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RECENT DEVELOPMENTS IN THE UTILIZATION OF WOOD WASTE FOR LIGNIN PRODUCTS

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Contents

INTRODUCTION

Much publicity has been given in recent and near recent years to the waste of material in the forest using industries. Books have been written on the amount of wood lost insaw kerf, slabs, and chips. Numerous articles have also been written on the percentage of the standing tree that ultimately finds itself in some usable material or product.

All of this publicity has tended to make manufactures cut down their waste to a minimum and make for closer all around utilization. One of the industries that seem to have their utilization down to as near rock bottom as possible is the paper and pulp industry.

This paper is compiled for the purpose of showing how in future years great savings may be made in all industries that utilize the cellulose of wood and consider lignin to be a waste material that must be disposed of in the least expensive manner possible.

While work with lignin has not progressed very far rapid strides are being made, and its hoped that the reader will get some idea of the work being done, its possibilities, and what can be expected.

Millions of tons of potential wealth rot like this every year, for lack of an economic use.

In dealing with the topic of lignin we must first get some idea of the quanitity of it available. Lignin composes 25 to 30 percent of the stem of a plant. In the making of paper the lignin and waste liquor is thrown away. To get a real picture of the importance of the problem it is necessary to get some conception of the amount of wood used for pulp. Also the supply, its location, and possibly some idea of the standard pulp and pulping processes.

Sixty years ago the quanitity of wood used as a raw material for paper in the United States was insignificant. Today about 85 percent of our paper has its origin in the forest. Wood, in short is the basic raw material for paper pulp. Although pulp can be produced from any fibrous material no source of cellulose has yet been discovered which either in suitability for most types of paper or in cost per unit weight, challanges the supremacy of wood.

Pulpwood--quanitity and location.

Pulp wood supplies present a highly specialized problem involving many economic and technical complexities, some of them matters of world supply and demand. Although a satisfactory estimate of economically usable present pulpwood supplies can hardly be attempted, it may be appropriate to present some quantitative estimates of the supplies of species either now cut in quantity for pulpwood or which seem to be technically capable of use by the pulp and paper industry.

The relation of pulpwood requirements and supplies is not static. The tendency in pulp and paper manufacture as in other fields of wood utilization is toward an increasing number of species regarded as suitable, with a consequent enlargement of the volume of potential pulpwood supplies. There has been a drift toward lower requirements as to size, form, and quality of material. In some regions, notably the Pacific Coast, a large part of the pulpwood is cut from saw-timber trees, with the tops and limbs left unutilized in the woods. In other regions, such as the Lake and South, much of the pulpwood comes from cordwood stands.

The pulpwood table (page) shows the gross estimate of the species more commonly used for paper pulp by regions, and for softwoods and hardwoods separately. This is presented without any implication that these supplies are anything like completely available in an economic sense either nationally or for any single region. Nor is any prediction here attempted as to what proportion may ultimately be cut for pulpwood and what for other purposes.

The 1,830 million cords thus indicated constitutes about one third of the gross volume of all commercial forest material in the United States--saw timber 860 million cords, or 47 percent; small trees on saw-timber areas 420 million cords, or 23 percent; and cordwood on cordwood areas 550 million cords, or 30 percent. Largely because of the inclusion

TABLE SHOWING THE LOCATION AND AMOUNTSOF

THE PRESENT PULP-WOOD SUPPLY

Kind of wood	Total	New England	Middle Atlantic	Lake
	Thousand cords	Thousand cords	Thousand cords	Thousand cords
Softwoods:				
Spruce and fir	431,242	45,030	5,931	17,526
Hemlock	206,825	10,467	9,100	12,619
S. Y. pine	623,525		8,751	
W., Nor., Jack pine	66,404	24,190	14,575	25,242
Tamarack	1,986	14		1,972
Total	1,329,982	79,701	38,357	57,359
	Thous			
Hardwoods:				
Cotton. & Aspen	30,463	10,590	1,752	10,662
Yellow poplar	38,702	152	3,338	
Bir. Beech Maple	305,404	115,235	68,581	74,610
Gum	124,694		2,601	
Total	1,499,263	125,977	176,272	185,272
All Species	1,829,245	205,678	114,629	142,621

Kind of wood	Central	South	Pacific Coast	N. Rocky Mount.	S. Rocky Mount.
	M.cords	M.cords	M.cords	M.cords	M.cords
Softwoods:					
Spruce and fir	610	781	205,861	48,174	107,329
Hemlock	3,962	3,883	166,794		
S.Y. Pine	10,453	604,321			
W.Nor. & jack pine	848	1,549			
Total	15,873	610,534	372,655	48,174	107,329
Hardwoods:					
Cotton. & Aspen	1,651	5,535			273
Yellow poplar	12,090	23,122			
Bir. Beech, Maple	31,430	15,548			
Gum	9,070	112,923			
Total	54,241	157,228			273
All species	70,114	767,762	372,655	48,174	107,602

*

of southern yellow pines (now used mainly for sulphate pulp) the South is shown to have two fifths of the total supply. The Pacific Coast region with only spruce, hemlock, and true fir included has one fifth. If the saw-timber stands of Douglas fir, ponderosa pine, western white pine, sugar pine, and larch--all western species potentially important for pulpwood--were included another 1,800 million cords would be added.

Over a third of the estimated pulpwood stands, or 638 million cords, consists of spruce, fir, and hemlock--species suited for all four types of pulp, but especially desired for mechanical and sulphite pulps which make up about two thirds of out total pulp requirements. The Pacific Coast region has about 60 percent of this spruce-fir-hemlock supply. Less than a third, or 500 million cords, consists of yellow poplar, birch, beech, maple, gum, cottonwood, and aspen--eastern species used mostly for soda pulp. The remaining 692 million cords consist mostly of southern yellow, white Norway and jack pines--species used largely for sulphate pulp.

With this understanding of the supply of pulpwood it is well that the reader get some idea of the methods used to make the wood into pulp.

Standard pulpwoods and pulping processes.

There are four standard process of making paper pulp from wood--the mechanical, the sulphite, the sulphate, and the soda. Each is especially adapted to the manufacture of of certain grades of paper or to the pulping of certain woods.

The various grades of papers, in fact, usually contain varying proportions of two or more types of wood pulp. Considerable old paper also mingles with new pulp in various papers, and pulp derived from nonwoody plants mingles with wood pulp in fine papers.

Newsprint, cheap magazine, cheap catalog, and similar papers, are made mostly of mechanical pulp, that is of uncooked wood mechanically ground into a pulp. Only the relatively soft, light colored, nonresinous spruces, firs, and hemlocks are suitable for the manufacture of mechanical pulp or are used enough to be considered commercial sources for this process. The menchanical process is the cheapest of all, and the pulp yield is by far the greatest. The quality of the pulp, however, is so low that in the manufacture of even cheap papers considerable quantities of long and stronger-fibered pulp are added. Of out total wood-pulp production, mechanical pulp comprises about a third.

The stronger and better-grade papers are made of pulps manufactured by one of the three standard chemical processes--sulphite, sulphate, or soda. In each processes a large portion of the wood is removed, leaving fibers consisting of almost pure cellulose. This is accompolished by cooking the chips of the wood with a chemical under steam pressure.

Some classes of book, wrapping, bond, and tissue papers are made largely from sulphite pulp, and considerable sulphite is used in mechanical papers. The sulphite process is a little more expensive that the other chemical processes, and the pulp yeeld is only about half as large as in the mechanical process; but the pulp is very strong and can be readily bleached to a high degree of whiteness. The woods used in the sulphite process are the same as in the mechanical process; the light colored, nonresinous softwoods, such as spruce, fir, and hemlock. Sulphite pulp accounts for about a third of the wood pulp produced in this country.

Draft or wrapping paper and high-test fiber board are made from sulphate pulp. The standard sulphate process is a little less expensive than the sulphite process; the yield is about the same. Any long fibered wood can be used for sulphate pulp, even one which contains resin and other alkaline-soluble materials. Sulphate pulp constitutes about a fifth of our total wood-pulp production.

Book, lithograph, and envelope papers are very often made from a mixture of sulphite pulp and pulp made by the soda process. This mixture gives a sheet of paper which is highly esteemed by printers. The soda process can be applied to softwoods without difficulty, but it is used almost entirely for the reduction of such hardwoods as aspen, cottonwood, beech, birch, and gum. Soda pulp is sometives used alone in the manufacture of some of the cheaper, bulkier book papers which have very low strength requirememts. Of out total wood-pulp production, soda pulp constitutes only about a tenth.

With the above facts as to pulping processes and woods suited to them as a background, the availability of present pulp-wood supplies should bear more interest and weight.

The table (page) shows that there is 1830 million cords available in our pulp-wood supply. With the inclusion of the western species potentially important for pulp-wood an additional supply of 1,800 million cords would be added to bring the total up to 3,630 million cords of pulpwood available. At present mechanical pulp comprises about one-third of our pulp and chemical makes up the other two-thirds, or about 2,420 million cords. As lignin makes up about one quarter of wood substance 605 million cords, or about one sixth of out total supply, will be dumped into rivers and streams if out present manufacturing standards are continued in this industry.

Chemical composition of wood.

To more fully gather the importance of the subject this paper is written on it is necessary for the reader to have some conception of the chemical composition of wood. Too much wood is thought of as being a substance fairly workable, stiff, and light--a material that houses and like structures are built of--a material we burn in our stoves to warm our houses. We must go deeper than this and see what makes wood what it is.

In the chemical utilization field it is the composition rather than the physical properties of the wood that determines its value as a raw material, and the size is of much less importance than in the lumber and structural field. All woods may be roughly described as composed of 25 to 30 percent of lignin, about 45 percent cellulose, and the rest mostly cellulose-like carbohydrates, with a few odd chemical groups like methyl alcohol--acetic acid sticking to them. The cellulose is the main constituent of value in making the chemical pulps that go into papers and the various modern products such as rayon, cellophane, films, lacquers, and explosives. The cellulose-like carbohydrates are the main source of methyl alcohol and acetic acid as obtained by destructive distillation. Lignin has remained a comparative chemical mystery; little is known of its chemical composition, and few and unimportant chemical wood products are all it has yielded in the past. At least that was the status of lignin until recent disclousures by the wood products laboratory at Madison, Wisconsin proved otherwise.

There are other diversified chemical wood products such as oxalic acid, acetic acid, methyl alcohol, ethyl alcohol, medicinal creosote, tanning extracts, dyes, wood preservatives, baking powder, guaiacol, toothpaste, and charcoal. Most of them are now being made commercially, although in a small way; others, such as fufural, protocatechuic acid, pyrocatechin, butyl alcohol, cresol, pyrogallol, glucose, mannose, and xylose, either can be made cheaper from other raw materials or there is no market for them. It must be admitted that from the point of view of large quantity utilization of wood such products as these are not especially important.

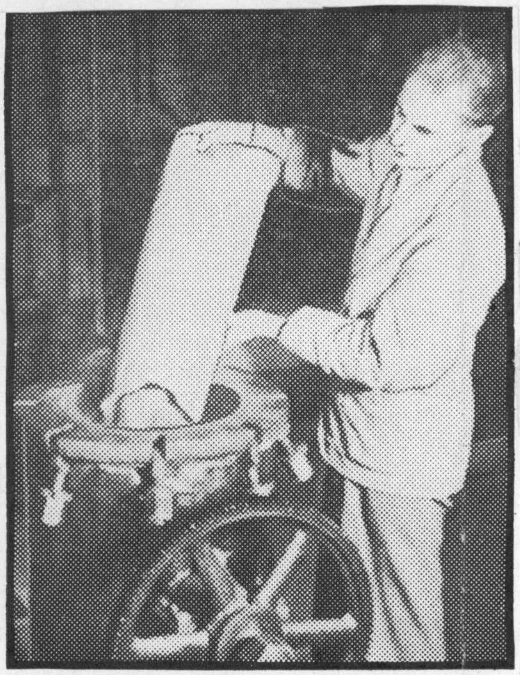
There are, however, certain products from wood employing chemical processes in manufacture that give promise of future large-scale utilization. Chief among these are lignin and pulp products. Pulp products are already farily well developed so it is certain that the greatest strides will come in the field of the until recently unknown quantity, lignin.

With the preceding pages of this report to serve as a build-up as well as to give information on the quantity of wood wasted, pulping processes, and the chemical composition of wood we will now go more specifically into the actual work on lignin.

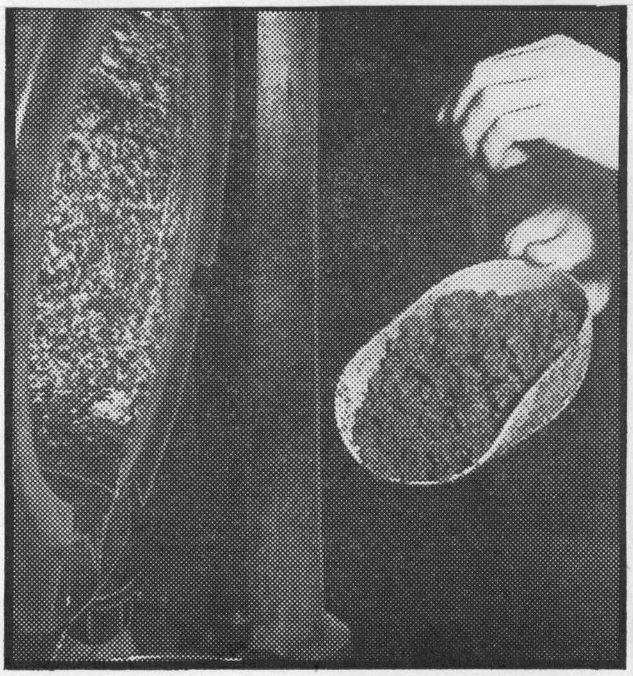
<u>The progress of the work on lignin.</u>

We all know cellulose. It is the white material in plants that comes in a thousand forms--as cotton and linen and hemp and ramie, as cornstalk pith and thistle down and the walls of cells of plants. Cellulose shirts and sheets woven out of natural fibers, cellulose paper for reading and writing, cellulose compounded into many synthetic things form rayon to atrificial leather. It is even used for explosives for guncotton is trinitro-cellulose.

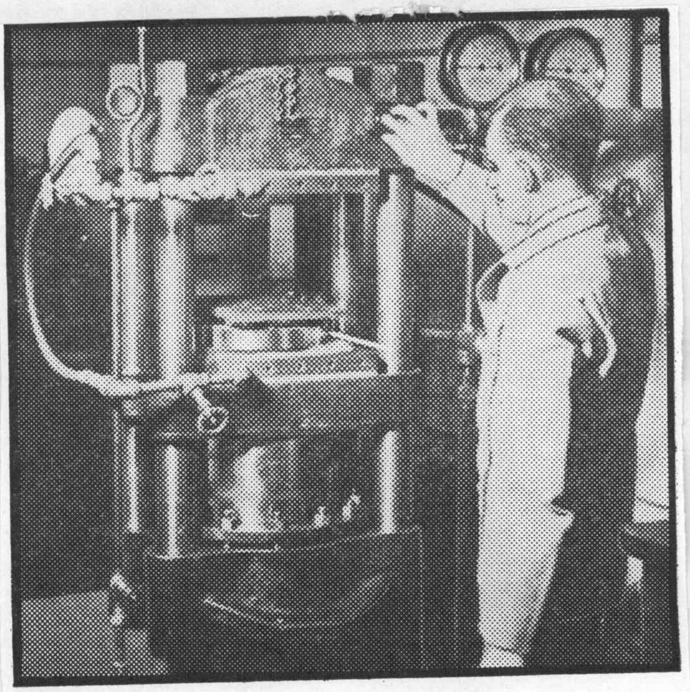
Now cellulose has a competitor in lignin. In nature, lignin and cellulose are always together. Cellulose forms the cell walls and lignin cements them together. Lignin gets its name from its importance in wood formation: The



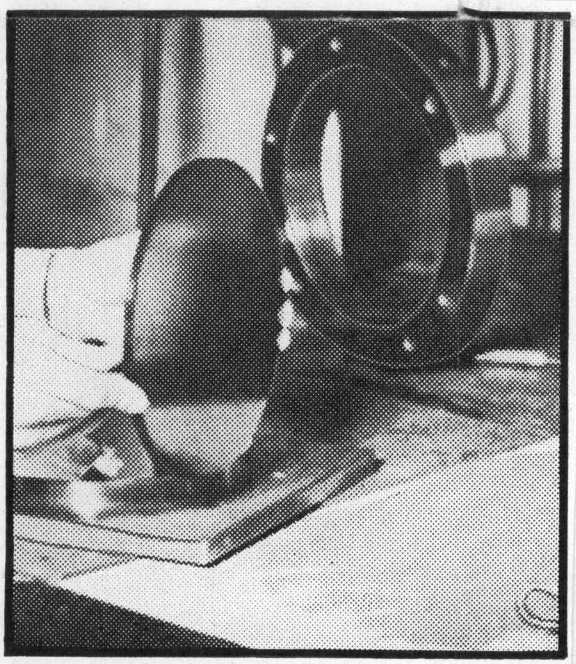
The first step in the process of making lignin useful; pouring sawdust into the digester.



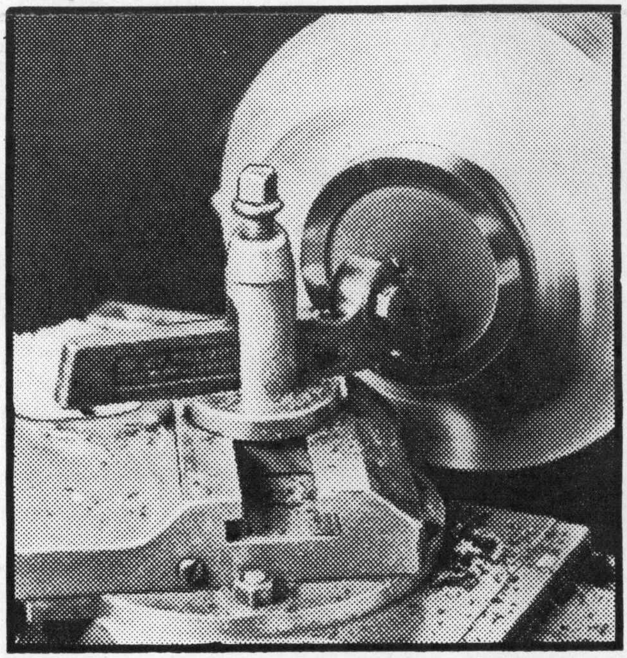
After digestion in the heavy kettle, the sawdust emerges in the form of "hydrolized wood."



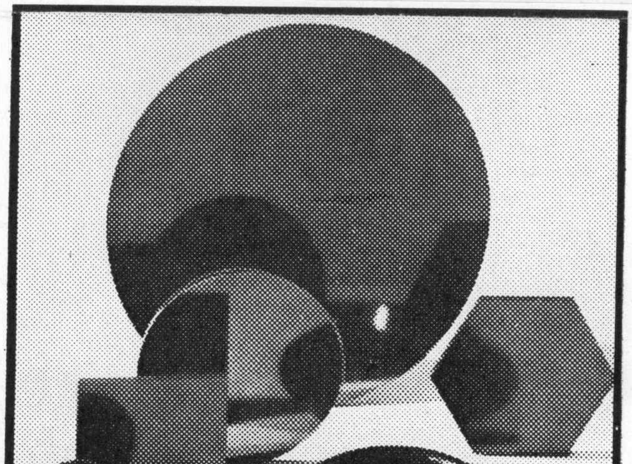
The powdery dough-like substance is then put into powerful presses to be shaped into solid forms.



Out of the press comes a hard disk, ready to be machined.



Lignin plastic can be turned on a lathe, like metal or wood.



Stock shapes of lignin plastic—and, in front, a molded ashtray.

Latin for wood is <u>Lignum</u>. We get a derivative in lignite, the fibrous, semi-woody brown coal used to some extent in this country and very widely in Europe. We get it again in lignum-vitae, a tropical wood which is highly valued foe its extreme hardness and durability.

It is not easy to separate cellulose form lignin, but chemists have secceded in doing so and have found many jobs for cellulose. Lignin, on the other hand, has remained in the background, and chemists do not know the structure of the lignin molecule, although they have been trying to find out for years. However, very recently chemists at the U. S. Forest Products Laboratory at Madison, Wisconsin have broken down lignin. With what knowledge they gained from this thay have put lignin to work as a plastic.

How important it is for American industry that a use has at last been found for lignin, has well been summed up by Carlile P. Winslow of the forest products laboratory. Mr Winslow says:

> "Lignin makes up 20 to 30 percent of the weight of the average plant stem. Billions of tons of it are present in the world at any one time, and the supply renews itself indefinitely by natural growth.
>
> "Limiting our view to present facts in the United States, we find the lignin problem pressing for attention in two forms; a million tons of it are dumped into our streams annually as waste from pulping mills; in the background, fifteen million tons more, contained in four times that tonnage of waste wood.
>
> "The question that faces the chemist and the inventor ishow can we change lignin from a source of stream pollution and a waste to a source of wealth and usefulness?"

Lignin has now been qualified for the plastics job. There seems to be no limit to the demand for the commodities that can be made out of plastics that harden, polish, and work up into exerything from ash trays and vanity cases and buttons to larger objects like floor tiles, wall panels, auto instrument boards, electrical insulators, and acid resisting containers for chemicals.

Plastics, all the way from the old fashioned hard rubber to the newer ones made of cellulose, phenol formaldehyde, etc., are taking over hundreds of jobs that used to be given to wood, metal, pottery, glass, and leather. Sometimes this is because of the increasing scaracity of the old material, but more often it is because the plastics can do the work better, ~~Now~~ Lignin plastics are entering a field that offers limitless possibilities which even numerous other plastics have not been able to fill.

To prepare lignin for its job in the plastic business, sawdust is shoveled into a heavy iron digester and the lid is clamped down. Dilute acid is added, and the digester is heated. The steam pressure and the acid vapor changes the chemical nature of the wawdust by a process called hydrolysis. When the digester is opened again, the sawdust is gone and in its place there is a dark powder and a dark syrup. The acid has changed the sawdust into a mixture of several different kinds of sugar that forms the syrup. This has its own chemical possibilities, but it is the dark powder we are interested in. So the syrup is drained off, leaving the powder to make the plastic.

This is put into molds of suitable shape and put in a hydraulic press. It comes out as slabs, disks, and other shapes, very dense, hard, strong, and black. By using dies of suitable shape it can be formed directly into trays, knobs, handles, bowls, or it can be pressed into flat blanks which can be turned on a lathe, sawed, bored, ot otherwise machined about the same as hard rubber.

Thus far, it has not been possible to prepare the lignin plastic in the beautiful transparent and light colored forms in which the phenol-formaldehyde and cellulose plastics can be had. This handicap, however, can be largely overcome by enameling, painting, lacquering and other surface treatments, for it accepts them all very well. An especeally interesting faceing can be given by sifting powdered metal into the mold before the plastic-powder is filled in. The metal then becomes an intergral part of the finished product.

The great advantage of the wood-waste molding is its very low cost. Preliminary estimates by the forest products laboratory indicate that it can be made in bulk for 2 or 3 cents a pound. Other types of plastic materials cost very much more than that. It is not improbable that lignin plastics will take over much of the field on price competition alone, and that it will also open up new fields of usefulness that the others can not not enter because of the high cost.

One advantage lignin plastic shares with other materials in its class is its high electrical resistivity. This makes it a good insulator. (The degree of the electrical resistivity will be given in the For? Prod. Lab. report at the end of the paper.) It is also resistant to acid and its waterproof qualities are very good. It is a poor conductor of heat--something like wood in this respect. This quality willgive it advantage in bidding for use in wall paneling and floor tile.

Prior to the hydrolysis process lignin was used to hold down linoleum. Waste liquor from the paper mills containing lignin had been dumped into streams, polluting rivers, destroying fish, and being an all around nuisance. Then it was discovered that boiling most of the water out of the waste liquor made a good adhesive for sticking linoleum to floors.

Lignin in the same waste liquor form pulp mills has been used to some extent on unpaved roads, to make the dird stick together better and raise less dust. (IN the state of Wash.) Recently some rather promising experiments with lignin as a soil conditioner have been made. Lignin has little if any direct value as a fertilizer, but it does make certain heavy soils lighter and more tillable.

The following seven (7) pages are direct copies of reports from the Forest Products Laboratory at Madison, Wisconsin. Acknowledgement is here given them.

The imposing U. S. Forest Products Laboratory at Madison, Wis., where chemists have found a way to put lignin to work.

THE FORMATION OF PLASTICS FROM HARDWOOD WASTE

There are a number ow ways by which hardwood sawdust or other hardwood mill waste can be converted into a moldable poweder suitable for the molding of many articles. Of all the methods so far experimented with, two stand out as being better suited for commercial exploitation or yield- a better or cheaper product than all others. These two processes are described more fully as follows:

1. Hydrolysis Process

Hardwood sawdust is hydrolyzed in the presence of 1 percent by weight of sulphuric acid and 2-1/2 times its weight of water, for periods of time varying from 1/2 hour to 3 hours at a steam pressure of 160 pounds per square inch. The residue left after the sugar solution formed by the hydrolysis is drained and washed off amounts to 60 or 65 percent by weight of the original wood. This material, after being ground, can be pressed in a hot mold at a tempreature of 190 degrees C. and 3,000 pounds per square inch if 8 to 16 percent water is present as a lubricator. Such a powder could be produced for about 1 cent per pound.

The properties of the molded articles can be modified to a very large extent by the use of the proper plasticizer. For instance, the addition of 6 to 8 percent aniline and 6 to 8 percent fuffural prior to pressing permits the molding of the material at 150 to 170 degrees C. and 2,500 pounds per square inch pressure. Other plasticizers such as triphenyl phosphate, dibutyl phthalate, and toluene sulphonamides also produce valuable materials which will differ somewhat from each other in their various properties. The use of the proper plasticizer will ge governed quite largely by the type of material which must be produced.

2. Aniline Process

When hardwood sawdust or other hardwood waste is digested with 2-1/2 times its weight of water and 20 percent of its weight of aniline at a steam pressure of 160 pounds per square inch for three hours, a yield of 90 to 95 percent by weight of product is obtained. This, when thoroughly washed free from soluble matter, is ready for molding by the use of water only. The product, which contains about 12 percent of furfural and aniline, is very nearly equivalent to that obtained by the use of furfural and aniline as plasticizers in the hydrolysis process. It should be produced for approximately 3 to 4 cents a pound.

Plasticizers have a considerable infuluence upon the properties of the finished material and upon its finish and molding. The addition of 8 percent furfural to the anilinated sawdust produces a material with a very brilliant finish, good strength and water resistance, and gives the appearance quite similar to jet black phenol formaldehyde resins.

....

The natural color of the finished, polished material is an opaque black. This should be satisfactory for the majority of uses to which the material will be put. Other colors can be produced only as a surface covering. This may be done by painting, enameling, or lacquering, or by making some decorative material such as paper, cloth, metal powders, or wood veneer an integral part of the finished material by inserting them before pressing. Very beautiful and attractive hard panels have been produced by the use of figured veneers such as walnut, woven veneers, and appliqued veneers.

Most of the work on plastics has been confined to the hardwoods such as maple, oak, and hickory, but we have evidence to indicate that the softwoods will also be suitable.

Forest Products Laboratory,
Madison, Wisconsin,
March 4, 1937

Properties of Hydrolyzed Wood Plastics

These figures are based on plastics obtained from maple sawdust hydrolyzed by 1 percent sulphuric acid. The residue after hydrolysis is washed with water to free it from sugar and acid. It is then ground mixed with 8 percent furfural, 8 percent aniline, and 2 percent barium hydroxide and pressed at 135 degrees C. for 10 minutes at 3000 pounds per square inch.

Density

1.39 to 1.41

Strength

Modulus of rupture $1400 \text{ lbs./sq.in.} \times 10^{-0.094M}$ where M is moisture content in percent moisture.

Electrical Resistance

At 30 percent humidity 5×10^{11} ohms/ sq. cm.
At 90 percent humidity 2.5×10^{7} ohms/ sq. cm.

Water absorption

Increase in weight	Time of absorption (Percent) 1 day	10 days	100 days
In water	1.0 to 2.0	4.5 to 7.0	8.0 to 10.0
In humidity of 90%	0.5 to 1.0	2.5 to 4.0	4.5 to 6.0
In humidity of 65%	0.2 to 0.4	1.0 to 1.3	2.0 to 2.7
Increse in length and breadth			
In water	0.2 to 0.3	0.7 to 1.0	1.2 to 1.40
In humidity of 90%	0.1 to 0.3	0.5 to 0.6	0.7 to 0.9
In humidity of 65%	0.1 to 0.2	0.2 to 0.4	0.3 to 0.5
Increase in thickness			
In water	0.9 to 2.0	3.0 to 5.0	8.0 to 13.0
In humidity of 90%	0.4 to 0.8	1.3 to 2.0	3.0 to 4.0
in humidity of 65%	0.1 to 0.5	0.5 to 1.5	1.4 to 2.0

Machinability

Like hard rubber.

Forest Products Laboratory
Madison, Wisconsin,
April 27, 1936

DESCRIPTION OF THE FOREST PRODUCTS LABORATORY'S WORK ON LIGNIN AND PLASTICS

Next to cellulose, lignin is the most abundant and most widely distributed organic substance. The chemistry of lignin has been of importance to the chemist working on on the pulping of wood since that industry began. Lignin is found to be the substance which cements together the cells of the tree or plant and also reinforces the cellulose within the cell. It must be removed before white paper, rayon, or many of the other cellulose products can be produced.

After almost 100 years of study the chemical nature of lignin still is a matter of controversy. Some have suggested that lignin is aromatic in nature on the grounds that it yields some small amounts of aromatic compounds, as vanillin and pyrocatechol, by alkali fusion, and aromatic tars when it is destroyed by the action of heat. The many attempts, however, to obtain intermediate aromatic products by less drastic treatments have failed. One must therefore conclude that the aromatic compounds are formed as a result of chemical decomposition.

Unlike cellulose, lignin does not exist in long chains of simple sugar groups connected through oxygen linkages which may be split by hydrolysis. Instead it seems to be a comparatively short chain of hydroxy-furan groups joined together by carbon-to-carbon linkages. Theoretically, this may be explained by assuming a condensation of pentoses or furanoses and methylation of some of thehydroxyl groups. Such an arrangement would account for its extreme stability toward hydrolytic reagents. This relationship of lignin to the furans is shown by a similarity of many of their reactions: it can be nitrated and coupled with other organic compounds to form dyes; it polymerizes easily and combines with other compounds to form resinous or plastic material.

In these days of labor-saving devices and processes, any material which promises to produce finished articles by casting, stamping, pressing, or molding is of great interest. The plastic properties of lignin and its associated materials displayed under certain chemical reactions make raw materials containing lignin of particular interest in the field of plastics.

The supply of sawdust suitable for this purpose runs into millions of tons, much of it now wasted or used for fuel or other minor uses. Simple hydrolysis of sawdust with dilute acid at the proper tempreature and pressure is sufficient to produce a powder which will mold to a hard, black, dense material not far different in appearance and properties from other well-known molding materials at only a fraction of their cost. A much better material can be obtained by incorporating 6 to 8 percent aniline and 6 to 8 percent furfural in the mixture before pressing. This plastic causes less trouble in sticking to the mold and can be pressed at a lower temperature. It has a dessity of approximately 1.35 to 1.41 and a machinability very much like hard rubber. Its modulus of rupture, as determined by static bending, is approximately 6,000 pounds at 4 percent moisture content, an equilibrium moisture content acquired at 30 percent relative humidity. The electrical resistance varies with the moisture content, at 30 percent humidity it is of the order of 5×10^{11} ohms per square centimeter. After 24 hours soaking in water it will take up between 1 and 2 percent of its weight, but only 0.2 to 0.4 percent in 60 percent atmospheric humidity for the same time. The maximum swelling in length and width, after soaking for 100 days, is less than 1.5 percent.

Preliminary estimates endicate that this molding powder can be made for 2 to 3 cents a pound, the increase in cost over that of sawdust being due to added chemicals.

A third modification is made by digesting sawdust with aniline and compounding the finished material with furfural. This material flows better in the mold and has a better finish than the previously described plastics. It appears to be somewhat weaker, but strong enough for the purposes for which plastics are generally used. It would cost about 5 cents per pound.

Forest Products Laboratory,
Madison, Wisconsin,
December 3, 1936

CONCLUSION

In conclusion we can only make the assurance that in the future we can expect to see many money saving developments in the field of lignin and wood plastics. How great or how valuable the recent developments may prove is hard to say or even to imagine. One thing tho is certain, and that is that wood and wood products are going to more deeply entrench themselves in the lives of the people of this country and abroad.

The Forest Products Laboratory at Madison, Wisconsin is to be commended on the good work they have done that resulted in finding a use for a waste that composes one-sixth (1/6) of our present total pulp wood supply in the United States. It is only by finding new uses for wood products, improving our methods of manufacture, and continual research that will keep wood and its companion industries in the positions that they rightfully belong.

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