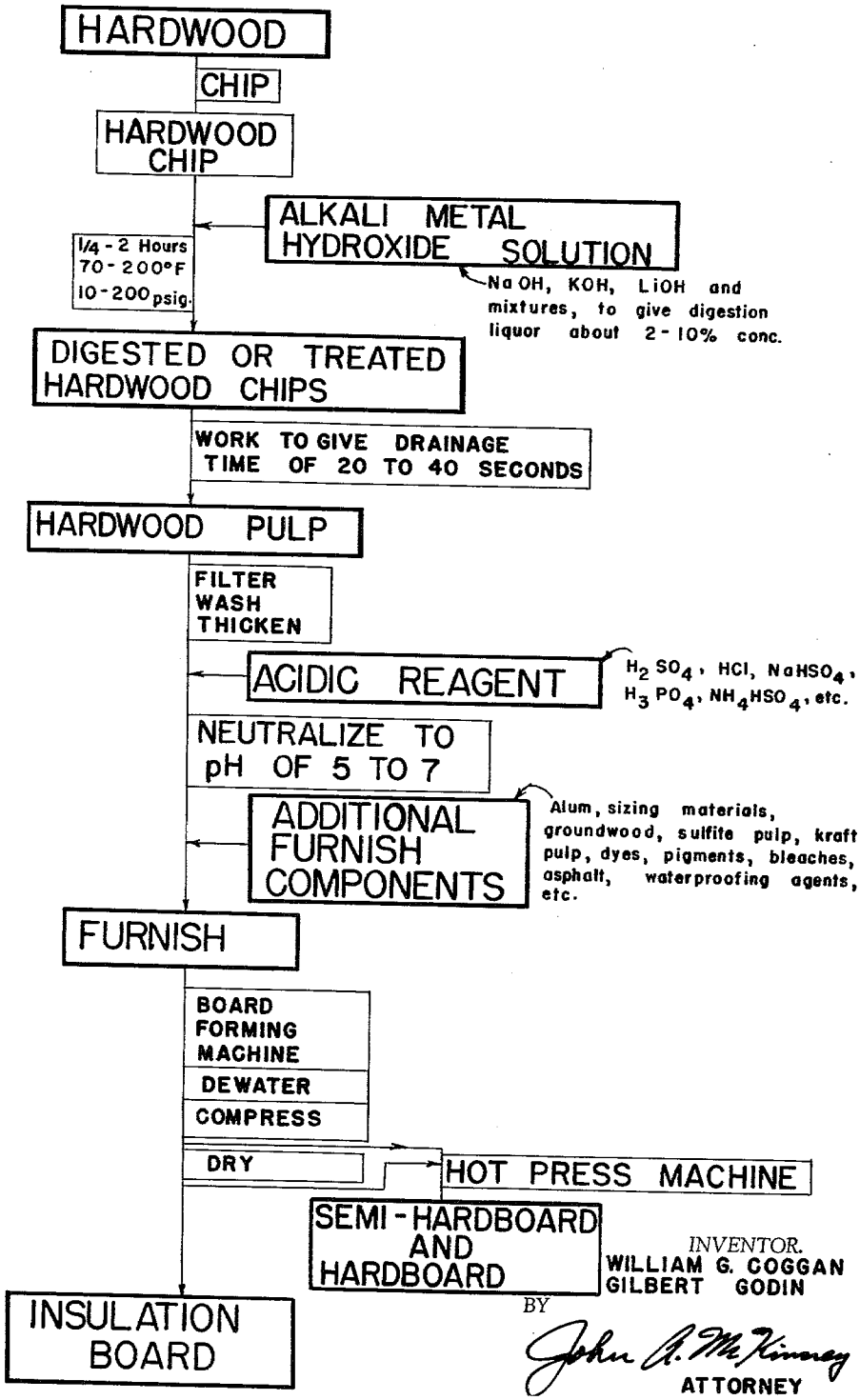
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COLD CAUSTIC FIBERBOARD MANUFACTURE

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COLD CAUSTIC FIBERBOARD MANUFACTURE

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This invention relates to wood fiberboard, commonly known as fiberboard, to processes for the preparation of pulp from hardwood, and processes for the preparation of fiberboard from such pulps.

FIELD OF INVENTION

Fiberboard is a general term applied to sheets or boards manufactured from fibers of wood or other lignocellulosic fiber material with the primary bond derived from the arrangement of the fibers and their inherent adhesive properties. Bonding agents or other materials may be added during manufacture to increase strength, resistance to moisture, fire, insects or decay, or to improve some other property of the product. Such fiberboards are to be distinguished from particle boards, as the former type of boards rely upon interfelting of the fibers, which interfelting produces a mat with a characteristically natural bond, while the latter boards do not partake of the interfelting characteristics of the fibers.

Fiberboards may be classified into several categories; for the purpose of this invention, the classification system found in "Fiberboard and Particle Board" published by the Food and Agriculture Organization of the United States (Rome, Italy, 1958), is used. The fiberboard is classified therein either as a non-compressed fiberboard or as a compressed fiberboard. The non-compressed fiberboards have a density in the order of about 25 pounds per cubic foot or less and may be further subdivided, on the basis of density, as semi-rigid insulation board and rigid insulation board. On the other hand, the compressed fiberboards have a density of over approximately 25 pounds per cubic foot, and this group may also be subdivided, on the basis of density, into semi-hardboard, hardboard, and special densified hardboards.

Semi-rigid insulation board has a very low density, and it is used primarily in insulation. Production of this type of board is small at the present time. Rigid insulation board, one of the types of boards with which this invention is primarily concerned, has a density range in the order of about 9½ to 25 pounds per cubic foot. It is used primarily as material for house construction, e.g., sheathing, interior paneling, acoustical panels, and as a base for plaster or siding. It is also manufactured into special forms for many additional uses. For example, it may be laminated into thick sheets for structural decking and for cores of doors and partitions.

The stated top limit of density of rigid insulation board, which is generally accepted by the fiberboard industry, is determined by practical considerations, since it is the top limit in density readily obtained on a Fourdrinier, cylinder, or deckle box former without auxiliary hot-pressing. Many industrial and commercial specifications indirectly control the top limit of density of a rigid insulation board by specifying the maximum allowed coefficient of thermal conductivity, which, in general, increases with density. The maximum coefficient is in the order of about 0.40 B.t.u./hour/sq. ft./° F./inch of thickness. The thickness of such rigid insulation boards (unlaminated) ranges from approximately ¼ inch to 1 inch, and the board sizes range from approximately 3′ x 4′ to 4′ x 12′.

The compressed fiberboards (i.e., compressed under relatively high pressure and the simultaneous application of heat) of the semi-hardboard type (known also as intermediate density or medium density fiberboard) vary in density from about 25 to about 50 pounds per cubic foot. The hardboard type of fiberboard ranges in density from about 50 to about 75 pounds per cubic foot. The densities of special densified hardboards are in excess of 75 pounds per cubic foot, but for purposes of this invention, they will be treated the same as hardboards. The semi-hardboards and hardboards may be formed in the same way as rigid insulation board, but subsequent to the step of the forming of wet mats of fibers they are hot-pressed, either by the "wet press" technique or by the "dry press" technique.

It is to be understood that the processes of making the rigid insulation board may also be used in the manufacture of the semi-hardboard or the hardboard type of fiberboards; the primary difference between the processes of manufacturing rigid insulation board and the processes of manufacturing semi-hardboard and hardboard is that the insulation board technique does not utilize a hot-press treatment which is necessary in forming semi-hardboard and hardboard.

The procedure used for the formation of rigid insulation board is essentially a filtration or dewatering operation. In the usual process, a layer of fiber slurry is applied to a foraminous support upon which the fiber layer is partially dewatered to form a wet fiber mat, which is then further dewatered, roller or belt compressed, and subsequently dried to form the final board. Such board forming operations are generally carried out continuously, principally on so-called "wire" (Fourdrinier) or "cylinder" (Oliver) machines, and consequently there is some similarity between the board forming operations and the operations used in making paper. However, the fibers needed for insulating board production are very significantly different, i.e., much coarser, than those used for paper manufacture. Moreover, the dewatering characteristics of board forming pulps are highly important to the success of a board forming process, because of the necessity of forming very thick felts, sometimes referred to as "mats" or "webs." Actually, it is principally the thicknesses of the mats which are handled in board manufacture, as contrasted to paper manufacture, which necessitate the principal differences in machinery, materials and processes employed.

Rigid insulation board is used today in enormous quantities for a wide variety of uses. Consequently, differences in cost of manufacture of the final product are critical factors in the making and selling of this type of product. It is necessary to provide insulating board having the highest possible strength characteristics at a minimum of cost in order for the product to be accepted and purchased by the ultimate user. Speed of production is a vital factor in overall cost of insulating board manufacture, since the higher the speed at which the board can be continuously made, the lower the cost of the product. Hence it is desirable to make the board from a furnish which possesses a fast drainage time so as to make possible the use of high forming speeds. Also, the fibers used in the manufacture of insulating board must be available in large quantities and at relatively low cost. The fibers should also be capable of forming a final dried mat having good strength characteristics without the use of substantial amounts of resins, gums, or other materials, as added binders. The fibers should also lend themselves to inexpensive pulp forming operations.

One factor which contributes to the cost of pulp used in the production of insulating board is the quantity and cost of chemical reagents required to form the pulp from wood. If pulp forming procedures can be devised which use only relatively small quantities of inexpensive chemical reagents, or in which it is possible to recycle

the processing liquors in order to digest very large quantities of wood for a given amount of chemical reagent, the cost of pulp production for insulation board manufacture will be decreased. These cost reductions may in turn be passed on to semi-hardboard and hardboard, since the latter two boards are derived from the basic insulating board or basic wet mat. The recycling of the digestion liquors offers further possibilities for reductions in pulp costs, because the recycling reduces the requirement for waste disposal of the liquors, which is a problem and a contributing factor to the over-all costs of the pulp. Thus, a pulping operation which would permit the digestion liquor to be recycled or reused many times, before it is necessary to discard it, would substantially reduce the portion of the pulp cost attributable to waste disposal.

Because of these various limitations which are imposed upon the procedures and materials used in the production of rigid insulation board, e.g., raw material costs, production speeds, and the like, manufacture of this type of product has been restricted, prior to the instant invention, to boards having densities within the limited range in the order of about 10 to about 25 pounds per cubic foot. Thus, while the rigid insulating board manufacturers have been attempting to produce and offer to the trade, on an economical basis, products having a wider range of density than have been available heretofore, they have been seriously restricted in that regard by these various limitations.

As noted, the upper limit of about 25 pounds per cubic foot is a practical limit of density for rigid insulating board, dictated by practical use of the board forming machines. One significant factor which has contributed in the past to this limitation on density range has been the characteristic of available board forming pulps to rebound or spring back, when the wet mat is compressed after it has been formed and before it is dried. Thus, after the wet mat is removed from the wire or cylinder machine and before it is dried, it is cold-compressed, usually by pressing rollers or belts, to force further water from it and at the same time to increase its density. However, with the prior available board forming pulps, there invariably has been a substantial amount of rebound or spring-back in the cold-compressed wet mat, so that before the mat can be dried, the thickness of the mat increases substantially over the thickness imparted to the mat in the cold-compressing step. Therefore, if a board forming pulp were available which would produce cold-compressed wet mats having significantly less tendency for this rebound or spring-back to occur therein, it would permit better control in the amount of compression put into and retained by the wet mat, and, consequently, would make it possible to obtain a wider range of board densities of the final dried products.

Having in mind the problems and limitations of the art discussed above, a principal object of this invention is the provision of new improvements in the manufacture of wood fiberboard comprising hardwood fibers, and especially rigid insulating board, usuable as such, in a density range of about 10 to about 35 pounds per cubic foot, or further hot compressed for use in the form of semi-hardboard or hardboard. Further objects include:

(1) The provision of a new variety of strong fibers for use in the manufacture of wood fiberboard which is compatible in all proportions with ground wood and which possesses very fast water drainage times, making possible production of fiberboard at high forming rates;

(2) The provision of fiberboard-forming fibers, which possess a higher degree of compressibility and lower degree of spring-back when cold-compressed in a wet mat than fibers available heretofore;

(3) The provision of new methods for digesting hardwood to form pulp for use in the production of wood fiberboard;

(4) The provision of new pulp forming methods for

production of wood fiberboard fibers which makes it possible to produce pulp in shorter time than with prior known pulping methods used in the formation of wood fiberboard fibers, and, in addition, which can be operated at relatively low digestion temperatures and with less problem as to disposal of waste liquors;

(5) The provision of such pulping methods which substantially reduce digester corrosion;

(6) The provision of a new variety of insulating board having a higher density than any insulating board known or available heretofore;

(7) The provision of new methods for forming insulation boards, which methods make possible a wider range in density of such products than prior known methods for their manufacture;

(8) The provision of new wood fiberboard forming fibers almost comparable in strength characteristics to kraft fibers, but with a drainage time more than five times as fast as kraft fibers; and

(9) The provision of new procedures for the pulping of hardwood to form wood-fiberboard-forming fibers at high yield rates with low chemical reagent consumption and without the need for use of special or complicated apparatus.

Other objects and further scope of applicability of the present invention will become apparent from the detailed description given hereafter; it should be understood, however, that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

GENERAL DESCRIPTION

These objects are accomplished by the processes which can be readily comprehended by reference to the accompanying flow diagram of the type suggested by N. O. Wolk, 30 J.P.O.S. 368, which outlines the steps and materials involved.

Briefly described, the new procedures of this invention for the formation of insulation board comprise chipping hardwood to form chips as uniform in size as possible, for example, forming chips capable of passing a 1-inch mesh screen but not a ¼-inch mesh screen, impregnating the hardwood chips with a 2.5 to 10% by weight solution of alkali metal hydroxide in water at about 70° to 200° F. under either atmospheric or hydrostatic pressure for sufficient time to obtain thorough impregnation of the chips, working the resulting chips, as by refining in a disc type refiner, until the Tappi drainage time thereof is between about 20 and 40 seconds, neutralizing the pulp to a pH of about 5 to 7 with sulfuric acid or other acidic reagent, forming a furnish from the pulp, with the inclusion, if desired, of additional furnish components, such as sizing materials, ground wood or other fiber, waterproofing agents, fireproofing agents, dyes, pigments or the like, then continuously creating a layer of the furnish on a foraminous support, dewatering the layer of furnish through said support to create a web fiber mat, compressing the partially dewatered mat to remove further water therefrom and to increase the fiber density, and finally drying the compressed web.

In addition, the basic insulation board, manufactured according to the techniques briefly described herebefore, can also be used in the manufacture of semi-hardboard or hardboard types of fiberboards, utilizing the basic insulating board in its wet or dry form. In the manufacture of such semi-hardboard and hardboard, the insulating board is transferred to a hot press where it is compressed under a relatively high pressure under controlled conditions of pressure, time, and temperature of the press.

Examples

More detailed understanding of the new procedures and products of this invention may be had be reference to the

following examples in which all parts and percentages are by weight unless otherwise specified.

Example I

A standard hardwood, as, for example, red gum logs and slabs with the bark on them, are fed through a chipper to form chips of substantially uniform size, the major portion of which pass a standard sieve of 1-inch mesh size, but which are retained on a sieve of ¼-inch mesh size. One hundred parts of these fresh, rough red gum chips are charged into a digester vessel, of the type mounted on trunnions to permit rotation about a horizontal axis and equipped with a large charging port and inlet conduits for introduction of reaction liquors.

In a separate mixing tank, a 6% solution of sodium hydroxide in water is prepared and heated to a temperature of approximately 160° F. Approximately 500 parts of this heated caustic solution are then pumped from the mixing tank into the chip-filled digester, a rotary pump in a recycle pipe line is turned on, building up within the digester a hydrostatic pressure of 150 p.s.i.g. If desired, the digester shell may be pre-steamed to heat the shell. The pressure is maintained for 30 minutes by automatic control of the pump, after which period the pump is stopped and air pressure is applied through an inlet valve and pipe to force the cooking liquor out of the digester though a suitable strainer opening into the adjacent storage tank. The digester is then uncapped and rotated on its trunnions to dump its load of digested hardwood chips to a receiving tank.

The complete cooking cycle takes only 110 minutes, including approximately 30 minutes to cap and load the digester, 10 minutes to pump in the cooking liquor, 15 minutes to pump the hydrostatic pressure up to 150 p.s.i.g., 30 minutes for cooking, 10 minutes for blow-down and 15 minutes to uncap and dump the digester. The heart of the operation is the cooking time of 30 minutes. If the process were to be continuous, the duration of the entire process could be reduced approximately to the cooking cycle time. By a constant feed and constant withdrawal system, the 80 minutes required for loading, pumping in the cooking liquor, building up the pressure, blow-down, uncapping and unloading the digester may be virtually eliminated, so that the process is essentially broken down to the cooking cycle, per se.

Where a non-continuous process is used, the digester is reloaded with another batch of hardwood chips, while the recovered liquor in the storage tank is reheated and refortified with a 50% caustic soda solution to bring the caustic soda content of the solution in the bank back to approximately 6% after about 20 parts of fresh water have been added. The fresh water may also be obtained by the condensation of steam used in preheating the digester tank. Then the reheated and refortified cooking liquor is pumped into the loaded capped digester, and the high-head, low-volume pressure pump is placed into operation to again pressurize the digester to 150 p.s.i.g. After 30 minutes of operation, the pump is again stopped, and the digester liquor is forced out of the digester, which is then uncapped and dumped as previously described.

The procedure of charging the digester, re-use of reaction liquor refortified with additional fresh caustic solution and fresh water is continued with removal for each full cycle of quantities of accumulated reaction liquor absorbed by the chips and replacement with added quantities of fresh concentrated caustic soda solution and fresh water to maintain a substantially constant concentration of caustic and soluble digestion products in the reaction liquor. The cooked wood mix dumped from the digester is conveyed to a Bauer-type double disk pulp refiner set with a plate clearance of 0.007 inch, and it is treated therein until the Tappi drainage time for the refined fiber measures between 25–30 seconds. The resulting fiber slurry is then acted upon by vibrating Johnson screens, of 3/16" perforations, to eliminate the

oversize fibers, and then sent to filtering screens where the fiber mix is simultaneously dewatered and washed with hot water showered onto the fiber mix from above. This filtering and washing operation, commonly called deckering, is carried out continuously so that a thick wet web of pulp is continuously delivered from the outlet side of the filter of deckering equipment.

The resulting pulp has the following physical properties:

Tappi drainage time (seconds)	30
Mullen strength (average) (percent)	19.2
Bauer-McNett fiber classification (percent by weight):	
+14 mesh	33.4
−14+28 mesh	14.7
−28+48 mesh	22.5
−48+100 mesh	7.8
−100+200 mesh	2.0
−200 mesh	19.6

A series of ten digester runs, conducted as described above, results in a consumption of caustic soda of approximately 10% based upon the dry weight of the wood chips charged to the operations, not including the caustic soda content of the reusable recovered cooking liquor to be employed in the mix cycle of operation. Also, in this series of digestions, it is found that the yield of fibers is approximately 85% of the weight of the hardwood chips charged to the operations.

The pulp web from the deckering operation is then conveyed to a stock chest where it is mixed with fresh water, or re-use water, in sufficient amount to produce an approximate 3½% fiber slurry. The pH of the cold slurry is then adjusted to approximately 6.7 by the addition of sulphuric acid streamwise to the stock chest. Approximately 1% of concentrated sulphuric acid, based upon the fiber weight of the slurry, is needed to attain this pH adjustment.

The neutralized fiber slurry is then allowed to mix in the stock chest; after mixing, it is pumped to the machine chest of the board-forming unit. The slurry is maintained at a solids content of approximately 3½%. Approximately 1% of a petroleum wax emulsion (relative to the fiber solids of the slurry), containing 50% by weight of wax, and sufficient alum to bring the pH of the fiber to between 5.0 and 5.5, are uniformly intermixed in the slurry in the stock chest by suitable agitation thereof.

The resulting slurry mixture has additional water added thereto to bring the solids content down to approximately 1%, and the new slurry is pumped to the head box of an Oliver cylinder machine, which is operated at a mat-forming speed of approximately 20 feet per minute. (It is understood, of course, that a Fourdrinier machine may also be utilized if the latter is available.) With the Oliver cylinder operating under a vacuum of approximately 10 to 20 inches of mercury, preferably approximately 14 inches of mercury, the pulp pick-up on the cylinder machine is approximately 1,300 pounds per thousand square feet (dry weight of pulp), and the resulting partially dewatered fiber mat removed from the cylinder machine onto the take-off belt has a caliper of approximately 1¼ inches and a solids content of 20 to 25%. The mat passes off the belt into the nips of a plurality of compressing rollers, of the types having foraminated belts therearound, with the gaps between belts being adjusted depending upon the ultimate solids content desired. In the instant case, the gaps are adjusted to result in mats having a caliper of approximately ¾ inch and a solids content of approximately 35 to 40%. These mats are cut into strips sixteen feet long and are conveyed to a conveyor belt for transportation to a tunnel drier, which they enter in substantially the stated condition.

The tunnel dryer is heated by steam pipes located therein to a temperature of approximately 340° F. Within the drier, the mats have the moisture removed there-

from and undergo a shrinkage of approximately 30% in thickness. Upon emerging from the dryer, or oven, the mats are timmed into sheets approximately 4 feet x 8 feet. If desired, the sheets may have moisture added thereto to bring the moisture content approximately to that level which would be reached by them under ambient temperature and humidity conditions. The resulting boards possess the following average physical properties:

Thickness (inches)	0.500
Density (per cubic foot)	30.6
Modulus of rupture (per square inch normal)	1,480
G.E. puncture dry (inch-pounds)	304
½ inch edge nail (pounds)	218
Nail withdrawal (pounds)	70
Brinell hardness No. (1 inch ball—50 pounds)	287
Water absorption (2 hour—percent by volume)	6.4

The tests used in obtaining data of physical properties reported in the above example and elsewhere in this specification are as follows:

Tappi drainage time.—This test is conducted using the standard drainage time method for pulp for insulating board Tappi T1002SM–51.

Mullen strength.—To make this determination, samples are made in a Williams sheet mold using 25 grams dry weight of pulp per sheet. The wet sheet is removed from the sheet mold and pressed against a steel plate on the face surface, and blotting paper to absorb the excess water is applied to the screen surface. A pressure of 85 pounds per square inch is applied for 30 seconds. Samples are dried, trimmed to 9" x 11", and weighed.

Six bursts are taken on each sheet using the apparatus described in ASTM D–744–46 and the percent Mullen is calculated.

Bauer-McNett fiber classification.—This determination is made using a Bauer-McNett classifier and the procedure of Tappi T233SM–53 for determining fiber length of pulp by classification. The results are recorded in percentages by weight of the fibers retained on each of the screens used in the classifier, namely, 14, 28, 48, 100 and 200 mesh.

Modulus of rupture.—This determination is made using the procedure specified in General Services Administration interim Federal specification LLL–F–00321b for transverse strength from which the modulus of rupture is calculated.

G.E. puncture test.—This determination is made using the apparatus and procedure specified in ASTM D781–44T with the exception that in place of the puncture point specified under heading "Apparatus (b)" there is used a puncture point affixed to the end of the rod and having the shape of a half round ball of 2" diameter.

Edge nail test.—This determination is made using the procedure specified in section 7, "Nail Holding Strength" of Building Materials and Structures Report BMS13 issued February 23, 1939, by the National Bureau of Standards.

Brinell hardness.—This determination is made using a size sample that will fit into an 8" gap. The sample is placed under the 1" ball of a dead weight tester and the tester dial is set to zero. Weights are added, depending upon the hardness of the sample to give an indentation of 0.16 to 0.35". The weight load is applied and the exact indentation depth is recorded after 15 seconds. The Brinell hardness is then calculated using the following formula:

$$\frac{BHN}{1000}=\frac{\text{Total weight used in pounds}\times 0.454}{\pi\times 25.42\times\text{indentation depth in inches}}$$

Water absorption test.—This determination is made using the procedure specified in Federal specification LLL–F–00321b supra.

Interlaminar strength.—This determination is made using the procedure specified in Federal specification LLL–F–00321b for tensile strength perpendicular to the surface except that a specimen 2" x 2" is used in place of a 6" x 6" specimen and the load is reported as per square inch instead of per square foot.

Moisture extension.—This determination is made using the procedure specified in Federal specification LLL–F–003215 for linear expansion.

Example II

In a stock chest equipped with propeller type beaters, 88 parts of the hardwood pulp of the kind initially prepared in Example I are charged into 5600 parts of fresh water. Then 64 parts of wet ground wood pulp made from mechanically ground cottonwood and willow fibers, having a drainage time of 60 seconds, are charged into the stock chest, along with 48 parts of asphalt solids in an emulsion form, the emulsion containing approximately 15% by weight of asphalt and 1 part of a 50% wax size emulsion. These ingredients are mixed for a short time in the stock chest, and then the pH of the slurry is adjusted to 4.9 by the addition of 1½ parts of alum. When tested by standard procedure, the drainage time of the slurry is found to be 45 to 50 seconds and the vat consistency to be approximately 1.2% to 1.3% solids.

By using the Oliver filter apparatus as described in Example I, along with the same type of sheet forming operation, a continuous, partially dewatered mat of the fiber and asphalt mixture is formed at a speed of about 40 feet per minute with a pick-up of about 1,000 pounds per thousand square feet (dry weight of pulp) and a thickness of about 1 inch. The partially dewatered mat, after passing the cold-compressing rollers, has a thickness of approximately ⅝ inch and a solids content of approximately 35 to 40%. In the drying ovens, the mat undergoes a shrinkage of about 25% and after being trimmed into sheets, construction insulation boards having the following physical properties are obtained:

Thickness (inches)	0.500
Density	26.0
Nail withdrawal (pounds)	43.9
½ inch edge nail (pounds)	143
Modulus of rupture (dry—per square inch)	1070
G.E. puncture (dry—inch pounds)	190
Interlaminar (per square inch)	17.3
Water absorption (percent by volume) (2 hours)	3.3

DETAILED DESCRIPTION

The formation of wood fiberboard by the procedures described herein can be accomplished using any type of hardwood which is available in large quantities and which is relatively inexpensive. By hardwood is meant the wood of any broad-leafed deciduous tree as distinguished from the wood of coniferous trees. From the viewpoint of availability and other considerations, the principal hardwoods recommended for use in the new operations include gum, birch, willow, oak, hickory, maple, pecan, cottonwood, and poplar. Coniferous woods are not as suitable for use in the process because their resinous content results in soap formation and foaming, and the resulting fibers do not possess the same desirable physical properties achieved when hardwoods are used.

A caustic alkali is an essential ingredient of the new pulp forming procedures. Sodium hydroxide is the preferred caustic to be used, but other alkali metal hydroxides, including potassium hydroxide and lithium hydroxide, or mixtures of any of these can be employed. The concentration of caustic alkali in the digestion liquor can be varied, but for most effective results the concentration should be maintained between about 2.5% and about 10% by weight. Above 10% concentration, the yield of pulp on the dry weight of the charged wood chips falls to an undesirably low level, i.e., below 75%. On the other hand, pulps prepared from cooks utilizing less than 2.5% caustic concentration contain a small amount of raw fiber which ultimately reduces compressibility and increases shrinkage.

The temperature of the caustic impregnation liquor when in contact with the wood chips may be varied, but preferably should be from about 70° to about 200° F. The time required for the formation of the hardwood pulp is an inverse function of the temperature and pressure. The best pulp is made by the use of a digestion procedure for which it has been found that about one-half hour's digestion at ambient temperature down to one-quarter of an hour at 200° F., other factors being the same, are satisfactory periods for completion of the single pulp batch. Most satisfactory results are obtained using a temperature within the range of 100° to 150° F.

The digestion procedure may be conducted at atmospheric pressure but it has been found that shorter times for processing a single batch of chips plus elimination of presence of raw fibers are obtained by the use of super-atmospheric pressures. Pressures of 300 pounds per square inch gage or higher may be used, and these pressures may be obtained in any suitable fashion, e.g., by the use of an impregnating and defibering screw press. However, it has been found that the most economical pressure for use in the process is about 100 to 150 pounds per square inch gage, and that this is best obtained by forcing digestion liquor into the digestion vessel under this hydrostatic pressure using a rotary impeller pump or other satisfactory pumping equipment.

In order to obtain the maximum penetration of the digestion liquors into the wood chips, vacuum may be applied to the chips before the caustic soda solution is introduced into the reaction vessel.

The ratio of digestion liquor to wood chips in the cooking step may be varied, although it has been found that for most efficient use of the digestion reagents and highest yields of desired wood fibers a caustic solution of the concentrations above-mentioned should be used in a ratio of between about 2 to 1 and 8 to 1 on the dry weight of wood chips, and that particularly good results are obtained using a caustic solution to wood fiber ratio of between 4 to 1 and 6 to 1. In addition to the caustic alkali, the digestion liquor can have other treating reagents added thereto. For example, small amounts, e.g., 0.1% to 1% by weight, of surface active agents which are effective in solutions having a pH of 9 to 11 may be included in the digestion liquors in order to foster penetration of the wood chips by the cooking liquor.

It is not necessary to remove the bark from the hardwood logs or slabs before they are chipped, although debarking may be employed if desired. The chipping may be accomplished on any standard available type of chipping equipment, but a chipper is preferably chosen and operated to obtain chips having maximum uniformity in size. Chips which will pass a standard one inch mesh sieve and be retained on a standard ¼ inch mesh sieve constitute a highly desirable type of chip for use in the new operations. While other size chips may be employed, it is recommended that chips be employed having an average size capable of being screened as indicated.

After the completion of the digestion operation, the cooking liquor is withdrawn from the digestion vessel through suitable screen devices and sent to storage tanks for reheating or re-use in subsequent digestion batches. However, the mass of digested wood chips, following this removal of the reaction liquor, contains an appreciable amount of reactive liquor in contact with the chips. If suitable storage facilities and other handling equipment are available, the drained mass of digested chips may be stored for periods of time ranging from ¼ hour to more than several hours. During such storage in the presence of the residual caustic solution, further digestion of the chips occurs. Hence, an after-storage procedure of this type can be combined with the digestion operation operated at elevated temperatures and super-atmospheric pressures in a closed digestion vessel to shorten the time of batch treatment in the digester, thereby increasing the output per unit time for each digester employed at any particular pulp plant.

Following the digestion operation, it is necessary to subject the cooked wood chips to a refining operation in which defibration of the chip mass is accomplished. There are a variety of suitable types of refining or defibration equipment commercially available for this purpose. A disc type pulp refiner, e.g., a Bauer refiner, in which the digested wood is forced between rotating grinding plates spaced approximately 0.005 to 0.1 inch from each other, is found to be very suitable for this purpose.

The working of the cooked chip mass is conducted in one or more stages in suitable refiners or in suitable refining and beating equipment and for sufficient time to produce a pulp having a Tapp drainage time of 10 to 60 seconds. The working can be in a single stage in one or more refiners or beaters. The exact procedure used for this chip working will depend to some extent upon the particular hardwood used in the digestion step, and upon the temperature, time, pressure and concentration of the digestion liquor during the chip impregnation period. Hence, the details of the operation of this working cannot be accurately specified for all of the varied digestion conditions, but the refining step can be satisfactorily handled by periodic testing of the drainage time of the pulp being processed and discontinuance of the refining on a particular batch of pulp when the drainage time comes within the range of 10 to 60 seconds. The fiber working preferably should also be conducted to produce a pulp having the following additional properties:

Mullen strength ..... =15 to 40 percent
Bauer-McNett fiber classification in percentages by weight:
+14 mesh ..... =10 to 40
−14+28 mesh ..... =10 to 20
−28+48 mesh ..... =15 to 35
−48+100 mesh ..... =1 to 10
−100+200 mesh ..... =1 to 10
−200 mesh ..... =5 to 30

When the caustic liquor reacts upon the chips, various water-soluble salts and other by-products are formed which should be removed from the fibers before the formation of the insulating board, since the presence of such materials in the board decreases the water-resistance of the board. Consequently, it is necessary to subject the fibers, following the digestion and refining steps, to one or more washings in order to remove occluded salts, caustic, and other water-soluble materials. It has been found that effective washing of the wood fibers can be accomplished on filtering screens where the fiber mass is dewatered subsequent to the refining procedure as previously described. Such washing can be accomplished by spraying the fiber mass with hot water from shower heads located over the top of the filtration screens. However, it has been found that the wood fibers produced in accordance with this invention have a tendency to retain some of the caustic cooking liquor even after a water washing. Hence, it has been found important to subject the refined wood fibers to a neutralization step using some suitable acidic reagent which will effectively neutralize alkaline material. Sulfuric acid is the preferred acidic reagent for the neutralization, but other mineral acids, such as hydrochloric acid, phosphoric acid and the like, may be used, as well as acidic salts, including sodium bisulfate, ammonium bisulfate, and the like. This neutralization is best carried out with the wood fibers suspended as a slurry of about 1% to about 10% fiber concentration in a suitable vessel equipped with impeller type or other adequate stirring device, sufficient acidic reagent being employed to bring the pH of the slurry to between about 5 and about 7.

Wood fiberboard may be made from a furnish formed of the caustic pulp, produced as described above, and water without the addition of any other ingredients. Thus, the fibers made by these new pulping operations are strongly cohesive when formed into webs and dried,

and create sheets or boards having high tensile strength, good modulus of rupture, and other desirable properties. However, the furnish used for forming the insulating board can have a variety of other materials added to it, including sizing agents, waterproofing agents, fireproofing agents, dyes, pigments, bleaching agents, or the like. Customarily, before the furnish is passed to the head box of a board forming machine, alum or equivalent reagent will be added to it to adjust the pH to between about 4.5 and 5.5, and a small amount, for example, 0.1 to 2% of petroleum wax, or other suitable size, usually in the form of an oil-water emulsion, can be added to the furnish in order to improve the moisture absorption characteristics of the fiberboard produced.

The fiber content of the furnish may be varied, but most satisfactory board forming operations result when the furnish contains about 0.5 to about 2% by weight of solids, of which at least about 70% by weight constitute wood fibers, either prepared as described above or obtained by grinding of hard or soft woods or from waste paper or like waste sources, e.g., waste kraft fibers. The precise proportion of the hardwood fibers prepared by the new digestion processes herein described to other fibers included in the board forming furnish may be varied. The new wood fibers provided by this development, however, are characterized by a critically improved degree of "freeness" and a substantial lack of "spring-back" when subjected to compression in wet webs. Accordingly, it is advisable to use at least 25% by weight of the total fiber content of the furnish of the new caustic hardwood pulp, and it is especially preferable that at least 50% to 100% of the total fiber content of the furnish should be the new caustic hardwood fibers.

A variety of board forming equipment is available for producing insulating board from furnish of the type just described. This includes Fourdrinier type machines and so-called cylinder machines, e.g., a continuous Oliver cylinder machine in which a foraminous cylinder is rotated partially submerged in a bath of fiber slurry with the interior of the cylinder being under substantial vacuum causing water to be drawn through the foraminous cylinder while the fiber content of the slurry is retained on the rotating cylinder forming a partially dewatered mat of fibers.

Using the new furnish, as described, with a cylinder type board forming machine, it has been found that no difficulty is experienced in forming the pulp into board having a final dried thickness of ¼ to ½ inch and a density of 30 to 35 pounds per cubic foot at forming speeds of 20 to 40 feet per minute. Of course, as the thickness of the board increases, the output of a board forming machine will decrease because the increased thickness requires an increasingly thicker fiber web to be picked up on the forming machine. For the production of a ½ inch thick board made of 100% of the new caustic hardwood fibers and possessing a density of 30 pounds per cubic foot, it has been found that a pick-up of 1,250 to 1,450 pounds per thousand square feet is necessary for a board forming speed of 20 feet per minute.

The drainage time, e.g., 25 to 30 seconds, possessed by these new hardwood pulps, makes it possible to form insulating board of such thickness and density at these production rates. At the same time, the new hardwood fibers may be subjected to a maximum wet compaction and shrinkage during drying to give the insulation boards the new high densities as reported herein.

Following formation and partial dewatering of the fiber mat on a foraminous support, the wet mat should be compressed in order to further express water therefrom and to densify the fiber content. This can be accomplished in a number of ways. For example, the mat may be passed between two traveling belts, both moving at the same speed and spaced closer together at the exit end than the inlet end, so that as the mat passes between them its thickness is reduced to the distance between the belts at the inlet end. However, it has been found that equally satisfactory results with fewer equipment problems can be obtained using a compression roller arrangement in which a roller is used to compress the wet fiber mat against a traveling, supporting belt or against another roller rotating at the same speed as the compression roller. The degree of compression applied to the mat will depend primarily upon the density desired in the final rigid insulating board. If a board having the lightest density is desired, e.g., about 10 pounds per cubic foot, substantially no compressive force will be applied to the wet mat. On the other hand, if insulating board of the highest obtainable density, e.g., up to about 35 pounds per cubic foot, is desired, the board will be compressed to the maximum to reduce the wet mat thickness as it is obtained from the cylinder machine by 50% or more. As previously indicated, one of the distinct advantages of the new hardwood pulps of this development is the lack of tendency to "spring-back" after this compressive step so that the fiber densities imparted to the board by the compression step will be retained therein. This is in contrast to the substantial spring-back effect noted in fiber mats formed from neutral sulfite pulp, ground wood pulp, and the like.

After the squeezing or compressive step just described, it is difficult to remove further water from the mat by suction or pressing operations. Accordingly, in order to dry the mat it is necessary to heat it in some suitable fashion because drying at ambient temperature is too slow for any commercial board forming operation. The heating can be accomplished by subjecting the mat to infra-red radiation, such as from a bank of infra-red lamps, by passing the mat between spaced electrodes connected to a high-frequency oscillator to heat the web by induction currents, or the like. However, for large-scale commercial operations, it has been found that banks of long tunnel dryers equipped with internal radiant steam or electrically heated coils, and forced draft withdrawal of moisture-laden air, are most satisfactory. Preferably, the drying oven is operated with the temperature at the inlet end of the oven lower than at the outlet end so that the web is subjected to progressively increasing temperature as it passes through the drying equipment. Although the new caustic hardwood fibers of this development exhibit a substantial degree of shrinking during drying and thereby produce high densities in the final insulating boards, the drying characteristics of the fiber are excellent, and the boards exhibit relatively low tendency to warp during the drying. It is believed that it is the shrinkage of the fibers, primarily, which causes boards utilizing such fibers to possess a high degree of resistance to spring-back and permits the manufacture of boards in the density range of 25 to 35 pounds per cubic foot. When the fibers shrink they become more tightly intertwined and entangled and the tendency to resist spring-back is increased.

The preceding description of the invention has been primarily confined to the description of the utilization of the instant process for the formation of insulation board, as defined herein. However, one of the particular advantages of the instant invention is the adaptation of the instant process for the manufacture of denser types of fiberboards, utilizing the basic insulation board formed, either in its final wet form (i.e., cold-compressed) or in its ultimate dry form. These greater density boards are produced primarily by transferring the insulation boards of the instant invention to a hot press, wherein the boards are subjected, at least momentarily, to high pressures, in the range of approximately 100 to 1,200 pounds per square inch, and to relatively high temperatures. For example, in the manufacture of semi-hardboard, the wet compressed mats may be subjected to an initial pressure of approximately 200 pounds per square inch and a temperature of 400–450° F., thereby densifying the boards still further, after which the pressure is released and a

lower pressure is maintained for a length of time sufficient to consolidate the mat further. In the manufacture of hardboards having a specific gravity of approximately 1.0, the wet mat, formed in the manner described herein, is inserted in a press and subjected to a pressure in the order of approximately 800–1,000 pounds per square inch at a press temperature of approximately 300°–750° F. The pressure is released after several minutes and reduced to a lower pressure in the vicinity of approximately 100 pounds per square inch. The lower pressure may be maintained for approximately 20 minutes, after which time, the board is removed upon release of pressure. The removed hardboard is densified to a specific gravity of approximately 1 and is completely dry.

The above processes described for the formation of semi-hardboard and hardboard utilize what is known as a "wet-press" technique, since the mat entering the press is in a wet condition, having a fiber solids content in the order of about 25% to 65%. Where dry insulating boards are utilized, the boards may be subjected to a "dry-press" technique for formation into semi-hardboards and hardboards. In such technique, the dry insulating board is subjected to heat and high pressure for a short period of time. The pressure is then reduced to a much lower pressure; however, the lower pressure of the cycle need not be applied as long as the time of low pressure application of the "wet-press" techniques, since most of the water has been driven out from the boards by the previous drying cycle.

CONCLUSION

The foregoing specification describes new processes for the preparation of wood fibers from hardwood, which fibers may be used to produce furnish that can be converted, with decided advantages in production economy, on standard fiberboard forming equipment, e.g., rigid insulating board forming equipment, into a variety of construction sheets or the like. Because the new hardwood fibers, which can be obtained from these new pulp forming methods, possess certain new and unique characteristics, it is possible to form insulating boards having density and strength characteristics, heretofore unobtainable in this class of product. Furthermore, the new hardwood fibers, as described herein, are compatible in all proportions with ground woods, waste kraft, or other wood fibers or wood materials used to form fiberboards. As a result, the new hardwood pulp may be used to form insulating boards, for example, having a range of density from below 10 pounds per cubic foot to approximately 35 pounds per cubic foot.

The invention makes possible the novel types of formation of rigid insulation board, as defined herein, having the following properties:

Thickness in inches	0.25 to 1.0
Density (pounds per cubic foot)	25 to 35
Modulus of rupture (pounds per square inch)	1000 to 1500
Nail withdrawal (pounds)	45 to 90
½" edge nail (pounds)	150 to 250
Brinell hardness No.	200 to 400
Interlaminar strength (pounds per square inch)	12 to 30
G.E. puncture (inch-pounds)	300 to 500

Mats of the new hardwood fibers may also be used in the formation of composite boards or of boards of the semi-hardboard or hardboard type. For example, a thin mat of the new hardwood pulp may be applied as a veneer to a thicker mat of ground wood fibers and roll pressed. The resulting veneer web upon roll pressing retains its densification while the ground wood mat springs back, creating a finished board with a veneer of substantially greater density than the main board section.

Simplification of waste disposal problems, and reduction of digester cooking times, digester corrosion and heat requirements also constitute worth-while features of the new pulp and board forming operations as described

While the invention has been described in rather full detail, it will be understood that these details need not be strictly adhered to and that various changes and modifications may suggest themselves to one skilled in the art, all falling within the scope of the invention as defined by the subjoined claims.

What we claim is:

1. A process for the production of wood fiberboard comprising the steps of digesting hardwood chips in a 2.5%–10%, by weight, caustic solution for about ¼ to 2 hours at about 70° F.–200° F. and at a pressure in the approximate range of from atmospheric pressure to 300 p.s.i.g., separating the digested chips from the body of the digesting liquor, refining the digested chips into a fibrous mass, neutralizing the separated fiber mass, forming a furnish comprising the refined fibers, forming a fibrous mat from said furnish by applying portions of the furnish to a foraminous support and partially dewatering the furnish on said support, sufficient furnish being applied per area of support to create a partially dewatered web having a thickness of at least about ½ inch, and then compressing said partially dewatered board to remove further water therefrom and to increase the density thereof.

2. A process for the production of pulp for use in the formation of wood fiberboard which comprises providing hardwood chips having an average size capable of passing a 1 inch mesh standard screen but not a ¼ inch mesh standard screen, digesting the hardwood chips in an aqueous alkali metal hydroxide solution, having a concentration within the range of about 2.5% to about 10% by weight, for about ¼ to about 2 hours at about 70° F. to about 200° F. and under a hydrostatic pressure of from about atmospheric to about 300 pounds per square inch gage, the ratio b yweight of said solution to the dry weight of said hardwood chips being between about 2 to 1 and about 8 to 1, separating the resulting chips and the body of the digestion liquor from each other, refining the chips until the resultant fibrous pulp has a Tappi drainage time between about 10 and about 60 seconds, and adjusting the pH of the pulp if necessary to a value between about 5 and about 7.

3. A pulp for use in producing water-laid wood fiberboards prepared by the process defined in claim 2.

4. A process of making wood fiberboard which comprises making a furnish comprising pulp produced by the process defined in claim 2, dewatering a layer of the furnish on a foraminous support to form a wet mat comprising the hardwood fibers, cold-compressing the mat to further dewater it and to increase its density, and thereafter drying the mat.

5. A process as defined in claim 4 wherein said furnish comprises, in addition to said fibers, ground wood and sizing material.

6. A process of making wood fiberboard which comprises making a furnish comprising fibers produced by the process defined in claim 2, at least partially dewatering a layer of the furnish to form a mat comprising the hardwood fibers, and subjecting the mat to the action of a hot press under controlled conditions of time, pressure, and temperature.

7. A process as defined in claim 6 wherein said furnish comprises, in addition to said fibers, ground wood and sizing material.

8. A process of making wood fiberboard having a thickness of the order at least about ¼ inch which comprises making an aqueous furnish having a solids content of which solids at least about 70% by weight constitute wood fibers, at least about 25% by weight of the total fiber content being constituted of fibers produced by the pulp-producing process defined in claim 2, and producing fiberboard of the stated order of thickness by

subjecting said furnish to board-making filtration and consolidation operations.

9. A process as defined in claim **8**, in which the solids content of said furnish is of the order of about 0.5% to about 2%, by weight.

10. A wood fiberboard produced by the process defined in claim **8**.

11. The process of making insulation board having a thickness of at least about ¼ inch, a density between about 25 and about 35 pounds per cubic foot and a modulus of rupture of at least about 1,000 pounds per square inch which comprises impregnating hardwood chips with an aqueous caustic alkali solution of between about 2.5% and about 10% concentration, by weight, at a temperature of an order between about 70° F. and about 200° F., using an elevated hydrostatic pressure sufficient to effect the substantially complete impregnation of chips during the time of contact of solution and chips at the elevated temperature, refining the impregnated chips to produce a pulp having a Tappi drainage time of between about 10 and about 60 seconds, adjusting the pH of the resulting slurry to a value between about 5 and about 7, forming an aqueous fibrous furnish, the fiber content of which includes a substantial portion of the refined fibrous material, forming a mat from the furnish by a dewatering operation, compressing the mat to remove further water therefrom and to increase the density of the mat, and drying the resulting mat.

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