July 31, 1956

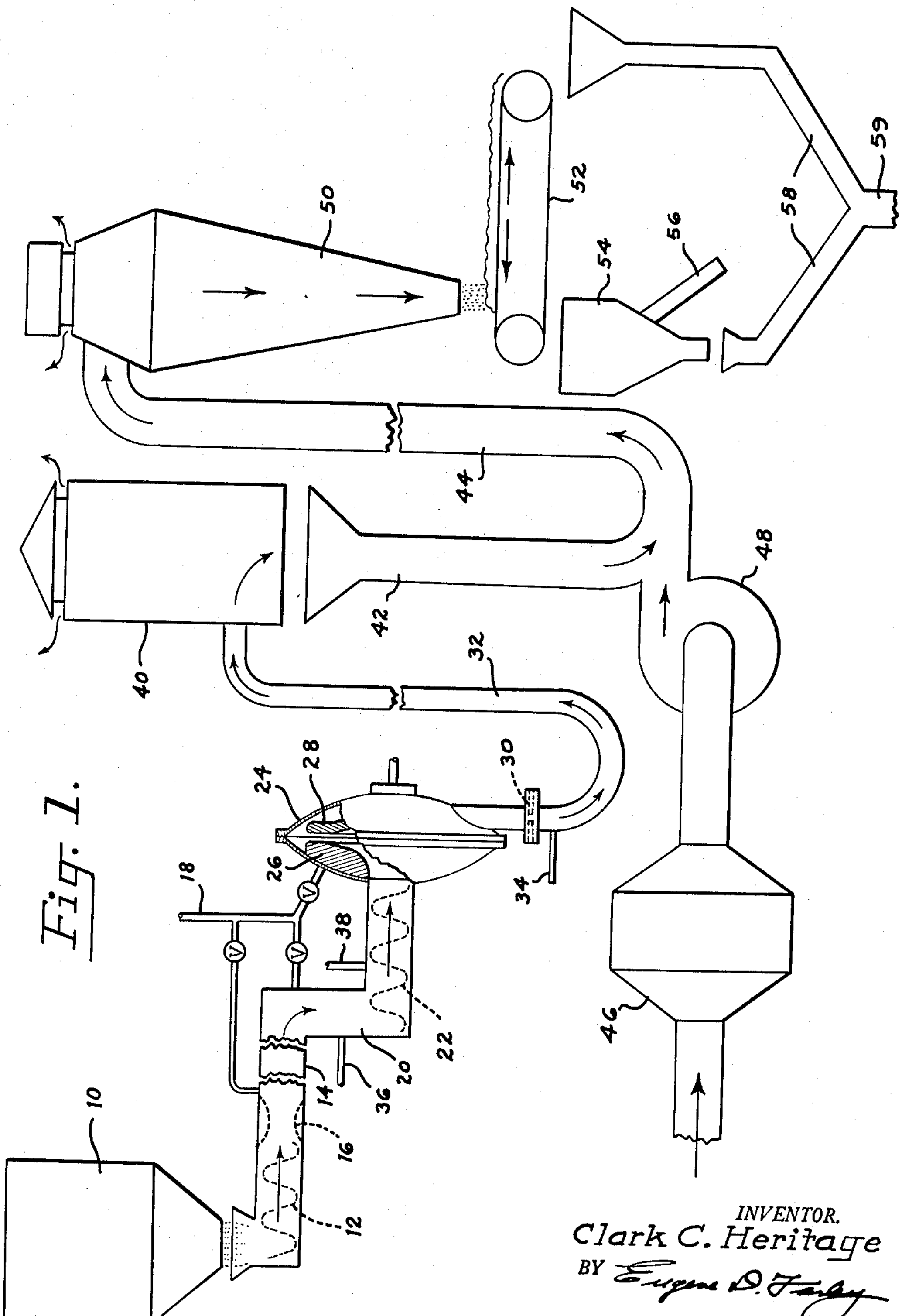
Filed Jan. 30, 1953

C. C. HERITAGE

FELTED, LIGNOCELLULOSE PRODUCTS AND METHOD OF MAKING THE SAME

2,757,115

3 Sheets-Sheet 1

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Filed Jan. 30, 1953 3 Sheets-Sheet 2

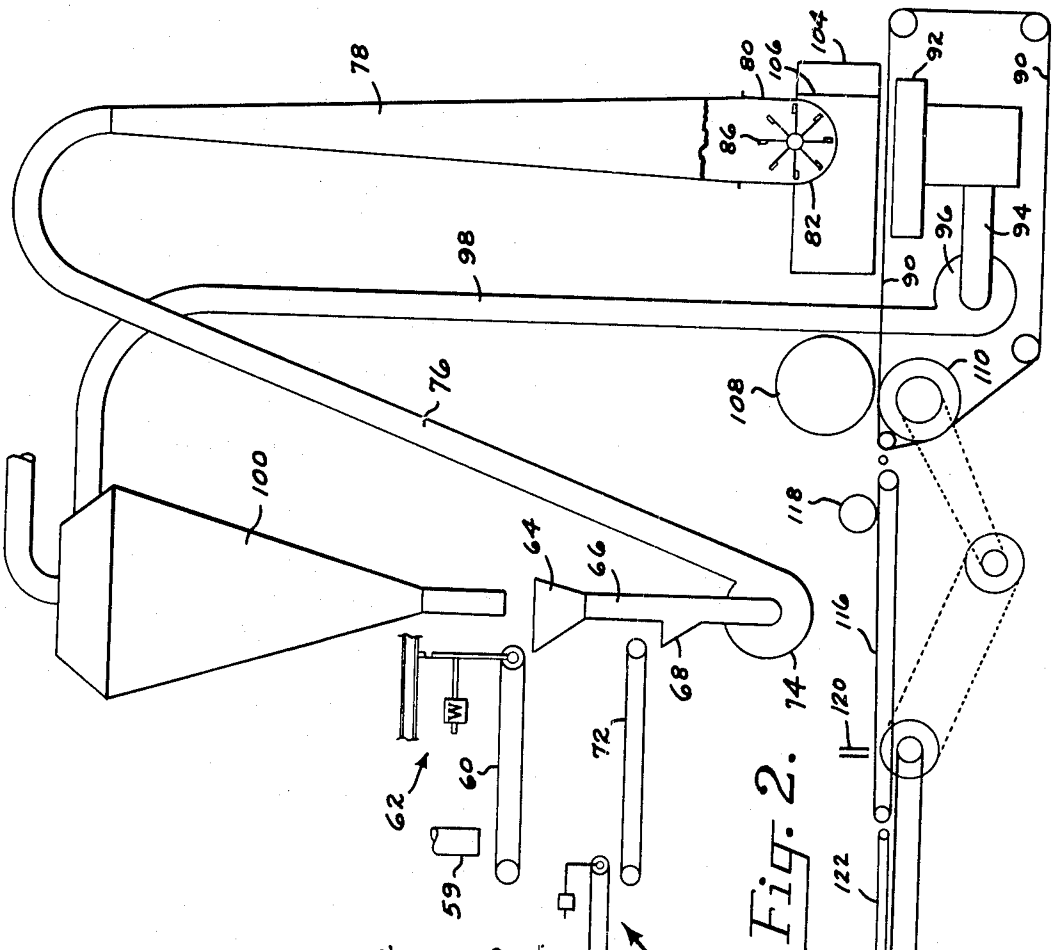


Fig. 2.

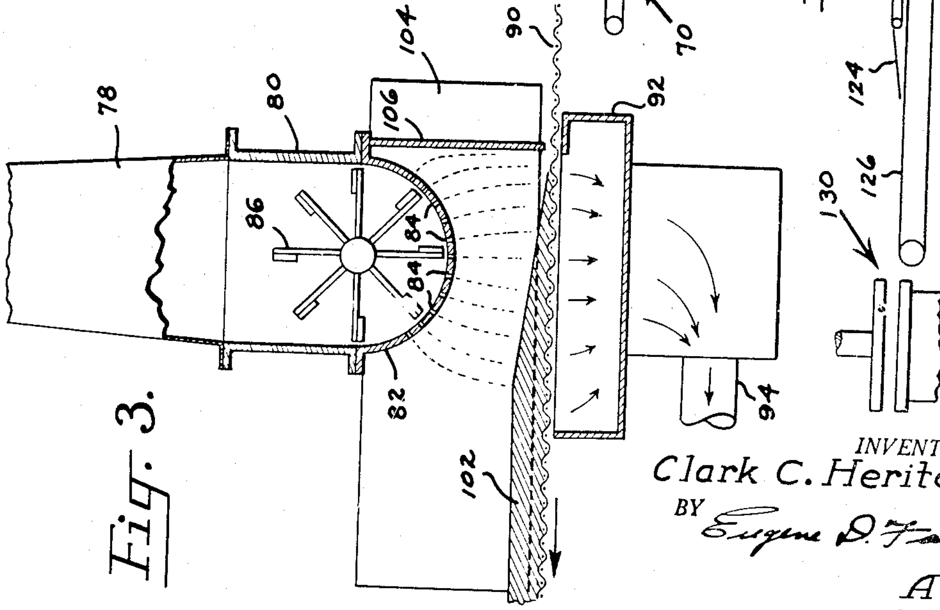


Fig. 3.


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Fig. 4.

Fig. 5.

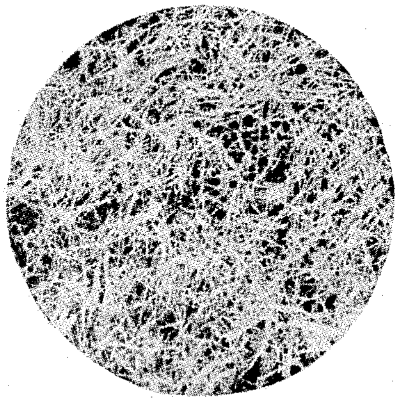

Fig. 6.

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United States Patent Office 2,757,115
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2,757,115

# FELTED, LIGNOCELLULOSE PRODUCTS AND METHOD OF MAKING THE SAME

Clark C. Heritage, Tacoma, Wash., assignor, by direct and mesne assignments, of one-half to Weyerhaeuser Timber Company, Tacoma, Wash., a corporation of Washington, and one-half to Wood Conversion Company, St. Paul, Minn., a corporation of Delaware

Application January 30, 1953, Serial No. 334,162

9 Claims. (Cl. 154—101)

This invention relates to felted, lignocellulose products, and to methods of making the same.

In the manufacture of hardboard and related products, lignocellulose materials such as wood, corn stalks, bagasse, straw, and the like, conventionally first are reduced to the form of small pieces. These are formed or felted into a predetermined shape which then is consolidated to the preselected density by the application of heat and pressure.

In this procedure, the quality and properties of the hardboard produced from a given lignocellulose material are determined by six principal factors, namely (1) the physical form of the lignocellulose particles, (2) the physical and/or chemical treatment to which the lignocellulose has been subjected prior to, during or after its reduction to the form of small particles, (3) the character and amount of materials added to the lignocellulose particles for such purposes as improving the strength and water resistance of the final product, (4) the type of forming or felting operation employed, (5) the conditions of pressing, and (6) any post-pressing treatment such as tempering or humidification. Of these, the physical form of the lignocellulose particles, the physical and chemical treatment to which the lignocellulose has been subjected, and the character of the felting operation are fundamental in determining the properties of the final product. If any one of these factors is neglected, no amount of improvement of the other variables will be successful in producing a hardboard of the maximum possible property values. It is to these factors that the present invention is directed.

Although hardboard heretofore has been made by many different processes, the properties of the product have not been as good as they might have been for failure properly to control one or more of the foregoing three fundamental variables. The lignocellulose particles have been used, for example, in either non-fibrous or fibrous physical forms. If in non-fibrous form, as where they comprise sawdust, wood flour, ground wood, shavings, or chips, the hardboard produced therefrom necessarily is of inferior quality since the particles of which it is composed, because of their shape and dimensions, cannot be intertwined and formed into a coherent felt prior to consolidation. As a result, the consolidated product is deficient in strength, a deficiency which can only partially be compensated for by the addition of relatively large proportions of binder. Also, where sawdust, wood flour, ground wood and other materials having large, porous surface areas are used, a substantial loss of binder occurs through impregnation of the particles.

When a fibrous lignocellulose starting material is employed, the foregoing difficulties are in large measure obviated because wood and other lignocellulose fibers may be intertwined and formed into a coherent felt having strength properties which are reflected in increased strength of the consolidated product. However, wood is a difficult material to reduce to the form of fibers, i. e. to the form of single tracheids, since the fibers which comprise the wood structure are breakable, and are bound together into a tough, coherent mass by the non-cellulosic content of the wood. Hence, any agency which is sufficiently potent to separate the fibers from each other, is also likely to break the fibers transversely. Also, it is difficult to reduce the material substantially completely to the form of individual fibers and as a result a large proportion of non-feltable, rigid, woody bundles and wood chunks are obtained.

Thus in one conventional defibering process, green or kiln-dried wood is combed or raked along the grain with steel brushes to separate the fibers. This necessarily mutilates and breaks the fibers transversely so that fiber fragments and chunks are obtained as the principal final products.

In another conventional defibering process, wood chips are rubbed between serrated metal discs. This method, like the combing procedure, suffers from the fundamental disadvantage that in order to separate the fibers from each other so much force is employed that the fibers are broken, and as a result fiber fragments, or a mixture of fiber fragments and woody chunks are obtained as products. To overcome this difficulty, the chips often are subjected to a prior treatment with steam or chemicals to soften them prior to defibering, but this also is disadvantageous, as will be pointed out hereinafter.

In still another widely employed defibering operation, wood chips are subjected to the action of steam at very high temperatures and pressures. After this the pressure is suddenly released whereupon the wood is exploded to fiber form. This process has the inherent disadvantage, however, of over-treating the material with subsequent degradation of its substance.

Turning now to the second fundamental variable which is of primary significance in determining the properties of a hardboard product, it again is noted that the properties of the lignocellulose may be deleteriously affected by subjecting it to the action of steam and other chemical agents before, during or after its defibration. Thus in the process described above wherein wood chips are subjected to a prolonged steaming procedure in order to soften them for defibration, the lignocellulose substance is hydrolyzed and thermally degraded.

This occurs because of the insulating qualities of the wood. In order to soften the chips, they must be treated with high temperature steam until the interior of the chips has been heated sufficiently to soften and plasticize the lignin. As a consequence, the outer portions of the chips are overheated and pyrolyzed. This degrades the wood fiber, adversely affecting its strength. It also converts a substantial proportion of the wood substance to water soluble materials which may be lost in subsequent processing operations, if at any time the fiber is suspended in an aqueous conveying medium.

Similarly, the same processes of degradation and solubilizing occur in the explosion process for defibering wood, but to even a greater degree. In this process the steam temperature and pressure employed are so high that the wood substance is scorched and darkened. This limits its use to the manufacture of dark colored products. It also weakens the fiber, a result which can only partially be compensated for by the addition of extraneous binder. Still further, it makes the fibers dead and non-resilient and causes them to lose a substantial measure of their ability to bind themselves together upon being pressed. In addition, as much as one-third of the total wood substance is converted to water soluble materials which may be lost if the fibrous product at any time during its processing is contacted with a substantial volume of water.

The third of the above noted factors which are fundamental in controlling the properties of the final product is the character of the operation by which it is formed into a mat or a felt prior to pressing. In general, there are two processes for accomplishing this result. In the wet process, a water slurry of the fiber is formed, which is passed on to a screen to drain off the water, following the orthodox paper making technique.

This procedure is undesirable for several reasons. It requires elaborate and costly machinery. It washes out the water solubles which may comprise a large proportion of the wood substance and which contribute in substantial degree to the bonding together of the fibers when they are pressed. Disposal of the white water creates a serious problem. The conveying water washes out some of the added binder and size, if present. The felts produced are heavy with water and difficult to handle. Because of their moisture content, they cannot be stored, transported or otherwise treated before being consolidated in a hot-press. The high moisture content of the felt markedly increases the heat usage during pressing, and correspondingly increases the cost of that operation. Satisfactory laminated felts cannot be produced. Under certain conditions the fibers tend to orient themselves in the machine direction as the felt is laid and hence a felt of randomly oriented, intertwined fibers is not formed. Also, the necessarily high density of the wet mat prevents random orientation of the fibers.

The dry or moist felting technique wherein dry or moist fibers are deposited in a mat or felt from a conveying medium comprising a gas such as air overcomes many of the foregoing difficulties. It employs simple equipment and obviously does not remove the soluble content of the fibers. Furthermore, any additive materials, such as extraneous binders, may be deposited efficiently upon the fibers and are not washed out subsequently in the white water, as occurs in appreciable degree in the wet process.

However, most of the conventional air laying operations wherein the fibers are permitted to gravitate onto the supporting member also have inherent disadvantages. In the first place, it is difficult to coat the fibers uniformly with binder where such is used. This is because in the absence of a suspending liquid, the binder is not deposited uniformly on the fiber surfaces. Also, the fibers tend to agglomerate and form clumps or flocs, and this leads to the production of a non-uniform felt.

Secondly, many of the air laid forms are hard to handle since they are loosely felted and not bonded and hence tend to disintegrate. Also, the surface fibers may not be anchored into the mat so that they blow away in air currents prior to pressing, and are easily rubbed off after pressing.

Thirdly, in some of the dry felting procedures, it is difficult to form an integral, multiple-layer felt, having for example, coarse fibers in the interior and fine fibers on the exterior. This is because condiions are not right for mixing and inter-locking the interfaced fibers of the laminae to form an integrated structure. As a result, the felt and the consolidated product derived therefrom are subject to delamination.

It is the essence of the present invention that the foregoing difficulties are overcome and a consolidated product of demonstrably superior properties is produced by using a fibrous starting material of selected physical form, produced while being subjected to carefully controlled non-degrading treating conditions, and felted by a pneumatic, impact-felting technique. As a result, all three of the above discussed fundamentally important variables are controlled to give optimum results so that a superior hardboard product may be made from a selected lignocellulose starting material.

This result is achieved by a novel process which basically comprises defiberizing the lignocellulose by rubbing and abrading it while subjecting it to an atmosphere of steam maintained at from about 50 to about 200 pounds per square inch gauge for from about ¼ minute to about 30 minutes. This produces a moist, fibrous product which consists primarily of discrete, whole, single tracheids and flexible opened up bundles of the same. The fibers having a water content insufficient to provide a fluid suspension of a mass of such fibers then are entrained in a stream of air or other gaseous vehicle and driven against a foraminous support member. This forms a felt containing impacted, driven fibers in which the individual fibers are randomly oriented and intertwined by the driving force of the entraining vehicle. The mat then may be consolidated by the application of heat and pressure to form the final hardboard product, wherein the driven fibers add to the strength and integrate the body to non-laminar form.

Considering the foregoing in greater detail and with particular reference to the drawings wherein:

Fig. 1 is a schematic view of the apparatus employed for preparing the fibers used in the preparation of the herein described consolidated product;

Fig. 2 is a schematic view of the felting apparatus which may be employed in forming a felt from the fibers produced in the apparatus of Fig. 1;

Fig. 3 is an enlarged detail view of the felting head assembly employed in the felting apparatus of Fig. 2;

Fig. 4 is a photograph, enlarged 40 times, of the herein described fiber as prepared from Douglas fir wood;

Fig. 5 is a photograph similar to Fig. 4, enlarged 15 times and illustrating a conventional fiber made by defibering steamed Douglas fir chips between serrated metal discs; and

Fig. 6 is a photograph, enlarged 15 times, of a felt made from the fiber of Fig. 4 using the hereindescribed pneumatic, impact-felting technique.

In accordance with the present invention lignocellulose, which may comprise corn stalks, bagasse, straw and the like, but preferably comprises wood in the form of chips, is introduced into bin **10**. It is fed from this bin by means of a screw conveyor **12** into the horizontal, steam heated preheater **14** of the defibrator. The latter may be of any suitable construction wherein the lignocellulose is rubbed and abraded while being contemporaneously subjected to the action of steam. Preferably, however, it comprises the defibrator known as the Asplund defibrator, substantially as described in U. S. Patent 2,145,851 to Asplund. The preheater of this machine has on its infeed side a constriction **16**. It is fed with steam under pressure through line **18**, which may also introduce steam into the defibrating chamber.

The chips after traversing the horizontal preheater pass into the vertical preheater **20**, whence they are forced through the spool piece **22** into the defibrating chamber **24**. There, having been softened by the steam environment present in the apparatus, they are fed between relatively rotatable discs **26**, **28**, which rub and abrade them to form a fibrous product consisting principally of ultimate fibers in the form of individual tracheids, together with a minor proportion of flexible bundles of fibers. This result is achieved because when the chips are defibered in a steam environment it is not necessary to heat each chip until it is entirely heated through, thereby degrading the wood substance. Rather, the surface of each chip is heated until the lignin is softened, whereupon the surface fibers are rubbed off by the defibering discs. This exposes a new surface which then is softened by the steam environment and further reduced to fibers by the action of the discs. This sequence continues until the chips have been entirely reduced to fibers, which are removed from the region of high pressure and temperature substantially as soon as they are formed so that they are not deteriorated thereby.

In order to obtain the desired result during defibering, i. e. the reduction of the lignocellulose to the form of individual tracheids with a minor proportion of flexible bundles of the same without chemically degrading the wood, it is necessary to control the conditions within the defibrator within carefully defined limits, which may vary for each specific material. These conditions are met when wood chips are defibered while subjecting them to an atmosphere of steam maintained at between about 50 and about 200 pounds per square inch gauge, and corresponding temperatures for saturated steam, for periods of time ranging from about ¼ minute to about 30 minutes, the lower limit of the pressure-temperature range applying to the higher limit of the time range. Preferred conditions are between about 80 and about 160 pounds per square inch gauge for from about ½ minute to about 6 minutes. When the lignocellulose is defibered under these conditions, a major proportion of substantially ultimate fibers or individual tracheids are produced with a minimum of degradation of the wood substance.

The fibrous product formed in the defibrating chamber is discharged through an orifice 30 which creates a plug of fiber at the outfeed side of the machine. This together with the plug formed at constriction **16** on the infeed side maintains the desired pressure.

The discharged fiber enters a first conduit **32** at substantially the machine temperature and in a moist condition, its moisture content being between about 30% and about 100% by weight (dry basis). Since it has been forced suddenly from a region of relatively high pressure to one of substantially atmospheric temperature, there is a marked lowering of the temperature as a result of the instantaneous and therefore near adiabatic expansion of the steam. The heat thus liberated assists in drying the fibers.

Also, the fibers are in a condition of great turbulence and may therefore now be mixed effectively with additive materials. Hence, a thermosetting resinous binder, if such is to be incorporated, may be introduced in a pumped, metered feed through line **34**. Other materials, such as thermoplastic binders, sizing materials, fire-proofing agents and the like, may be introduced at this point, as well as at other points, as for example, in the preheater, via line **36**, or ahead of the defibrating discs via line **38**.

Suitable thermosetting resins for use in conjunction with the presently described process comprise the urea-formaldehyde resins, the melamineresins, and the phenol-aldehyde resins including the thermosetting, resinous condensation products of phenol and formaldehyde, phenol and acetaldehyde, phenol and furfural, the cresols and formaldehyde, resorcinol and formaldehyde, etc.

A fast curing thermosetting resin which is particularly suitable for use in this process is the phenol-formaldehyde resin having a formaldehyde-phenol ratio of about 1.5–3 to 1, i. e. one prepared using from about 1.5 to about 3 mols of formaldehyde for each mol of phenol. In addition, it may be characterized by the following approximate properties:

| | |
|---|---|
| Viscosity (cp. at 25° C.) | 100–1000 |
| Specific gravity at 25°/25° C. | 1.14–1.16 |
| Percent alkalinity (NaOH) | 2–6 |
| Non-volatile content (percent) | 30–50 |

These and other thermosetting resins may be employed singly or in admixture with each other in amounts of between about 0.1% and about 15%, preferably between about 2% and about 6% by weight based on the dry weight of the fibrous composition.

Where a thermoplastic resin is employed alone or with a thermosetting resin, it may be used in amount of between about 2% and about 60%, preferably between about 5% and about 40% by weight, based on the dry weight of the fibrous composition. A variety of thermoplastic resins thus may be employed, suitable ones being the asphalts, the gilsonites, the pine wood resins including extracted pine wood pitch (Vinsol), the thermoplastic natural gums such as Congo gum, the thermoplastic cellulose ethers, the thermoplastic cellulose esters, the thermoplastic polyvinyl chlorides and acetates, and the like.



In order to dry the moist mixture of fiber and binder as well as to advance the thermosetting resin to the optimum extent without rendering it inert and infusible, the fiber-binder mixture formed just beyond orifice 30 is passed rapidly through the elongated conduit **32** where it is thoroughly mixed, cooled by the expansion of the steam as well as by radiation from the conduit, partially dried, and its resin content only partially cured because of the short duration of passage through the conduit. From conduit **32** the mixture passes through steam separator **40** where some further cooling may occur, after which it enters a second conduit **42**.

The latter communicates with a heating chamber **44** supplied with air or other dehydrating gases, such as nitrogen or flue gas, heated if necessary in heater **46** and forced into the conduit by means of fan **48**. The air supplied by this heater is at a temperature sufficient to raise the temperature of the mixture to a level at which it is dried to a value of between about 5% and about 40%, preferably to between about 10% and about 30% by weight. It also effectuates a further advancement of the resin, but without destroying its bonding and fusible qualities.

When it is to be used as felting stock, the dried mixture may be separated from the entraining air in cyclone **50** where it is cooled rapidly. This prevents further advancement of the resin. The fiber product with or without added resin then is deposited on conveyor **52** for conveyance to storage, or to the felting means, or to a fiber fractionating means **54**. The latter may be a series of vibrating screens, a winnower, or one or more whizzers (Crites U. S. Reissue 20,543) and has for its function the division of the fiber product into a plurality of size fractions. One such fraction may be a relatively small proportion of fines, which may be discarded. Another fraction may be coarse particles, which may be discarded, recomminuted in a second refiner, or recycled via conduit **56** to hopper **10** for feeding again into the defibrator. Still another fraction may be the bulk of the material which constitutes the acceptable fraction for the purposes of the present invention. The acceptable fraction passes in a conduit **58**, to a conduit **59** which conveys it to the felting apparatus. Conduit **58** may also receive run of the machine fiber from conveyor **52** when this is desired and when conveyor **52** is run in the appropriate direction.

By the foregoing procedure there is obtained the fiber product which is uniquely suited for the felting operation described below. In the first place, the fiber is in the form of single tracheids or flexible opened up bundles of the same, as is illustrated in Figure 4. This figure is to be compared with Fig. 5, which illustrates a conventional fiber prepared by defibering previously steamed chips between mechanical discs operating under atmospheric conditions. It is at once apparent that the conventional product contains a high proportion of sticks, ribbons and chunks. Furthermore it contains a relatively high proportion of fiber fragments. From this it is clear that even if this fiber is fractionated to remove the sticks, ribbons and chunks, the remaining product will consist not primarily of individual tracheids and flexible, opened up bundles of the same, as in the case of applicant's products, but rather of a large proportion of fiber fragments which do not have desirable felting qualities, as will be more fully developed hereinafter.

The desirable properties of the presently described acceptable fraction of fibers for fiberboard manufacture are further indicated by their particle size distribution, compressive properties and feltability. As measured in a Clark Classifier, less than 5% falls in the plus 8 mesh fraction indicating a substantial absence of chunks and large particles, while less than 25% falls in the minus 80 fraction, indicating that only a relatively minor proportion of fines is present and of this proportion a major fraction consists of small, whole fibers. The fibers have, furthermore, a high resistance to compression, a typical value being about 80 pounds per square foot (see Anway U. S. 2,325,026). This indicates the fiber to be live and springy so that it may be felted efficiently to form a strong, coherent felt. Feltability tests to be described in detail hereinafter indicate this felt to have a tensile strength of about double that of a felt made from the same wood species which has been steamed and then defibered at atmospheric pressure to a fiber designed for felting to mats for hot pressing to hardboard.

The presently described defibering process thus produces a fibrous product which is uniquely suited for use in the production of fiberboard. This is because of all fiber types, it most nearly approaches natural wood in its properties, while still being producible in high yield, This is a direct result of the defibering operation which permits separation of the individual tracheids from each other under conditions so mild as to inhibit the formation of degradation products of the lignocellulose, such as an unduly large proportion of water solubles and particularly of products which hide or darken the wood color. Such water solubles as are formed, moreover, are retained by the fiber, thereby increasing the yield of fibrous product and supplying a native binder available for bonding in subsequent consolidating operations.

The native binder present may be reinforced and supplemented by the presence of added binder introduced at a suitable stage, preferably during the defibering operation in one or more of the ways described above. This enables utilizing the binder in the most efficient manner, spreading it over the fiber surfaces as opposed to impregnating the fibers, and in the case of a thermosetting binder, advancing it to the optimum point for a rapid pressing schedule. Still further, the fiber contains a very high proportion of flexible, resilient individual tracheids and flexible aggregates of the same, all of which may be intertwined and interlocked to form a coherent, strong, felt of demonstrably superior qualities.

In order to take advantage of the foregoing desirable qualities of the presently described fibrous product, however, the ensuing felting procedure must be so designed as to preserve and utilize them. Thus is should not degrade the fibers by subjecting them to the action of excessive heat or strong chemical agents. Also, it should not remove from them the desirable content of water soluble materials.

Still further, the felting procedure should be so designed as to take advantage of the physical form of the fibers, intertwining and interlocking them with each other to form a strong coherent felt which may be handled easily. Then upon pressing the felt the fibers are pressed and bonded to form a pressed product which is remarkably strong because of the inherent strength developed through interlocking of the fibers as well as through the adhesive forces developed by the native and added binder.

It is another fundamental aspect of the present invention that the above desiderata are achieved by felting the fibers using a pneumatic, impact felting technique, which will be described below with particular reference to Figures 2 and 3.

In accordance with the illustrated embodiment, the acceptable fraction of fiber from fiber fractionator **54** is conveyed via conduit **59** to belt **60**. This belt has associated with it a weighing mechanism **62**, so that the combination comprises a weighing feeder for feeding a measured amount of fiber into a hopper **64**.

Hopper **64** communicates with a conduit **66** having therein a chute **68**, positioned for feeding additive material such as extraneous size or binder. The additive materials are fed to chute **68** by means of a suitable weighing and feeding mechanism including the weighing unit **70** which deposits the additive upon a conveyor **72**, which in turn empties into chute **68**.



Suction is applied to conduit **66** by means of a rotary fan **74** which drives the mixture of fiber and additives through an elongated conduit **76** where mixing of the fiber with the additives occurs. Conduit **76** in turn empties into a housing **78** which serves as an expansion conduit for the air-entrained fibrous mixture.

Hence, it serves the functions of reducing the velocity of the fibers, minimizing felting in the housing, and of equalizing the air stream over the discharge area of the housing. Accordingly, housing **78** flares downwardly through increasing rectangular cross-sections as by means of a pyramidal structure. In practice, housing **78** may flare from a rectangular cross-section at the bottom opening of about 24 x 54 inches in a vertical drop of about 17 feet.

The bottom or discharge opening of housing **78** may be extended by a suitable tubular means such as head-box **80**. The length of the head-box may be varied to suit particular installations, since it serves as a connecting link between housing **78** and the felting head **82** connected to the head-box at its discharge end.

Felting head **82** comprises a semi-cylindrical member disposed substantially at right angles to the machine direction. A suitable arc, for example, an arc of about 100°, of its periphery is perforated symmetrically with openings **84** having a diameter calculated to pass individualized fibers of the air-entrained fibrous mass fed thereto under pressure from fan **74**. In practice, when felting wood fibers, the diameters of these openings may be from ⅜ to ⅝ inch in diameter and counter-sunk deeply from the exterior side. The openings thus serve the function of breaking up any fiber clumps and of passing a uniform rain of individual fibers to the exterior. The countersinking minimizes the extent of cylindrical wall in the openings, thereby minimizing the tendency of the holes to plug during fiber delivery and to deliver slugs felted within the holes.

To assist in breaking up the fiber clumps and transmitting them through the openings in the felting head, there is provided agitating means which in a preferred embodiment comprises the paddle-wheel **86** mounted coaxially with the felting head and driven by a suitable power means.

The individual fibers passing through perforations **84** are driven in a steady stream by the force of the entraining air against a foraminous support member which preferably is a moving, continuous screen **90**. Screen **90** is driven by suitable means at a rate correlated with the rate of deposition of the fibers to form a felt of the desired thickness.

The felting of the fibers on screen **90** is assisted by establishing a vacuum beneath the screen. To this end there is provided a suction box **92** of suitable dimensions. It communicates with a conduit **94** which in turn leads to a fan **96**, which exhausts through conduit **98** into a solids separator such as cyclone **100**. The latter serves the function of separating any finely divided materials which may have passed through screen **90**. These then are reintroduced into the feed by transferring them into hopper **64** where they are mixed with the fresh feed.

The fibers then are formed into a continuous, uniform mat or felt **102** by the co-action of the driving force of the pressure stream in the felting head above the screen and the suction stream in the suction box below the screen. It will be apparent that the felting conditions are subject to a certain degree of variation in order to accommodate various fiber types and to build felts of preselected characteristics.

Such variation may be accomplished, for example, by varying the ratio of feed to entrained air, the speed of rotation of rotor **86**, the dimensions of the felting area, the relative pressures of the pressure and vacuum streams, and the like. In general, however, in order to achieve the desired result of driving the felting fibers into the partially formed felt to secure the critically necessary random orientation and intertwining of the fibers, the conditions should be adjusted so that the fibers are traveling at a velocity of between about 100 and about 1500 feet per minute in the region directly above the screen. This is achieved by maintaining a pressure of from about 0.1 to 1.0 inches of water in the head-box and a pressure of from about 2 to about 30 negative inches of water in the suction box.

Felt **102** is contained within and dimensioned laterally by a pair of opposed vertical side walls, one of which is indicated at **104**, stationed on opposite sides of the screen and connected by a vertical end wall **106**.

After the felt leaves the forming area it passes between the pressing rollers **108**, **110** which effect a partial consolidation and make the felt self-sustaining. Thence it passes to a conveyor **116**, past side trim saws **118** and beneath an automatic cut-off saw **120**, which moves angularly across the moving mat to cut rectangular sections therefrom of the selected length. These sections then pass to a conveyor **122**, over blade **124** and thence to a conveyor **126**. The latter conveyor moves at a different rate than do the preceding conveyors in order to separate the felt sections. These then are transferred to caul plates, preferably placed on the stretch of conveyor **126** below conveyor **122**, and thereafter conveyed to the press indicated schematically at **130**.

The pressing conditions are somewhat variable depending upon the type of fiber employed, the thickness of the product to be produced, the moisture content of the felt, the character of any resinous binder which may be present therein, the density and surface characteristics desired in the final product, and the like. In general, however, when making ⅛ inch hardboard from a felt having a moisture content of between about 5% and about 40% by weight, the felt may be pressed at from about 120 to about 250° C. at a pressure of between about 50 and about 1000 pounds per square inch for a time of between about 2 and about 10 minutes.

From the foregoing it is apparent that the superior properties which are characteristic of the fibers produced by the present process are in no way deleteriously affected by the felting procedure. Furthermore, the felting operation is of a character such as to make the best possible felt from the fibers. This is attributable to the fact that the fibers first are entrained in an air stream and then impacted or driven individually toward the felting screen. This effect is clearly apparent from Figure 6.

It will be noted from this view that the fibers, initially resilient, curly, individualized, and retaining substantially their original length, lie at all angles to each other. Some of them lie in the horizontal plane, some at an angle thereto, and some in the vertical plane. The latter may be considered as "nailers" holding together the more horizontally disposed fibers. All of the fibers are intertwined and interlocked with each other to form a coherent mat. This effect is further evidenced by the fact that the felt may be flexed and even rolled up on itself without surface cracking or interior delamination.

It is evident that when this mat is consolidated by the application of heat and pressure, the randomly oriented fibers will be crimped together and locked in those position by the native and added binder to form a fiberboard product of maximum strength for the given raw materials. Also, the product is characterized by superior bendability, making possible the fabrication of severely and permanently contoured objects without delamination.

The presently described process is illustrated further in the following example:

*Example*

Douglas fir wood chips were defibered in an Asplund machine regulated to provide a steam environment of 140 pounds per square inch gauge and a corresponding temperature for saturated steam. The dwell time of the chips within the machine was about 1 minute.

About 1% phenol-formaldehyde resinous binder employed in the form of an alkaline aqueous solution having a resin solids content of about 40% and a pH of about 11 was introduced just downstream from the orifice of the machine. The resulting fibers were dried to a moisture content of 25% by weight.

As a control, there was obtained a quantity of Douglas fir wood fiber manufactured by steaming whole wood chips at a steam pressure of about 60 pounds per square inch gauge and a corresponding temperature for saturated steam for a time period of about 30 minutes. The steamed chips then were transferred to an Allis-Chalmers Interplane Grinder set to produce the maximum proportion of individual fibers obtainable from this device. The fibrous product then was dried to a moisture content of about 15%.

The two products were compared as to appearance, particle size distribution, bulk density, compressive properties, and feltability. The comparison as to appearance already has been discussed above in connection with Figures 4 and 5, the predominance of ultimate fibers and the relative absence of woody chunks, slivers and ribbons in the presently described fiber again being noted. The comparative particle size distributions in percent by weight of the two products as determined by a Clark Classifier were as follows, the values being mesh sizes:

| Fraction | Present fiber (percent) | Control fiber (percent) |
|---|---|---|
| +8 | 2.4 | 21.4 |
| −8 +24 | 30.2 | 36.0 |
| −24 +50 | 31.4 | 21.0 |
| −50 +80 | 12.0 | 7.8 |
| −80 | 24.0 | 13.8 |

From a comparison of the above values it becomes apparent immediately that run of the machine fiber as produced by the presently described process is almost entirely free of the +8 fraction, which contains substantially all of the large non-fibrous particles which are undesirable for the present purposes. The control fiber, on the other hand, contained over 21% of this fraction.

A comparison of the fiber lengths of the two products is given below:

| | Percent of Product having a particle length of 7 mm. or less | Percent of Ultimate fibers |
|---|---|---|
| Present fiber | 83.0 | 78 |
| Control fiber | 81.0 | 38 |

In interpreting the above data it is to be kept in mind that Douglas fir wood fibers have a maximum length of about 7 mm. It then becomes apparent that in the case of the present fiber 83% of the product had a particle length of 7 mm. or less and of this 78% was in the form of ultimate fibers. In the case of the control fiber, although 81% had a length of 7 mm. or less, only 38% was in the form of ultimate fibers. Hence it is clear that the presently described defibering process produces an amount of ultimate fibers which is more than double that produced by the most closely competitive defibering procedure.

A comparison of the unimpacted bulk densities of the two fibrous products revealed that the present fiber had a bulk density of 1.34 pounds per cubic foot, while that of the control fiber was 1.27 pounds per cubic foot.

Comparison of the compressive properties of the two products indicated a resistance to compression of 81.0 pounds per square foot for the present fiber and a resistance to compression of only 53.5 pounds per square foot for the control fiber. These values indicate that the present fiber is a more resilient, feltable material than is the control.

In comparing the feltability qualities of the two products an impacted mat was formed using a sufficient thickness of fiber to produce a one-eight inch board having a density of 64 pounds per cubic foot. This mat was compressed at room temperature and 600 pounds per square inch for 1 minute. The tensile strength of a 6-inch wide strip of the resulting felt then was determined immediately. The felt formed from the present fiber had a tensile strength of 11.3 pounds while the control fiber had a corresponding strength of only 6.6 pounds, thereby again illustrating the inherent strength present in the felts made in accordance with the present invention.

The two fibrous products then were made into hardboard by entraining the fibers in a stream of air at a fiber velocity of about 200 feet per minute in accordance with the process described above using a pressure in the felting head of about .40 inch of water and a pressure in the suction box of about 5.7 negative inches of water. The felts then were pressed at 750 pounds per square inch and 200° C. for 8 minutes and the modulus of rupture of the two fiberboard products determined. The presently described fiber produced a hardboard having a rupture modulus of 6900 pounds per square inch, while the control fiber produced a hardboard having a rupture modulus of only 5500 pounds per square inch, these values being corrected to a density of 64 pounds per cubic foot.

Furthermore, the presently described fiber produced a hardboard of remarkably improved bending properties. This was indicated by the results of comparative bending tests carried out on the instant hardboard, as well as on four currently marketed commercial products. The tests were carried out by soaking the hardboard sheets in water for varied periods of time and thereafter bending them to a 135° angle on a conventional bending machine having a 3.5 inch roll diameter. The results are summarized in the following table.

| Presoaking | Presently described Hardboard | | | Commercial Hardboard #1 | | | Commercial Hardboard #2 | | | Commercial Hardboard #3 | | | Commercial Hardboard #4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Break | Surface | Angle, degrees | Break | Surface | Angle, degrees | Break | Surface | Angle, degrees | Break | Surface | Angle, degrees | Break | Surface | Angle, degrees |
| 35 min | 0 | 1 | 134 | 0 | 1.2 | 128 | X | 3 | 129 | X | 3 | 113 | X | -------- | 133 |
| 5 min | 0 | 1 | 122 | X | 1.5 | 108 | X | -------- | 121 | X | -------- | 114 | X | -------- | 127 |
| 3 sec | 0 | 3 | 134 | X | -------- | 118 | X | -------- | 126 | X | -------- | 117 | X | -------- | 132 |

NOTE.—X—Signifies sample broke in bending; 0—Signifies no breakage during bending; 1—Signifies satisfactory surface; 2—Signifies marginal surface—useful for limited applications; 3—Signifies unsatisfactory surface.

The foregoing tests indicate that the hardboard of the present invention is characterized by several fundamentally improved bending characteristics. It is easier to bend than are the competitive hardboards, requiring a much shorter presoaking period. It may be bent to a sharper angle and once bent, has a reduced tendency to spring back. The surface at the bend is improved on both the tension and compression sides of the board in that the surface is smoother and less subject to delamination. The board is stronger at the bend. Also, it may be bent equally well in random direction as opposed to some boards which may be bent in one direction only depending, for example, upon the orientation of the fibers. These properties are clearly attributable to the fact that in the production of the hereindescribed hardboard product a superior fiber first is provided which then is felted prior to pressing into a mat wherein the fibers are intertwined and interlocked, thereby permitting bending without breaking, delamination or weakening of the board.

From the foregoing it will be apparent that by the present invention control has been achieved for the first time over the three fundamental variables which must be regulated in order to obtain a hardboard of maximum quality. Thus a fiber starting material has been produced in the form of individual tracheids which are curly, elongated, resilient, and free from chunks and slivers. This product is obtained with minimum transverse breakage of the fibers and without subjecting them to any degrading chemical treatment which weakens the wood structure, causes the fibrous product to lose life, and which results in the production of an inordinate amount of water soluble materials. The relatively small amount of the latter substances which are produced by the present process are fully retained and spread on the fiber surfaces where they serve as a valuable native binding agent.

Still further, the character of the felting operation is such as to utilize to the greatest extent possible the desirable felting qualities of the fiber employed. Thus, as has been fully brought out hereinabove, the fibers are impacted into a felt in random orientation and with the individual fibers intertwined and interlocked. Hence, as is fully apparent from the superior strength obtained for the presently described hardboard product, the superior qualities and strength of the felt are reflected in a corresponding improvement in the final pressed product with the result that for the first time a hardboard has been produced which may be manufactured in large volume and in which are developed to the maximum degree the desirable properties of products of this class.

Having now described my invention in preferred embodiments, I claim as new and desire to protect by Letters Patent:

1. The process of making consolidated fibrous products which comprises defiberizing lignocellulose by rubbing and abrading it while contemporaneously subjecting it to an atmosphere of steam maintained at from about 50 to about 200 pounds per square inch gauge and corresponding temperatures for saturated steam for periods of time ranging from about ¼ minute to about 30 minutes, the lower limit of the pressure-temperature range applying to the higher limit of the time range, fractionating the fibrous product thus produced at a moisture content of from about 5% to about 40% to effect separation of the fibrous product into a plurality of size fractions, one of which consists primarily of discrete whole ultimate fibers and flexible opened up bundles of the same having a particle size in the range of from +8 to −80 mesh particles as measured by a Clark Classifier and contains less than 5% of the +8 and less than 25% of the −80 mesh particles, entraining the said fraction in a moving gaseous vehicle, driving the component fibers while so entrained against a foraminous support member, thereby forming a mat of impacted fibers in which the individual fibers are randomly oriented and entrained by the driving force of the entraining vehicle, and consolidating the resulting mat by the application of heat and pressure.

2. The process of claim 1 in which the fiber velocity in the entraining moving gaseous vehicle is between about 100 and about 1500 feet per minute.

3. The process of making consolidated fibrous products which comprises defiberizing lignocellulose by rubbing and abrading it while contemporaneously subjecting it to an atmosphere of steam maintained at from about 50 to about 200 pounds per square inch gauge and corresponding temperatures for saturated steam for periods of time ranging from about ¼ minute to about 30 minutes, the lower limit of the pressure-temperature range apply-

ing to the higher limit of the time range, mixing with the fibrous product thus produced from about 0.1% to about 15% by weight of thermosetting resin, fractionating the resulting fibrous product at a moisture content of from about 5% to about 40% to effect separation of the fibrous product into a plurality of size fractions, one of which consists primarily of discrete whole ultimate fibers and flexible opened up bundles of the same having a particle size in the range of from +8 to −80 mesh particles as measured by a Clark Classifier and contains less than 5% of the +8 and less than 25% of the −80 mesh particles, entraining the said fraction in a moving gaseous vehicle, driving the component fibers while so entrained against a foraminous support member thereby forming a mat of impacted fibers in which the individual fibers are randomly oriented and entrained by the driving force of the entraining vehicle, and consolidating the resulting mat by the application of heat and pressure.

4. The process of making consolidated fibrous products which comprises defiberizing lignocellulose by rubbing and abrading it while contemporaneously subjecting it to an atmosphere of steam maintained at from about 50 to about 200 pounds per square inch gauge and corresponding temperatures for saturated steam for periods of time ranging from about ¼ minute to about 30 minutes, the lower limit of the pressure-temperature range applying to the higher limit of the time range, mixing with the fibrous product thus produced from about 2% to about 60% by weight of thermoplastic resin, fractionating the resulting fibrous product at a moisture content of from about 5% to about 40% to effect separation of the fibrous product into a plurality of size fractions, one of which consists primarily of discrete whole ultimate fibers and flexible opened up bundles of the same having a particle size in the range of from +8 to −80 mesh particles as measured by a Clark Classifier and contains less than 5% of the +8 and less than 25% of the −80 mesh particles, entraining the said fraction in a moving gaseous vehicle, driving the component fibers while so entrained against a foraminous support member thereby forming a mat of impacted fibers in which the individual fibers are randomly oriented and entrained by the driving force of the entraining vehicle, and consolidating the resulting mat by the application of heat and pressure.

5. The process of making consolidated fibrous products which comprises defiberizing lignocellulose by rubbing and abrading it while contemporaneously subjecting it to an atmosphere of steam maintained at from about 50 to about 200 pounds per square inch gauge and corresponding temperatures for saturated steam for periods of time ranging from about ¼ minute to about 30 minutes, the lower limit of the pressure-temperature range applying to the higher limit of the time range, mixing with the fibrous product thus produced from about 0.1% to about 15% by weight of thermosetting resin and from about 2% to about 60% by weight of thermoplastic resin, fractionating the resulting fibrous product at a moisture content of from about 5% to about 40% to effect separation of the fibrous product into a plurality of size fractions, one of which consists primarily of discrete whole ultimate fibers and flexible opened up bundles of the same having a particle size in the range of from +8 to −80 mesh particles as measured by a Clark Classifier and contains less than 5% of the +8 and less than 25% of the −80 mesh particles, entraining the said fraction in a moving gaseous vehicle, driving the component fibers while so entrained against a foraminous support member thereby forming a mat of impacted fibers in which the individual fibers are randomly oriented and entrained by the driving force of the entraining vehicle, and consolidating the resulting mat by the application of heat and pressure.

6. Fiberboard comprising essentially a hot bonded consolidated mixture of vegetable fibers consisting predominantly of whole ultimate fibers and opened up aggregates of ultimate vegetable fibers containing substantially all of the organic substance of the vegetable matter from which the fibers have been derived, the fiberboard having a density of at least 30 pounds per cubic foot and interfiber bonds set at said density, the component fibers of the fiberboard having a particle size in the range of from +8 to −80 mesh particles as measured by a Clark Classifier and comprising less than about 5% by weight of the +8 and less than 25% of the −80 mesh particles, the said component fibers being interfelted in at least as great a degree as that characteristic of the same fibers in substantially uniform 3-dimensional distribution at a felt-forming density of from 1 to 6 pounds per cubic foot and having positional relations relative to each other determined by the positions taken by the fibers on compression of the felt.

7. Fiberboard comprising essentially a hot bonded consolidated mixture of vegetable fibers consisting predominantly of whole ultimate fibers and opened up aggregates of ultimate vegetable fibers containing substantially all of the substance of the vegetable matter from which the fibers have been derived admixed with from about 0.1% to about 15% by weight of a cured thermosetting resin, the fiberboard having a density of at least 30 pounds per cubic foot and interfiber bonds set at said density, the component fibers of the fiberboard having a particle size in the range of from +8 to −80 mesh particles as measured by a Clark Classifier and comprising less than about 5% by weight of the +8 and less than 25% of the −80 mesh particles, the said component fibers being interfelted in at least as great a degree as that characteristic of the same fibers in substantially uniform 3-dimensional distribution at a felt-forming density of from 1 to 6 pounds per cubic foot and having positional relations relative to each other determined by the positions taken by the fibers on compression of the felt.

8. Fiberboard comprising essentially a hot bonded consolidated mixture of vegetable fibers consisting predominantly of whole ultimate fibers and opened up aggregates of ultimate vegetable fibers containing substantially all of the substance of the vegetable matter from which the fibers have been derived admixed with from about 2% to about 60% by weight of a thermoplastic resin, the fiberboard having a density of at least 30 pounds per cubic foot and interfiber bonds set at said density, the component fibers of the fiberboard having a particle size in the range of from +8 to −80 mesh particles as measured by a Clark Classifier and comprising less than about 5% by weight of the +8 and less than 25% of the −80 mesh particles, the said component fibers being interfelted in at least as great a degree as that characteristic of the same fibers in substantially uniform 3-dimensional distribution at a felt-forming density of from 1 to 6 pounds per cubic foot and having positional relations relative to each other determined by the positions taken by the fibers on compression of the felt.

9. Fiberboard comprising essentially a hot bonded consoliated mixture of vegetable fibers consisting of predominantly of whole ultimate fibers and opened up aggregates of ultimate vegetable fibers containing substantially all of the substance of the vegetable matter from which the fibers have been derived admixed with from about 0.1% to about 15% by weight of a cured thermosetting resin and from about 2% to about 60% by weight of a thermoplastic resin, the fiberboard having a density of at least 30 pounds per cubic foot and interfiber bonds set at said density, the component fibers of the fiberboard having a particle size in the range of from +8 to −80 mesh particles as measured by a Clark Classifier and comprising less than about 5% by weight of the +8 and less than 25% of the −80 mesh particles, the said component fibers being interfelted in at least as great a degree as

that characteristic of the same fibers in substantially uniform 3-dimensional distribution at a felt-forming density of from 1 to 6 pounds per cubic foot and having positional relations relative to each other determined by the positions taken by the fibers on compression of the felt.


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