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MOMENTARILY CONSOLIDATED BOARD
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tion of DelawareNo Drawing. Application December 10, 1938,
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4 Claims. (Cl. 92—39)

My invention relates to board or sheet products of ligno-cellulose which has been subjected to high temperature and pressure in the presence of moisture. Under this treatment the material undergoes hydrolysis and the easily hydrolyzable components are converted to water-soluble or water-dispersible compounds, and largely removed, and the balance of the material converted to a predominantly plastic state. The new board is made of the predominantly plastic material so derived from ligno-cellulose. The present application is a continuation-in-part of my prior co-pending application Serial No. 104,780, filed Oct. 9, 1936, now Patent No. 2,140,189.

With one form of my invention such predominantly plastic ligno-cellulose is formed into a sheet from a suspension thereof in water and dried, as by drying in an oven-dryer, which accomplishes the drying without application of pressure. Such oven-dried board of predominantly plastic ligno-cellulose is suitable for wall boards and other uses, such as for being processed into the denser board referred to below, and is of a specific gravity which is well under 1 but still quite high, as approximately .7 specific gravity.

The second and preferred board of predominantly plastic ligno-cellulose which is embraced within the present invention is a denser board. This denser board may be produced in the same way as the oven-dried board just referred to, but in addition it is consolidated. By pre-converting the ligno-cellulose into a predominantly plastic condition, it becomes possible to effect permanent consolidation of the board of this material by making a very short or momentary application of pressure thereto, and this notwithstanding the pressure is released practically immediately after its application has been completed.

Thus the board can be consolidated rapidly and progressively, as between rolls for example, giving a roll-consolidated board with two finished surfaces, and the usual platen press can be dispensed with.

The board is immediately ready for use when cooled and preferably humidified to contain approximately the normal water content of board, after long time exposure to the atmosphere.

The main objects of the invention are the provision of the boards or sheets referred to above. Further objects will appear from the following description.

In order to put the ligno-cellulose material into such state that it can be permanently consolidated substantially momentarily by means of

pressure rolls or other means for making substantially momentary application of sufficient pressure, it is first largely converted to a predominantly plastic state by high temperature heat treatment carried out in the presence of moisture and applied for a time suited to the temperature used, and to the particular source of ligno-cellulose material.

The heat-treated material, preferably after being subdivided and reformed into desired formation, as sheet formation, for example, is dried, and the dry material superheated, and when in the dry, superheated and predominantly plastic state it can be permanently consolidated practically momentarily.

The heat treatment for hydrolyzing is preferably carried out by means of steam. When the ligno-cellulose material made use of is wood, which is preferable, the wood is desirably air-dried down to a substantially uniform water content, as for instance about 30% of water content. Avoidance of presence of water in undue quantities in this or other ways is of advantage in securing uniform control of the time for heat treatment by means of the high temperature steam. In order that all parts of the ligno-cellulose material may be heat-treated substantially alike, the wood is preferably reduced to small chips preparatory to the heat treatment, as for instance, chips which pass through a one-inch screen.

Ligno-cellulose material which has been heat-treated by means of steam at 350 lbs. pressure per sq. in. (225° C.) for an unduly long time, is largely devoid of material in fibrous-appearing state and not well adapted for being readily de-watered and felted into sheets, whereas with a shorter time, preferably about 5 minutes, at this pressure and temperature, a predominantly plastic ligno-cellulose material is obtained which is well adapted for use in making my new boards. As the pressure and temperature are increased, however, the time at the maximum pressure (after an initial period of pressure rise) can be decreased and relatively more of the fibrous-appearing ligno-cellulose material obtained without sacrificing the plasticity characteristics. For example, at 600 lbs. per sq. in. (255° C.), the time at full pressure for heat treatment of hardwood, such as gum, can be approximately 45 seconds, and for soft wood, such as pine, can be approximately 60 seconds; and at 1000 lbs. per sq. in. (285° C.), it can be approximately 10 seconds for gum to 15 seconds for pine. The time and/or temperature is somewhat less for woody

growths, such as corn stalks, cane bagasse, etc., which can be used if desired. These times are subject to modification by various operating conditions, such as size of gun or other treating apparatus, rate at which the steam is admitted, water content of chips, and the like. It is to be noted that in making a predominate conversion of the ligno-cellulose material into plastic state as herein described, the time in the gun at full pressure is considerably longer than heretofore required for making relatively coarse fiber for manufacture of fiber boards.

The heat-treated ligno-cellulose material is reduced to a state of relatively fine subdivision, permitting reforming into desired shapes, as for example into sheets. The subdivision may be accomplished in various ways, but is preferably accomplished by carrying on the heat treatment in a closed container or gun such as described in my Patent No. 1,824,221, and, when the heat treatment has been carried on for the predetermined period of time, a small outlet is opened whereby the heat-treated material is explosively discharged into a state of relative fineness, and the heat treatment is terminated. The heat treatment may be carried out in other ways, as in an autoclave, and in such case the heat treatment may be terminated, after a suitable time has elapsed, as by flooding with water, and the material may be reduced to fineness by means of a rodmill or the like after the autoclave is emptied.

The fibrous ligno-cellulose wood or woody starting material should contain a sufficient portion of the fiber-encrusting substances containing lignin to impart self-bonding properties. Cellulose fiber made by chemical digestion, such as soda pulp, for example, from which the non-cellulose constituents have been removed, is not adapted for the making of the board. Preferably the material taken for treatment is raw wood with the natural encrustants retained, which is the most readily available source of fibrous ligno-cellulose substance, and contains (together with the cellulose), the lignin and other natural non-cellulose, i. e., constituents other than cellulose.

I discovered that if the ligno-cellulose material, which has been rendered predominantly plastic by high temperature heat treatment in presence of H_2O , which is considered to effect an action of hydrolysis, is dried completely dry, and further heated, such dry, hot material can be permanently consolidated into a dense board or sheet of high specific gravity by application of sufficient pressure thereto, even though the pressure application is momentary, that is to say applied for a short time and released substantially immediately.

While the dense board is preferably made from a wetlap formed from water, such as a wetlap $\frac{3}{8}$ " to $\frac{1}{2}$ " thick, for example, it may be made by applying said steps of drying dry, and heating, and momentary permanent densifying, to a sheet or a plurality of superposed sheets of relatively thin paper formed by ordinary paper-making procedure from the ligno-cellulose material which has been rendered predominantly plastic by heat treatment.

When using times for heat treatment of the ligno-cellulose material as above described, especially from about 255° C. to about 285° C., the ligno-cellulose material as discharged from the gun appears to largely lose its fibrous structure. With such fibrous material as remains there is a quantity of quite finely divided material. Both

these parts, however, are predominantly plastic, and exhibit this characteristic when the material is put through the various steps of making the board of my invention. The fibrous-like material present is of advantage in that it enables the material to be dewatered and felted into sheet form for making wetlap sheets.

The heat-treated material usually contains about 20% or more of water solubles which are removed or substantially reduced, preferably reduced to about 5% by washing in water, or by squeezing out with rolls, opposed screws and the like apparatus, or both, thereby making the final product more water-resistant.

Sizing materials may be incorporated for further enhancing the naturally high water resistance, as for example 2% of petrolatum or paraffin sizing is useful for this purpose.

The heat-treated and finely divided material, largely freed from the water solubles, and preferably sized, is preferably formed from water into wetlap sheet formation, and excess water removed as by passing through squeeze rolls, and the sheet is dried completely dry. The drying (and heating in dry state referred to below) is preferably effected by means of heated gases, preferably air with the oxygen largely replaced by products of combustion, in order to reduce the likelihood of burning at the high temperature made use of. If the operation is interrupted at this point and the sheets stored temporarily before proceeding with further treatment described below, the sheets will absorb moisture. This moisture should be dried out before proceeding with the further treatment.

As already stated, the dried sheet, which is usually of about .7 sp. gr., can be taken for use as a wallboard if desired, instead of being put through the further treatment as hereinafter described.

After the material is dry, it is further heated to over 150° C. and preferably to over 180° C. Constituents which are converted into gaseous form at such temperature, and might produce blisters during later application of pressure, can be eliminated during such heating operation. The sheet after being so dried and heated can be consolidated by immediate application of sufficient pressure, and the consolidation so effected is permanent, even though the pressure be applied for a very short time and then released.

While such pressure application may be made in various ways, the most convenient mode consists in passing the sheet through between a pair of press rolls forced toward one another at high pressure, as by means of hydraulic rams.

The rolls are not primarily relied upon to supply heat to the sheet since the sheet when delivered to the rolls is at high temperature as above described.

However, the rolls are preferably heated to a temperature which may somewhat exceed the temperature of the sheets being rolled. In this way the rolls of steel or the like serve to prevent the sheet from cooling during the rolling operation, and impart additional heat at the surface, giving improved surface qualities.

The rolls are preferably smooth cylindrical rolls, thus making a sheet which is finished smooth, preferably on both surfaces. If desired, one or both of the roll surfaces may contain patterns which will appear upon the sheet after rolling.

The roll speed can be varied throughout a fairly wide range, as indicated in the examples given

below. When the holls are heated materially above the temperature at which the sheet is delivered to the rolls, low roll speeds, as for example roll speed below about 2 feet per minute, should be avoided because the additional heat delivery to the sheet from the slowly turning rolls tends to produce formation of gases and resulting blisters in the product sheet. The sheet is preferably formed continuously, and may not be cut into lengths until it has passed through the rolls, or it may be cut into desired lengths either before or after the drying and/or heating treatment.

Roll speed per min.....inches.....	70	150	150	200	300
Roll diameter.....do.....	36	36	36	36	36
Roll pressure.....pounds per linear inch.....	3,260	4,500	3,800	4,500	3,800
Roll temperature.....°C.....	270	225	270	270	270
Sheet drying and superheating time.....minutes.....	25	17	23	23	24
Temperature of superheated sheets.....°C.....	200	225	200	200	200
Specific gravity of product.....	1.20	1.22	1.16	1.16	1.14
Modulus of rupture dry.....pounds per square inch.....	8,300	6,965	6,500	7,090	7,365
Modulus of elasticity.....do.....	1,022,000	1,101,000	910,000	982,000	922,500
Water absorption in 24 hours.....Per cent.....	6.3	6.1	8.1	9.3	7.2
Residual strength (ratio of modulus of rupture after 24 hr. soaking in water to modulus of rupture dry).....per cent.....		88.8	72.8		61.4

As an illustrative example, gum wood was air dried to about 30% water content and hogged into chips. The chips were screened, and those passing through a one-inch screen taken for use.

A gun was charged with chips and closed.

Steam was admitted and the pressure raised to 600 lbs. per sq. in. (225° C.) and held at this pressure for 45 seconds.

A small outlet was opened and the contents of the gun explosively discharged through the opening.

With the heat-treatment and disintegration regulated in this way, the resulting relatively finely divided material was in part fibrous in appearance, with the remainder of finely divided material.

This subdivided ligno-cellulose material was put into water and lightly beaten in a beater of the Jordan type to make a pulp containing about 95% water. It was found that the exploded ligno-cellulose material contained about 20% of water soluble materials, and the water soluble content was reduced to about 5% by being dissolved out by the water.

The water and fiber mixture was heated above the melting point of paraffin, and molten paraffin added in an amount about equal to 2% of dry ligno-cellulose material by weight, and the paraffin was taken up by the ligno-cellulose material.

The resulting ligno-cellulose material, representing about 60% of the weight of the chips, was felted into sheet form from the water. The stock was somewhat "slow" due to its fineness but sufficient fibrous material was present to permit egress of water and to form felted sheets.

Water was pressed out of the sheet, bringing the water content down to about 50% (100% on weight of the dry ligno-cellulose material).

The resulting sheets, which were about $\frac{3}{8}$ " thick, were dried until completely dry as indicated by the fact that there was no further loss of weight, and were further heated for several minutes with indications of evolution of gaseous material. During the drying and further heating the sheets had shrunk to less than $\frac{1}{4}$ inch in thickness and were about .7 sp. gr., and as already stated, could be used for wall boards if desired.

These sheets were converted into the board product about $\frac{1}{8}$ " thick by passing same in dry, hot state immediately between hot pressure rolls. The board products thus prepared are quite dense having a specific gravity of about 1 to 1.25. The products are also relatively stiff and strong hav-

ing a modulus of elasticity dry over 900,000 lbs. per square inch, and a modulus of rupture dry over 6,000 lbs. per square inch. Such board products after being soaked in water for a period of 24 hours have a modulus of rupture wet equal to 60% of the dry modulus of rupture, or higher. If the material is sized, as for example with 2% of paraffin during the manufacturing process, the final product will not absorb water in excess of 15% upon 24 hours soaking in water.

The following table gives representative conditions and the results obtained:

This new board having high dry and wet strength can be used for practically all the purposes to which boards of coarse fiber material are adapted, as for building purposes and for myriad uses in industry.

The new momentarily-consolidated, preferably roll-consolidated, board is dependent primarily for its strength and stiffness upon the bonding effect obtained from the predominantly plastic make-up of its self-bonding material, produced as hereinabove described, rather than being dependent primarily for strength and stiffness upon fiber length and strength of fiber.

Products having the characteristic properties hereinabove described are preferably made directly from the heat-treated ligno-cellulose material alone, without incorporation of extraneous bonding or filler constituents. However, additions of binders, fillers, pigments and other materials, while unnecessary, may be made to the heat-treated ligno-cellulose material and will be embraced within the invention so long as the principles hereof are utilized.

I claim:

1. That improvement in roll-consolidated board products having two finished surfaces, which improvement consists in that the board product is composed essentially of extensively hydrolyzed ligno-cellulose material in predominantly plastic state and containing water soluble materials from hydrolysis only in relatively small proportions, and in that the board product is largely without fibrous structure and is principally dependent for strength and stiffness upon the predominantly plastic character of its constituent material rather than upon fiber length or strength, said board having a specific gravity of about 1 to 1.25 and a modulus of rupture of about 6,000 to 8,300 pounds per square inch.

2. Product as claimed in claim 1, and containing waterproofing material, said board having a water absorption of less than 15% on 24 hours soaking.

3. Product as claimed in claim 1, and in which the ligno-cellulose material is wood.

4. Product as claimed in claim 1, and in which the ligno-cellulose material is wood, and containing waterproofing material, said board having a water absorption of less than 15% upon 24 hours soaking.

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