beech, 
maple, tupelo (gum), and cottonwood; northern pines, such as jack, red, and 
white; tamarack; western species including larch, white pine, redcedar, and 
Douglas-fir; and some southern pine. During the last 15 or 20 years, in-
terest has expanded in the use of these so-called "inferior" species in an 
endeavor to broaden the pulpwwood base, and considerable literature has 
appeared on the subject. In practice, several mills have utilized this source 
of wood to considerable advantage. The present appears to be a favorable 
time to utilize these less common pulping species to the utmost.

Certain disadvantages may attend the use of such woods as the hard-
woods, pines, and other little-used conifers. The pulps obtained from them 
may be relatively low in strength, shivey, of poor color, or bleachable only 
with difficulty. Some of the species, such as Douglas-fir, southern pine, 
and tamarack containing a large portion of heartwood, may have to be cooked 
drastically to produce an acceptable pulp. Others may be limited to uses 
permitting unbleached pulp. Such inferiorities, however, can be tolerated 
in the face of a serious pulp shortage. On the other hand, some of these 
species possess the advantages of low cost, large yields of pulp from a unit 
of wood volume, and increased digester yields. Further, pulps from certain 
of these species may have particular properties which make them especially 
suitable for special purposes.
Physical and Chemical Characteristics

The densities and chemical compositions of a number of the common and some of the less commonly used pulpwoods are given in table 1, which can be used as a general guide to the properties of numerous species of potential use in sulfite pulping. It should be recognized that the values given in table 1 were obtained from random samples tested at the Forest Products Laboratory. Many of the species show a wide variation in properties within the species itself, and other similar shipments could have properties considerably different from those given in table 1. In addition to the variation within a species, certain outstanding differences exist between various species. In general, the hardwoods, as is well known are denser, have shorter fibers, and are lower in lignin and higher in pentosan contents than the softwoods. Density is an important property from the standpoint of pulp yield obtained from a unit volume of wood, and fiber length has an important effect on pulp properties. The softwoods themselves, which include the common pulping species, vary relatively little in percentage of the main chemical constituents in the wood, but show an appreciable variation in their contents of the minor constituents. The ether-soluble values given in table 1 for the various woods illustrate this variation. Other minor constituents, whose identities have not been fully established, are believed also to affect the pulping of some species and the color of others.

Pulping Procedures

Pulping most of the less common species by the sulfite process requires no radical changes from the pulping procedures used for the customary pulpwoods, although several points of difference in pulpability and pulp characteristics can be mentioned. These differences are outlined in table 2.

Aspen and Cottonwood

Since aspen and cottonwood, because of their relatively lower densities (particularly that of northern grown aspen) may be charged in slightly lower weights than spruce or hemlock (approximately the same as that for fir) some slight adjustment in acid concentration or temperature schedule may be made with advantage. In practice, however, the cooking procedures for woods of either higher or lower density are generally the same. Controlled chip packing, with the resultant increase in digester charge, may offset natural differences in density between these hardwoods and other softwoods. Aspen and cottonwood chips are penetrated with sulfite acid in the same time as spruce chips, but they appear to delignify somewhat more rapidly than the spruce. Other conditions being equal, these hardwoods will, therefore, require a shorter cooking time than spruce. The color of the waste liquor at the end of the digestion will be darker than that of spruce but lighter than that of hemlock. The percentage yields by weight of pulp from aspen and cottonwood will be higher than those from most other species because of their higher cellulose contents, and this partially offsets the effect of their low densities on yield per unit of wood volume, as shown in table 2. The aspen
and cottonwood pulps will have strength properties, especially tearing strength, inferior to those of pulps from the commonly used conifers. Nevertheless, these hardwood pulps will be valuable for many purposes. Aspen pulp from green wood may have a tendency to be pitchy.

Birch, Beech, Maple, and Tupelo (gum)

The heavier hardwoods, birch, beech, maple, and tupelo, in contrast with the lighter ones discussed above, will make up a heavier digester charge than spruce or hemlock. Sometimes an increase of 30 percent or more may be realized. Since the volume of acid charged will be equal to or less than that usual with these heavy woods, an increase in the contents of both total and combined sulfur dioxide in the cooking liquor is usually considered essential. The chips from these hardwoods are penetrated by the sulfite acid with slightly more difficulty than spruce, so that a somewhat longer penetration period is generally recommended for the hardwoods. Although birch chips (and probably maple and tupelo) are delignified at the same rate as spruce chips, the dense nature of the wood appears to cause the diffusion of the cooking liquor into and out of the chips to be somewhat slower than for spruce. Consequently, a slower rise to the cooking temperature may be necessary in order to ensure uniform pulping action. The sulfite pulps from birch and tupelo will approach eastern hemlock in all but tearing strength. The maple and beech pulps will be somewhat inferior to the birch and tupelo pulps. White birch pulp will tend to exhibit the same pitchy nature as spruce.

Northern and Western Pines and Western Larch

These coniferous species, although available in considerable amounts as second-growth material and sawmill waste, have found only limited utilization in the sulfite pulping industry because of the incomplete and unsatisfactory reduction to pulp of some growth types under ordinary sulfite pulping conditions. The difficulty in pulping these species lies in the heartwood. It is well known that the sapwood from these species can be pulped with no trouble. The reasons for the refractoriness of the heartwood toward sulfite pulping liquor cannot be gone into in a report of this kind, but there is evidence that small amounts of certain chemical constituents are present in the heartwood which render the lignin insoluble under the usual conditions of pulping. The difficulties arising from this situation, for which no specific remedy is now available, can be alleviated considerably, however, by cooking these refractory species under milder temperature conditions for longer times and with liquors stronger in sulfur dioxide than normally employed in cooking spruce. Ordinarily, a long cook at a low temperature is not attractive to the quick-cook sulfite operator, but in view of the present shortage of the standard pulpwoods new species and procedures are worthy of serious consideration. Even though, with the suggested modifications, the screenings obtained may be high and the pulp quality inferior, such pulp can find an important place in fulfilling the pulp requirements for the next year. Sawmill waste, if consisting mostly of slabs and edgings, may contain a high percentage of sapwood. In this case pulping processes satisfactory for the common pulpwoods can be applied.
Southern Pine, Tamarack, and Douglas-fir

The heartwood of the southern pines, tamarack, and Douglas-fir is generally too refractory for the practical application of the sulfite process, although with drastic pulping procedures a low yield of product may result which is suitable for certain chemical derivatives or, where color is not important, for use as an unbleached pulp. The changes in the cooking procedure suggested for the northern pines may be helpful. There may, however, be available to sulfite mills in southern pine areas wood of young growth containing little or no heartwood; or, at sawmills, wastes of southern pine or Douglas-fir slabs and edgings composed predominately of sapwood may be available. In these cases usual sulfite pulping practice can be employed.

Western Redcedar, Sitka Spruce, and Alder

Western redcedar is reported to be satisfactorily reduced by the sulfite process. The pulp, however, is said to be difficult to bleach and therefore probably would find its best outlet as an unbleached product where color is not important. Sitka spruce is readily reduced by the sulfite process to a high-quality pulp with exceptionally long fibers but with a very high resin content. There appears to be no information available on the sulfite pulping of alder, but presumably it would react similarly to birch or beech.

Mixed Species

Because of differences in the pulping characteristics of various species it is usually considered to be best practice to pulp them separately. This recommendation is often extended to include widely differing growth types within the same species. Although there are undoubtedly many advantages to be gained from cooking only one kind of wood at one time, the pulping of mixtures of conifers and hardwoods is a practical possibility and has been done in many mills to some extent for a number of years. Certain adjustments in the pulping procedure may be needed. Probably these adjustments should be in favor of species difficult to pulp.

SULFITE PROCESS VARIABLES AFFECTING PULP PRODUCTION

The daily production of a sulfite digester is measured by the amount of pulp made per digester, or the digester yield, and the number of times the digester can produce this pulp in a day, or the digestion cycle. These main factors have subfactors determining their magnitude. Some of the subfactors and their interrelations are outlined in figure 1. In considering this chart, it is essential that pulp production be considered in relation to pulp quality. It also must be noted that certain factors, such as wood species and digestion conditions, affect the final product in several perhaps conflicting ways, and should, therefore, be considered on an overall basis. Finally, control of the sulfite process variables to the greatest extent

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possible is a prime necessity if the pulping reactions are to be conducted so as to get the most out of the wood.

Since the daily digester production is dependent on the yield per digestion and the digestion cycle, it is obvious that the largest possible amount of pulp of the desired quality that can be produced in the shortest possible time will lead to the greatest daily production. An optimum balance between these two factors thus becomes necessary. Under circumstances of an adequate pulpwood supply and a pressing pulp demand, the emphasis undoubtedly would be on cooking in the shortest time possible. Although a few mills, favorably situated with respect to pulpwood supplies, may find it advantageous to produce pulp under conditions of maximum daily production, most mills under current conditions, prefer to emphasize digester yield in order to obtain the maximum yield per unit of wood volume. As indicated in figure 1, digester yield depends on the weight of the wood substance charged as chips and the yield by weight of acceptable pulp, whereas the digestion cycle depends simply on how rapidly the desired product can be made. An examination of the manner in which chip charge and pulp yield are increased or decreased and, to a lesser extent, how the digester cycle is lengthened or shortened by the numerous variables of sulfite pulping, may indicate means for conducting a sulfite digestion to the best advantage for pulp production.

**Digester Yield**

It would seem to be simple enough to obtain the maximum production from each digestion by insuring, by proper control, that the maximum amount of wood substance enters the digester and the maximum amount of pulp of the desired quality is obtained from this wood charge. In actual operation such control is not entirely possible, since regulation of all the variables is not within the power of the operator. Nevertheless, it is suggested that much can be done to control many of the factors affecting digester yield. In order to govern the controllable factors effectively, however, it is necessary to know to what extent variations influence the digester yield.

**Wood Substance Charged**

The actual amount of wood substance charged into a digester depends, in reality, on (a) the average weight of wood substance in each chip of average size and (b) the number of chips in the digester. The maximum charge, then, should be realized by charging the greatest number of chips having the greatest amount of wood substance. Practically, a number of things affect this simple statement. The weight of wood substance in a chip of a given size, for example, depends primarily on its density, which in turn depends on the species and its growth characteristics. If density were the only consideration, the maximum wood charge would obviously be obtained by using wood of the highest density. The effect of density on pulp yield was explained and illustrated earlier in this report. The advantages gained by using as dense a wood as possible cannot be emphasized too strongly.
The number of chips present in a unit of digester space depends mainly, as indicated in figure 1, on (1) the average size and the uniformity of size of the chips, (2) the arrangement of the chips in the digester, and (3) the apparent density of the chip mass. An orderly arrangement of the uniformly sized chips of medium length (1/2 to 3/4 inch) will undoubtedly lead to more efficient use of the digester space and of the wood than an uncontrolled charge of chips varying widely in length and shape. With chips of uniform size there will be less void space and, hence, a larger charge. The pulping reaction will proceed more uniformly, not only within the chips themselves, but also throughout the entire digester charge, and a higher weight yield of pulp will result. It may be necessary, however, to sacrifice to some extent the advantages of chip uniformity, in order to utilize the productive capacity of the chipper to the best advantage.

In mills where the pulpwood supply is adequate it is desirable to use the digester space as efficiently as possible. This necessitates a dense as well as an orderly arrangement of the chips. The factors affecting the density of the chip charge are weight and the settling of the chip mass in the digester. The density of the wood, the moisture content of the chips, and the height of the digester all affect the weight of the chip mass and its settling. The use of high-density, wet wood, with steaming of the chips during charging, can increase the wood charge as much as 25 percent. In this step caution is necessary because, with an excessively large charge of wood, there may not be enough acid charged, the acid may be too weak to carry on the pulping reactions, or the contents of the digester may not be discharged satisfactorily. Each mill needs to determine the proper balance between the wood charge and the pulping operation.

**Percentage Yield**

Whereas the difference in weight of a light wood poorly charged to a digester and a heavy wood well charged may amount to 40 percent, the maximum variation in yield obtained in pulping a favorable wood with optimum conditions and pulping an unfavorable wood with poor conditions is possibly 20 percent. Many of the factors contributing to this relatively large variation are within the operator's control, so that their proper regulation may bring about a substantial increase in pulp yield. As shown in figure 1, the percentage yield of pulp by weight of wood is determined by (1) the initial cellulose and lignin contents of the wood; (2) the amount of material removed during pulping; and (3) the amount of unpulped material, or screenings. The effect of each of these factors will be considered in some detail.

The highest percentage of cellulosic material obtainable from a given weight of wood is determined by its holocellulose (total carbohydrate fraction) content. The holocellulose values for various pulping species given in table 1 show the variation existing between species. Only about two-thirds of the holocellulose is alpha or resistant cellulose, the difference being hemicellulose (polysaccharides and polyuronides). The variation in these cellulose contents accounts for a large part of the difference in sulfite pulp yield from different species and illustrates again a point mentioned earlier, the advantage of using species high in cellulose. It is true that significant differences in cellulose content and pulp yields can also
occur within one species because of growth structure, heartwood and summerwood contents, and other variables, adequate discussion of which space does not permit. The lignin and extraneous materials present have an indirect effect on yield, since, if their content is high, the cellulose content must be low.

The amount of wood material made soluble by the sulfite pulping reaction controls the percentage yield of pulp from a particular wood. An ideal pulping process would preserve all the alpha cellulose plus as much of the hemicelluloses, lignin, and extraneous matter as could be included without affecting adversely the quality of the pulp for papermaking or other purposes. Actually, a large portion of the hemicelluloses and a portion of the alpha cellulose which has become nonresistant in the strongly acid conditions prevailing during cooking are made soluble before the desired delignification has taken place. The relative proportions of cellulose and lignin removed depend on the rate and extent of the reactions involved. Practically, they depend on (a) the degree of pulping, (b) uniformity of pulping, and (c) pulping conditions. The first of these factors is generally controlled by the use requirements for the pulp. Since an increase in the chlorine demand of the pulp of 1 percent is equivalent to an increase of approximately 0.5 percent in pulp yield, a definite advantage exists in pulping to the highest chlorine demand compatible with the use to which the pulp is to be put.

The maximum yield of pulp is limited by the point at which fiberizing occurs upon discharging the wood from the digester. As this point is approached (55 to 60 percent yield for most species) the screenings often become excessive because of nonuniform pulping and the yield of useful pulp decreases. To obtain a high utilization of the wood, it may be definitely advantageous to terminate the pulping short of the fiberizing point and to complete the fiberization mechanically. The exceptionally high yields of semichemical pulp thereby resulting will then be limited only by the ability of the material to be blown from the digester, usually near the 60 percent yield. On the other end of the scale, cooking to a very low lignin content can be disadvantageous from the standpoint of yield of pulp, since the rate of cellulose removed increases rapidly during the final stages of lignin removal.

The effect of uniformity of pulping on percentage yield is concerned mainly with digester operation. A chemical process conducted on as large a scale as is a sulfite digestion is naturally carried out with a certain nonuniformity of cooking temperature throughout the digester. It is believed that some digesters are operated with too little regard for this point. Since in zones of high temperature in the digester the pulp is being overcooked, with the reverse occurring in zones of low temperature, the resulting nonuniform pulp, although possibly having the overall desired chlorine demand, will be produced in reduced yield. This reduction, which may amount to as much as 2 percent in yield, can be lessened by an orderly arrangement of the chips in the digester and other means provided for circulation of the liquor, which will result in uniform temperature conditions throughout the digester. There is also the possibility of nonuniform pulping within the individual chips themselves. Large, thick chips, although not showing evidence of "burning," may be less completely pulped in their centers than on their
exteriors. In this case the remedy lies in the use of small, more readily pulped chips.

The third point mentioned above, that of the effect of pulping conditions on percentage yield, can be of considerable importance. The concentration of the cooking liquor affects the relative rates of solution of the lignin and the cellulose substances. An increase in the excess sulfur dioxide content, other things being equal, causes a slight decrease in yield, although generally this decrease can be more than offset by adjustments in the other conditions which are allowed by the use of the increased acid strength. An increase in the concentration of combined sulfur dioxide of approximately 0.2 percent (at a constant acid-wood ratio), on the other hand, is reported to bring about a yield increase of 1 percent. This increase is mainly in the hemicellulosic constituents, whose retention in the pulp may or may not affect its quality; for example, pulp for glassine can contain these constituents to advantage, but in pulp for rayon their presence can be tolerated only in very small amounts. The limited range of variation in combined sulfur dioxide concentration which is available to the acid maker makes the overall variation in pulp yield from this source about 3 percent. The percentage yield is definitely unfavorably affected by high pulping temperatures. An increase in temperature of 5°C within the usual range of pulping temperature causes a yield loss of approximately 1 pound of pulp for every 100 pounds of moisture-free wood charged to the digester. This loss is somewhat higher at higher temperatures and lower at lower temperatures. It is apparently good advice from a standpoint of yield to select the lowest cooking temperature which will give the required pulping action in the available time. Digester pressure has an indirect effect on yield in that it controls the concentration of excess sulfur dioxide available at the cooking temperature.

The screenings, or incompletely pulped chips, which do not readily fiberize upon discharge of the digester represent for the most part a loss as far as higher grade sulfite pulp is concerned. It is obvious that each pound of screenings avoided means approximately an additional pound of usable pulp produced. Although screenings after suitable refining do have some fiber value (and they should be so utilized as much as possible under present conditions) their production means a partial loss of valuable raw material. When cooking proceeds beyond the fiberizing point, screenings arise mainly from the formation of insoluble lignin compounds in the interior of the chip, caused by an incomplete penetration of the bisulfite at the cooking temperatures. The cooked chips then possess the familiar dark, hard centers. The production of this type of screenings can be avoided by any means that will ensure the presence of the bisulfite in the chip before the maximum pulping temperature has been reached. Obvious remedies are (1) a longer time at the penetration temperature, (2) a high concentration of excess sulfur dioxide (which aids bisulfite penetration), and (3) use of small, uniform chips. A less serious source of screenings, or tailings, is the chip that is uniformly but not quite completely delignified past the fiberizing point. This type of screenings is caused by zones of low temperatures or by insufficient chemical in the digester, the remedies for which are obvious. In the case of a semichemical digestion, all of the cooked chips will, of course, be of this type. Other sources of screenings are the nonpulpable
knots and bark that unavoidably accompany the chips. Preparation of the chips in such a way as to keep fiber loss at a minimum may mean, on the other hand, a relatively high percentage of the last-mentioned type of screenings.

Digestion Cycle

Normally, a high pulp demand can be met by increasing the digester output through decrease of the "cover to cover" cooking time to the extent that a satisfactory pulp is produced with no serious disruption of the chip, acid, and pulp flow through the digestion operation. A decrease in the time may be advantageous, even if at some expense of the yield of pulp from the wood. Under these conditions, the factors affecting the number of blows per day are of prime importance. In most mills today, however, the yield of pulp is the more important of the two chief factors affecting digester production. Nevertheless, the factors affecting the digester cycle have an indirect bearing on the yield and therefore merit brief mention. The digestion cycle can be conveniently divided into (1) charging, (2) penetration, (3) cooking, and (4) discharging periods.

Charging Period

Raw materials should be charged in the digester in a minimum time consistent with having the materials in the most favorable condition for the penetration period. This means that sufficient time should be allowed for chip charging, so that a desirable orderly arrangement is obtained. The importance of proper chip arrangement with respect to uniformity of pulp and pulp yield has already been stressed. Although steaming the digester during or after the chip charging is not universal procedure, the time so spent may be well worth while from the standpoints of increased wood charge, moisture uniformity, and penetrability. The acid pump should be of adequate size, and there appears to be no advantage in pumping the acid at a rate below its maximum capacity.

Penetration Period

As mentioned earlier, penetration of sulfite cooking liquor must be substantially completed before a certain critical temperature is reached if burned centers in the wood chips are to be avoided. To insure the best yield, therefore, an adequate time should be allowed for penetration. In addition to chip size, the penetration time is dependent on (1) species and structural features of the wood, (2) chip moisture content, (3) pretreatment, (4) penetration conditions. A detailed discussion of these factors cannot be given here, but certain highlights may be helpful. As far as wood species and structure are concerned, the spruces, firs, and poplars are somewhat more readily penetrated than dense hardwoods and the pines; sapwood is more rapidly penetrated than heartwood, and springwood more rapidly than summerwood. Chips with a uniform moisture content are more satisfactorily penetrated than those
of varying moisture content. Pretreatment -- for example precirculation of hot acid -- enables a considerable shortening of the normal penetration time. A high sulfur dioxide content in the liquor aids the penetration of the bisulfite, and the higher the penetration temperature (below the critical temperature) the more rapid the penetration. A high operating pressure, permitted by high sulfur dioxide concentrations, indirectly aids penetration.

Cooking Period

Dissolution of the lignin in the wood, which is the prime purpose of the cooking period, depends on many factors, as shown in figure 1. Essentially, the time required for lignin removal depends on the amount initially present, the rate of its removal, and the amount left in the pulp. Certain species, or growth types within species, may require a longer cooking time or a faster pulping rate than others because of a high initial lignin content; further, because of a low cellulose content in such wood, the additional pulping may cause the normally low yield of pulp to be still lower. As explained before, lignin and valuable cellulosic material are removed concurrently. For the highest cellulose yield, it is necessary to balance these two reactions, possibly at the expense of cooking time. Since the most important single factor determining the rates of reaction is temperature, the temperature schedule used should be that which results in the most rapid removal of lignin consistent with minimum cellulose removal. Generally this condition is satisfied at temperatures below 140° C. In this connection a uniform temperature throughout the digester is a necessary condition for a controlled balance of the pulping reactions.

A less important factor affecting the reaction rates is cooking liquor concentration; an increase in total sulfur dioxide increases the rates of reaction of the cooking liquor with the lignin and the cellulose, and an increase in combined sulfur dioxide acts in the opposite way.

Another factor affecting the reaction rates in the cooking period is the blowdown time. A lengthy blowdown lowers the reaction rates because of removal of sulfur dioxide. A blowdown accompanied by steaming for high chemical recovery may be unfavorable to pulp yield, because of the resulting dangerously localized high temperatures and presence of organic acids.

The final major factor affecting the cooking period is the degree of pulping. This variable is complementary to pulp yield. Other conditions being the same, the less a pulp is delignified (by use of a shorter cooking time) the higher is the yield obtained. As has been emphasized, it is desirable to produce the highest yield possible for the particular use requirements of the pulp.

Discharging Period

The final period of the digester cycle, the time consumed in discharging the digester, is affected by the method of discharge, whether by blowing or dumping. Digester yield is not believed to be related to this operation.

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Although the main purposes of this report were to point out possible sources of pulpwood not now utilized and to discuss the factors affecting the yield of pulp from the wood in the digestion itself, there are other operations in the sulfite mill, such as chip preparation and pulp washing, screening, and bleaching, which can bear close scrutiny in the interest of increased pulp production. These operations are often the source of considerable fiber loss. For instance, intense wood cleaning may be accompanied by as much as a 15 percent wood loss, several percent of the potential paper production may go to the sewer as a fiber loss, and bleaching shrinkage may amount to as much as 8 to 10 percent. All of these operations merit a careful check by the operator to determine whether the losses are at a minimum. Since each mill operates individually in its wood preparation, chipping, washing, screening, and bleaching setups, only a few general observations can be made here.

In order to realize the maximum amount from each log entering the mill, it may be advisable to sacrifice pulp cleanliness to some extent. This means that the barking and wood cleaning operations should be conducted so as to remove a minimum of good fiber at the expense, perhaps, of leaving an appreciable amount of dirt-producing material with the chips. This scheme will throw an increased burden on the pulp screens. The slashing, sawing, and chipping operations should be done to produce a minimum of fine material. The chip screening operation should eliminate only the decidedly objectionable material. The chips that then go into the digester will be somewhat nonuniform in size, and adjustments in the cooking procedure may be needed to counteract this. The use of the pin chips and coarse sawdust from the chip screens should warrant consideration. For example, the pin chips may be cooked in admixture with the regular chips or separately.

The white water from washers and the thickeners can be used to supply part of the wash water in the blowpit. In this way the fibers are filtered from the white water. There should, if at all possible, be some kind of fiber recovery system for the white water. The pulp screenings should all be collected, refined if need be, and utilized in such products as roll wrapper, car liner, and board filler. The rejects from the knotter screen can be refined in a hammermill and blended with the screenings. The screen efficiency should be high so that the screenings contain as little acceptable fiber as possible.

The relatively low pulp brightness ceiling now permitted makes it possible to conduct the bleaching operation with a low shrinkage. A single stage hypochlorite bleach, may produce a pulp with the necessary brightness without the losses of carbohydrate materials which occur in multiple stage bleaching, especially in those employing caustic extraction.
References


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Table 1.—Density and chemical composition of the common pulpwoods and some woods less-commonly used for sulfite pulping

<table>
<thead>
<tr>
<th>Species</th>
<th>Density (moisture-free)</th>
<th>Chemical composition of wood (moisture-free)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>lb. per cu. ft.</td>
<td>%</td>
</tr>
<tr>
<td>Aspen (Populus tremuloides)</td>
<td>22</td>
<td>82</td>
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<tr>
<td>Beech (Fagus grandifolia)</td>
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<td></td>
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<tr>
<td>Birch, paper (Betula papyrifera)</td>
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<tr>
<td>Birch, yellow (B. lutea)</td>
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<td></td>
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<tr>
<td>Cottonwood (Populus deltoides)</td>
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<td></td>
</tr>
<tr>
<td>Maple (Acer saccharum)</td>
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<td></td>
</tr>
<tr>
<td>Tupelo (gum) (Nyssa aquatica)</td>
<td>30</td>
<td></td>
</tr>
</tbody>
</table>

Hardwoods

Softwoods

Douglas-fir (Pseudotsuga taxifolia) 29
Fir, balsam (Abies balsamea) 21
Fir, grand (A. grandis) 23
Hemlock, eastern (Tsuga canadensis) 24
Hemlock, western (T. heterophylla) 29
Larch, western (Larix occidentalis) 26
Pine, jack (Pinus banksiana) 24
Pine, northern white (P. strobus) 21
Pine, red (P. resinosa) 27
Pine, southern slash (P. caribaea) 30
Pine, western white (P. monticola) 23
Redcedar, western (Thuja plicata) 13
Spruce, black (Picea mariana) 24
Spruce, red (P. rubra) 24
Spruce, Sitka (P. sitchensis) 24
Spruce, white (P. glauca) 24
Tamarack (Larix laricina) 31

1 Average values for samples tested at Forest Products Laboratory; wide variations may occur within single species.

2 W 50047 F
<table>
<thead>
<tr>
<th>Species</th>
<th>Density (weight per cord)</th>
<th>Moisture (free wood and green moisture-free per cord)</th>
<th>Yield of moisture (free wood: free screened pulp per 100 pounds)</th>
<th>Base of pulping by usual procedures (length, color, fiber)</th>
<th>Pulp characteristics (bleachability, remarks)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hardwoods</strong></td>
<td></td>
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<tr>
<td>Aspen</td>
<td>22</td>
<td>1870</td>
<td>49</td>
<td>855:No difficulty</td>
<td>Short:Light:No difficulty:Possible pitch</td>
</tr>
<tr>
<td>Beech</td>
<td>34</td>
<td>2890</td>
<td>44</td>
<td>1195:Slight difficulty</td>
<td>Short:Dark:Some difficulty:Possible pitch</td>
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<tr>
<td>Birch</td>
<td>34</td>
<td>2890</td>
<td>46</td>
<td>1250:Slight difficulty</td>
<td>Short:Medium:Slight difficulty:Possible pitch</td>
</tr>
<tr>
<td>Cottonwood</td>
<td>23</td>
<td>1350</td>
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<td>900:No difficulty</td>
<td>Short:Light:No difficulty:Possible pitch</td>
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<tr>
<td>Maple</td>
<td>35</td>
<td>2970</td>
<td>45</td>
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<tr>
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<td><strong>Softwoods</strong></td>
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<td>Fir, balsam</td>
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<td>1780</td>
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<tr>
<td>grand</td>
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<td>1350</td>
<td>49</td>
<td>900:No difficulty</td>
<td>Medium:Light:No difficulty:Possible pitch</td>
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<tr>
<td>Hemlock, eastern</td>
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<td>2040</td>
<td>44</td>
<td>840:No difficulty</td>
<td>Medium:Medium:Slight difficulty:Possible pitch</td>
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<tr>
<td>western</td>
<td>25</td>
<td>2120</td>
<td>47</td>
<td>940:No difficulty</td>
<td>Medium:Medium:No difficulty:Possible pitch</td>
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<tr>
<td>Larch, western</td>
<td>28</td>
<td>2380</td>
<td>45</td>
<td>865:Some difficulty</td>
<td>Medium:Medium:Some difficulty:Pitchy</td>
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<tr>
<td>Pine, jack</td>
<td>27</td>
<td>2300</td>
<td>45</td>
<td>970:Some difficulty</td>
<td>Medium:Medium:Some difficulty:Pitchy</td>
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<tr>
<td>red southern</td>
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<td>2550</td>
<td>47</td>
<td>1125:Heartwood difficult:Long:Medium:Heartwood difficult:Pitchy</td>
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<tr>
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<td>46</td>
<td>810:Some difficulty</td>
<td>Medium:Medium:Some difficulty:Pitchy</td>
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<tr>
<td>Redcedar, western</td>
<td>19</td>
<td>1610</td>
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<tr>
<td>Spruce, black</td>
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<td>2040</td>
<td>48</td>
<td>920:No difficulty</td>
<td>Medium:Medium:No difficulty:Possible pitch</td>
</tr>
<tr>
<td>red</td>
<td>24</td>
<td>2040</td>
<td>48</td>
<td>920:No difficulty</td>
<td>Medium:Medium:No difficulty:Possible pitch</td>
</tr>
<tr>
<td>Sitka</td>
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<td>2040</td>
<td>48</td>
<td>940:No difficulty</td>
<td>Medium:Long:No difficulty:Possible pitch</td>
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<tr>
<td>white</td>
<td>24</td>
<td>2040</td>
<td>48</td>
<td>920:No difficulty</td>
<td>Medium:Light:No difficulty:Possible pitch</td>
</tr>
<tr>
<td>Tamarack</td>
<td>31</td>
<td>2040</td>
<td>--</td>
<td>----</td>
<td>----</td>
</tr>
</tbody>
</table>

1. Average values for samples tested at Forest Products Laboratory; wide variations may occur within species.
2. Based on 50 cubic feet per cord. Logs 4 feet long with bark on, stacked pile 4 feet high, 5 feet long.
3. Allowing 6 percent barking, chipping, and fiber loss.
Figure 1.—Sulfite Process Variables Affecting Pulp Production

**DAILY DIGESTER PRODUCTION**

**DIGESTER TIME**

- Wood Density
- Chip Size
- Average Chip Size, Variability of Size
- Chip Arrangement
- Apparent Density of Chip Mass

<table>
<thead>
<tr>
<th>Wood Substance per Chip</th>
<th>M.</th>
<th>M.</th>
<th>M.</th>
<th>M.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Chips</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

**DIGESTION TIME CYCLE**

**CHARGING PERIOD**
- Charging of Chips
- Steaming
- Pumping of Acid

**PENETRATION PERIOD**
- Species
- Chip Size and Moisture Content
- Pretreatment
- Acid Concentration, Temperature, and Pressure

**COOKING PERIOD**
- Initial Composition
- Species
- Wood Characteristics
- Rate of Reaction
- Uniformity of Rate Throughout Digester
- Blowdown

**DISCHARGING PERIOD**
- Extent of Pulping