

[54] **PROCESS FOR SUBJECTING WOOD CHIPS
TO IRRADIATION WITH ELECTRONS**

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[58] Field of Search **162/50, 1; 204/158 HE**

[56] **References Cited**

UNITED STATES PATENTS

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FOREIGN PATENTS OR APPLICATIONS

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[57]

ABSTRACT

In the making of pulp from wood, wood is subjected to irradiation with electrons in an amount less than 1.0 megarad but sufficient to modify wood structure such that pulping process is facilitated by energy requirement reduction, and yield and quality of pulp maintained or improved.

6 Claims, No Drawings

PROCESS FOR SUBJECTING WOOD CHIPS TO IRRADIATION WITH ELECTRONS

This application is a continuation-in-part of Ser. No. 117,722, filed Feb. 22, 1971, now abandoned.

BACKGROUND OF THE INVENTION

The objective in producing paper type products from wood is to produce a sheet of material which has strength and flexibility properties. Wood is composed essentially of a cellulose fraction, a hemicellulose fraction and a lignin fraction. The cellulose fraction is the component which is desirable in the production of paper type products. In chemical pulping the native lignin in the wood is usually required to be removed to greater or lesser extents depending upon the type of material to be produced. Native lignin in itself does not contribute anything to the required strength properties of the eventual product but does consume bleaching chemicals in bleached pulp production. In cases where the pulp is to be used in its unbleached form, higher native lignin contents can be tolerated. If the pulp is to be used in its bleached form, much lower native lignin contents are required since the lignin imparts a brown coloration to the pulp and in brightening the pulp consumes excessive bleach chemical. Normally, in pulp to be bleached, about 80 per cent of the native lignin is removed and for unbleached production about 50 per cent is removed. The pulps thus produced give reasonably acceptable properties.

Wood is essentially constituted of tracheids or fibers which are constructed of concentric layers. The outermost layer of the fiber is called the primary wall and is separated from the primary wall of the next fiber by the middle lamella. Inside the primary wall towards the center of the fiber is the transitional lamella, then inside of this is the main layer or secondary wall and inside this, the tertiary wall or secondary lamella of the secondary wall. The cellulose content of the fiber is mainly concentrated in the main layer or secondary wall. The relative thicknesses of these layers for spruce tracheids (fibers) are as follows: The primary wall 7 to 14 per cent, the transition lamella 5 to 11 per cent, the main layer 78 to 84 per cent, and the tertiary wall or secondary lamella 3 to 4 per cent. The middle lamella is intimately connected to the primary walls of two adjacent fibers and is heavily lignified containing as much as 70 per cent lignin and is very stiff. Its high lignin content makes the middle lamella a hard and hydrophobic sheathing around the fibers which has to be weakened or removed to allow their separation. The primary wall has a low percentage of lignin, the transitional lamella an even less concentration of lignin and the main layer and tertiary wall or secondary lamella a very small concentration of lignin. Thus, the lignin concentration is essentially in the middle lamella and constitutes and provides the bonding and strength in the wood material.

In the production of pulp, the object of the process is to defibrate the wood. This means separating the cellulose fibers in the region of the middle lamella. All chemical pulping processes are designed to effect this fiber separation. The fiber separation in mechanically produced pulps is performed by forcing the fibers apart. In chemical treatment of pulps, the lignin is removed or weakened by chemical action such that the fibers can be separated. After fiber separation, the pulp is beaten to fibrillate the fibers which increases their

flexibility and improves their interfiber bonding ability in paper making.

It is normal in chemical pulping processes to remove at least 50 per cent of the native lignin to enable good defibration to occur and more is removed if the pulp is to be bleached. Freeness is an arbitrary measure of the rate at which a dilute pulp suspension parts with water when being formed into a sheet under standard conditions. The freeness of a pulp depends mainly upon the quantity of fiber debris present, the degree of fibrillation of the fibers, their flexibility and their fineness. In normal chemical pulps, the higher the lignin content the greater is the initial freeness of the pulp. Thus, with higher native lignin content pulps, more beating has to be performed on the pulp to bring it to an acceptable standard of freeness for papermaking. The degree to which the native lignin has been removed is indicated by a bleachability test, such as the Kappa number test. In mechanical pulps freeness of the pulp is not correlated with the amount of lignin present since essentially all of the lignin is retained in the pulp.

In chemical pulping the mechanism of solubilizing the lignin is by breaking the cross-linking in the polymer and attaching chemical groups to the broken polymer links to form soluble compounds. The exact molecular structure of lignin is as yet still unknown and the mechanisms of delignification are still unknown. However, it is known that lignin is a complex, randomly branched and cross-linked long chain polymer.

Very little work has been performed on the effects of electron beam radiation on wood. Literature shows that some work has been done using very heavy dosages of electron beam radiation on wood to attempt to break down the wood such that the celluloses are converted into sugars and glucoses thus enabling the wood to be used as animal fodder. Some work has also been performed upon pulp handsheets containing essentially cellulose in an effort to cross-link the cellulose in the pulp to produce a stronger product. In these experiments, the electron beam dosages were so high that they broke down the cellulose into the glucose and sugars.

BRIEF DESCRIPTION OF THE INVENTION

The present invention resides in the discovery that the yield and other properties of pulp made from wood chips are enhanced by subjecting wood chips to charged particles preferably high energy electrons, within certain dosage limits prior to subjecting the wood chips to a pulping process.

DETAILED DESCRIPTION OF THE INVENTION

I have discovered that when wood is subjected to irradiation with high energy electrons, i.e., electrons of several hundred thousand volts within certain dosage limits, the pulp from such wood can be substantially enhanced both in quantity and quality and economies can be effected in the pulping process. The effect produced in the wood is apparently one of modifying the lignin, the hemicelluloses and the cellulose. It is postulated that the electron beam breaks down the long chain molecules into smaller chain lengths and at the same time provides a degree of cross-linking among the fragments of the long chain molecules and the other molecular constituents of wood to produce molecules having entirely different properties than those in unirradiated material.

Whatever the mechanism, the new complexes formed have properties which enable defibration to be more easily performed, and under controlled process conditions do not detract from most physical strength properties of the pulp produced. Higher apparent lignin contents can be tolerated in the pulp without the pulp suffering any serious deleterious effects thereby increasing the yield of pulp. In many cases, most physical strength properties of the pulp produced with the higher lignin contents are improved or maintained. Under such conditions, one would normally expect them to be impaired.

Pulp produced from the irradiated wood develops papermaking properties much faster than from unirradiated wood. Thus, for example, with pulps produced from woods with increasing radiation dosages, the freeness of the pulps with otherwise equivalent processing decreases. This indicates that the defibration is much easier to perform from the irradiated pulp wood product than from the unirradiated wood product and that the defibration is easier the greater the irradiation dosage. In the pulping process, this property can be utilized to produce a certain quality pulp in much shorter time by pulping irradiated wood chips. When the cooking time is lessened greater lignin concentrations are included in the pulp. As the lignin is not deleterious in its modified form it can be retained in the pulp, thus increasing the pulp yield.

Lignin modification also appears to make the lignin more resistant to alkali attack and solubilization. Thus, it is desirable to reduce the alkali concentration in pulping irradiated wood. Alkali application in usual amounts serves only to solubilize excessive amounts of carbohydrates thereby weakening the ultimate product and decreasing the yield. Where mechanical pulping is performed the modification of the irradiated wood enables the wood to be defibrated with the expenditure of less energy.

There is an optimum dosage of irradiation to enhance the pulping properties of wood and for Western Hemlock the optimum appears to be about 0.5 Megarads. As the dosages of irradiation increase up to about 0.5 Megarads, the yield in chemical pulping can be increased and most strength properties of the pulp and pulp products can be maintained. Above 0.5 Megarads dosage the chemical pulp yield and some strength properties such as tensile strength and burst strength start to fall off, (this is particularly noticeable in unbleached chemical pulps with high Kappa numbers.) The decrease in chemical pulp yield is apparently due to a modification of the carbohydrate fraction rendering it at least partially soluble. The cause of the fall off in strength above 0.5 Megarads is not definitely known; it may be due to breakdown of the cellulose structure.

The energy of the irradiation and the thickness of the wood must be such that sufficient energy penetrates the wood to effect the modification desired. Conveniently the wood may be irradiated in the form of wood chips while being pneumatically conveyed through apparatus such as shown in my copending U.S. patent application, Ser. No. 93,060, filed Nov. 27, 1970, now abandoned.

The advantages and benefits of my invention are further illustrated in the following examples:

EXAMPLE I

Western hemlock (*Tsuga heterophylla*) logs from trees about twenty to 35 years old were debarked. Each

log was cut on a radial arm saw into 0.5 inch sections at an angle of 40 degrees to the grain. These sections were chipped at a 40 degree angle by a laboratory "chip slicer" into two to four mm. thicknesses. The resulting "cards" were handbroken into one-half inch to one inch widths and knots, compression wood or bruised chips removed and discarded. The chips were thereafter blended and air dried in a constant temperature and humidity room for four days before use. The procedure described above followed as closely as possible the wood preparation procedure which has previously been established by the Vancouver Forest Products Laboratory, Vancouver, British Columbia, Canada.

Wood chips prepared as described above were subjected to electron bombardment by passing the wood chips on a conveyor belt beneath an electron beam of 500 Kilovolts anode potential with the beam current of 20 Milliamps. The chips were turned on the conveyor belt and repassed through the beam so as to obtain substantially equal exposure amounts on opposite sides of the chips and radiation amounts indicated in the table below, that is, some of the chips were treated to 0.20 Megarads of electron bombardment, some to 0.50 Megarads, and some to 1.0 Megarads.

After irradiation, the chips were subjected to pulping in a microdigester such as that described by J. L. Keays and J. M. Bagley, "Digester Assembly for Precision Pulping Studies," *Tappi*, October, 1970, Volume 53, No. 10, pages 1935-1940. The chips were cooked under the following kraft cooking conditions:

Effective Alkali (on oven dry wood)	17%
Sulphidity	22.6%
Liquor to wood ratio	6.6:1
Maximum cooking temperature	334°F
Time to maximum temperature	60 min.
Time at maximum temperature	180 min.
Total cooking time	240 min.
Maximum thermal exchanger pressure	100 PSI

Non-irradiated chips prepared as described above were also pulped under similar conditions.

Thereafter the pulps from the various cooks were each beaten in a P.F.I. mill for 444 revolutions per gram. Freeness tests were made on such pulps in accordance with Tappi Standard T 227 M-58. Hand sheets for physical testing were made in accordance with the conditions set forth in Tappi Standard T 205 M-58. The sheets were tested for various properties as follows:

Test	Tappi Test Procedure
Kappa Number	T236 m - 60
Burst Factor	T403 ts - 63
Tensile Strength	T404 ts - 66
Zero-span Breaking Length	T231 sm - 60
Tear Factor	T220 m - 60

The results of these experiments resulted in the production of pulps shown in Table I and indicates that chips cooked under identical conditions show increasing lignin content (as indicated by the Kappa number), decreasing freeness, comparable yield and essentially comparable strength properties with increasing radiation dosage.

With unirradiated wood pulps, when Kappa number increases, the freeness value normally increases and strength properties are normally considerably impaired.

TABLE I

AMOUNT OF IRRADIATION (MEGARADS)	KAPPA NUMBER	TOTAL YIELD	FREENESS	TEAR FACTOR	BURST FACTOR	O-SPAN TENSILE	% TENSILE
0	96	54.4	504	105	95	19,100	10,650
0.2	102	54.3	481	97	94	19,600	11,030
0.5	124	54.5	450	84	83	19,200	10,280
1.0	134	54.0	318	76	86	18,100	10,200

EXAMPLE II

Wood chips of hemlock were prepared as in Example I. After irradiation of some of the chips at dosages of 0.20, 0.50 and 1.0 Megarads and the other conditions set forth in Example I, such chips and unirradiated chips were digested in the same microdigester as in Example I under the following Kraft cooking conditions with time at temperature being varied to achieve constant Kappa number:

10 such chips and unirradiated chips were digested in the same microdigester as in Example I under the following conditions:

15	Sulphidity	29%
	Lignin to wood ratio	5.2 to 1
	Maximum cooking temperature	340°F
	Time to maximum temperature	90 min.
	Time at maximum temperature	150 min.
	Total cooking time	240 min.
	Maximum thermal exchanger pressure	100 PSI
	Effective alkali	(see Table III)

20 The pulps were tested as in Example I, with the results as set forth in Table III:

TABLE III

	Unirradiated Control Pulp at 60 Kappa	Unirradiated Control Pulp at 90 Kappa	Irradiated Pulp at 90 Kappa (0.50 mrad)
Effective Alkali	14%	13%	13%
Total accept pulp yield after single refining (% accepts on O.D. wood charged)	44.2	40.5	47.9
Pulp properties:			
Freeness at 444 rpg	524	604	485
Burst factor	99	92	98
Tear factor	119	122	93
O-span tensile	18870	18,800	18,680
Tensile B.L. (m)	10690	10,400	10,640
Brightness at 457 mu	14.5	11.5	14.1

Effective Alkali (on oven dry wood)	17.0%
Sulphidity	25%
Liquor to wood ratio	5.2 to 1
Maximum cooking temperature	340°F
Time to maximum temperature	90 min.
Time at maximum temperature	90 to 150 min.
Total cooking time	180 to 240 min.
Maximum thermal exchanger pressure	100 PSI

Nonirradiated chips prepared as described above were also pulped under similar conditions.

The results of these experiments results in the production of Kraft pulps shown in Table II and demonstrates that at essentially the same Kappa number, pulp produced from irradiated wood develops papermaking properties much faster than unirradiated wood.

TABLE II

AMOUNT OF IRRADIATION (MEGARADS)	KAPPA NUMBER	FREENESS	TEAR FACTOR	BURST FACTOR	O-SPAN TENSILE	TENSILE
0	44	435	124	95	19440	10650
0	38	404	122	82	18070	9810
0.20	34	384	102	84	17830	9590
0.50	44	299	91	102	18140	11610
1.0	41	196	81	103	17990	11990
1.0	38	157	82	103	18600	12320

EXAMPLE III

Wood chips of hemlock were prepared as in Sample I. After irradiation of some of the chips at 0.50 Megarads and the other conditions set forth in Example I,

40 The results of Example III show that reduction in effective alkali application from 14 to 13 per cent (about a seven per cent reduction) results in an increase in accept pulp yield from 44.2 to 47.9 per cent with comparable pulp quality. On the other hand, unirradiated chips when pulped at 13 per cent effective alkali to a pulp of the same lignin content as the pulp from the irradiated wood, gave a decreased yield of 3.7 per cent with important impaired properties such as freeness and brightness and burst factor. The substantial lesser freeness figure of the irradiated wood pulp, as compared to the unirradiated control is evidence of the improved beatability of such pulp.

65 Having illustrated and described a preferred embodiment of the invention, it will be apparent to those skilled in the art it permits of modification in arrangement and detail.

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I claim:

1. In a process of making pulp from wood chips the step comprising subjecting the wood chips to irradiation with electrons in an amount less than 1.0 megarad but effective to improve at least one of the following pulping characteristics of the wood yield, pulp beatability, strength properties, and brightness.

2. A process in accordance with claim 1 wherein said wood chips are Western Hemlock and are subjected up to about 1.0 Megarads of electron beam irradiation.

3. A process in accordance with claim 1 wherein said wood chips are Western Hemlock and are subjected to about 0.5 Megarads electron beam irradiation.

4. The method of increasing the yield of pulp from wood which comprises irradiating such wood with elec-

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tron beam irradiation in amount effective to increase pulp yield therefrom and thereafter subjecting said wood to a chemical pulping process.

5. The method of decreasing the refining energy in the making of mechanical pulp from wood which comprises irradiating such wood with high energy electrons in amount sufficient to decrease the energy required to defibrate the wood.

6. The method of improving the production of pulp from wood by a chemical pulping process which comprises irradiating wood with high energy electrons in amount sufficient to reduce the energy required to cook the wood and to defiberize the same.

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