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# UNITED STATES PATENT OFFICE

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## SHOCK-RESISTANT PRODUCT

Elbert C. Lathrop and Theodore R. Naffziger, Peoria, Ill., assignors to the United States of America as represented by the Secretary of Agriculture

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This application is made under the act of March 3, 1883, as amended by the act of April 30, 1928, and the invention herein described, if patented, may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment to us of any royalty thereon.

This invention relates to an improved form of board product which is highly resistant to delamination or shattering when subjected to sudden explosive shock or continued vibration.

It has for its particular object the provision of a board product which may be punched to produce a superior wad for firearm cartridges, especially shotgun shell wads. It has for its further object the provision of a board product which is particularly suited for use in constructions which are subject to continued vibration, such as trucks or other machinery, or for pads used in reducing the vibration and noise of machinery. Other objects of the invention will be apparent in the disclosure.

Explosive shock is much more violent in producing delamination and shattering of such fibrous products than repeated vibration over a long period of time. The usefulness of the invention in providing an improved shotgun shell wad will, therefore, bring out fully its novel features.

Ballistic studies of shotgun shells have taught the desirability of securing the highest possible muzzle velocity of shot, which in turn depends to a great extent on the efficiency of the wad which is placed between the powder or propellant charge and the shot. An entirely satisfactory wad must be rather impervious to the gases resulting from the explosion of the propellant so that gases do not leak through it. The wad further must be constructed so that it discharges from the muzzle in one piece and is not delaminated, shattered, or broken by the explosive forces into pieces called "confetti." The wad, on the other hand, must be of rather low density so that it does not become itself a missile capable of breaking or penetrating a target.

Shotgun shell wads were for many years made from felted animal hair. These wads have proven most satisfactory, but they are very expensive. Many attempts have been made to prepare satisfactory wads from wood or vegetable fibers by felting or compressing these together either in the presence of some binding material, such as polymerized vegetable or other oils, resins, waxes, or the like, or impregnating these felted fibers with similar binding materials. When

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sufficient binding materials of suitable properties are so combined with fibers, more or less satisfactory wads have been made, but the binding materials comprise 20 percent or more of the composition of the wads. These binding materials, however, are expensive and the wads so formed, if sufficiently bound together, are dense and lack resiliency. All attempts thus far to produce satisfactory wads from wood or vegetable fibers alone have failed.

This invention constitutes the discovery that only certain types of mature plants are suitable as a raw material for the manufacture of highly efficient shotgun shell wads requiring no other binding agent. The mature plants belonging to this class are constituted of rather long hollow stems carrying more or less leaf sheaths and possessing little or no associated pith particles. To this class belong the cereal straws, such as wheat, rye, rice, oat, barley, together with certain grasses, such as esparto, sedge, buffalo, and the like.

We have discovered simple and inexpensive means of producing long hair-like, springy fiber bundles from this class of mature plant stalks. The long hair-like fiber bundles constitute 60 or more percent of the finished board product.

The length of these fiber bundles is such that a majority extend unbroken through the planar dimension of the wad. Their hair-like character, springiness, and flexibility are in many respects similar to those of the animal fibers used in the prior art in producing wads. These characteristics permit the fibers to intertwine and to intermingle in wet felting so that a portion of the bundles is felted diagonally into association with the main body of fiber bundles above and below the planar dimension of the felted board. This type of felting produces a board of great resistance to delamination and shattering.

Contrary to the characteristics of animal fibers these vegetable fiber bundles do not have sufficient felting strength of themselves to form a strong wad product. We have discovered that a natural binding agent may be produced from the same plant material by well-known processes of chemical cooking to produce papermaking pulp and by beating to definite degree of hydration. When the long hair-like fiber bundles are intimately mixed in a water suspension with the hydrated fibers and felted, pressed to remove excess water, and dried, the superior board product of our invention results. In producing the hydrated fiber, wood pulp suitable for paper-

making, such as ground wood, kraft, soda, sulfite, or other pulps, may be used. The proportion of such pulps to the long hair-like fiber-bundle fraction in producing a suitable product will vary somewhat depending upon the particular papermaking pulp, but will not be found to depart widely from the proportions of 20 to 40 percent by weight which has been found desirable when using hydrated pulps made from the mature straw or grass stalks.

Wood or stalks of a distinctly woody character derived from mature annual plants, such as hemp, flax, soybean, cotton, or castor bean, are not suitable for the practice of this invention. It is impossible in the present state of our knowledge to produce the long hair-like fiber bundles required from these raw materials. The wood fibers found useful in the art of manufacturing insulation board, quarter board, or hardboard products are too short and too coarse for use in our invention. Wads punched from such products, known to the art, delaminate and break upon being expelled from the gun barrel, producing objectionable "confetti."

We have also discovered that pith-bearing plants, such as sugarcane bagasse, cornstalks, sorghum stalks, crotolaria, sunflower, and the like, are unsuited for the practice of our invention. Plants of this character contain more or less reservoirs of pith particles which are closely associated with and cling to the fibro-vascular bundles. These pith-like particles can only be separated from the fiber bundles with difficulty, and processes for such removal are expensive. The fibro-vascular bundles in these plants, moreover, are more difficult to separate into the long hair-like fiber bundles which constitute an important part of our invention. When boards are produced by methods known to the prior art or by the steps of our invention from these pith-bearing plant stalks, it has been found that the boards show a tendency to delaminate and when used as wads, they shatter and produce confetti on discharge from the gun. The pith particles are nonfibrous and possess neither felting nor binding properties in the board. Rather they fill in between the fibers as separating particles and prevent the intimate bonding of the fibers produced in the practice of our invention. Moreover, the pith particles are irregular in mass and form and do not distribute evenly throughout the fibrous mass during felting. The delamination, shattering, and production of confetti of wads made only from sugarcane bagasse or other plants is to be attributed in large part to the pith-like particles and the relatively coarse stiff fiber bundles which constitute these plants.

The composition of this invention will characteristically contain from 60 to 80 percent, and preferably 65 to 75 percent, of long hair-like, springy, fiber bundles substantially free from pith particles, the remaining portion being papermaking fibers known to the prior art and hydrated to the desired degree. These fiber bundles are derived from a class of mature annual plants constituted of rather long nodular hollow stems carrying more or less leaf sheaths and possessing little or no associated pith particles, to which class belong the preferred plants known as the cereal grain straws.

The method of producing said fiber bundles is generally as follows:

Ordinary straw is cut so that a plurality of the lengths are between ¾'' to 1¼''. They are preferably screened to remove oversize fibers as well as dirt, dust, and fines. The cut straw is then cooked in water under mild conditions to soften and make flexible the fiber and to remove solubles. At the end of this treatment, the physical appearance of the cut straw does not change substantially, that is to say, it is not changed into pulp. The resulting treated straw is then subjected to a rubbing action for the purpose of splitting the large straw pieces into long hair-like, springy bundles of fibers without substantially reducing the length of the bundles. A plurality of the long hair-like, springy bundles should be of the approximate thickness of animal hair. This treatment may be accomplished by utilizing many of the various refining engines known to the prior art, such as attrition mills, Jordans, rod mills, and so forth, under properly controlled conditions of operation.

The fiber bundles produced will contain the individual fibers in the same simple echelon relationship in which they exist in raw straw and will be held together by the natural cementing elements of the straw in a plasticized condition. The fiber bundles because of their hair-like, springy character will be sufficiently flexible when felted together in water suspension to intermingle and entwine such that terminal parts of a plurality of fiber bundles will felt in a diagonal direction above and below the felting plane of the main portion of said fiber bundles. These bundles of fibers are then mixed with beaten and hydrated paper-making fibers heretofore used in the prior art in the proportions indicated above from which the resulting fiber board is fabricated in the required thickness in the usual manner, such as on an Oliver, Fourdrinier, or cylinder machine, and the board is dried, preferably between plane and parallel hot platens to produce a product of uniform thickness.

The following examples will illustrate the manner in which this invention may be practiced.

## EXAMPLE 1

A bale of wheat straw (70 pounds) was chopped in a small ensilage cutter so that about 80 percent of the pieces were from ¾'' to 1¼'' in length, after screening through a 2-mesh per inch screen to remove the long fibers. The chopped straw was loaded into a 3-foot rotary digester to which water was added in a 7:1 ratio based on the weight of the straw. The straw was cooked 1.25 hours at 40 pounds' gage pressure using indirect steam. At the end of the cooking period the straw was removed from the digester, drained of its liquor, washed with cold water, and run at room temperature through a 24-inch Bauer pulper fitted with grid plates. It will be noted that the cooked straw had not been dried between the cooking step and pulping step. The softened, flexible fiber is run through the pulper. The clearance between the grid plates was maintained between 0.018–0.030 inch. This pulp was delivered from the machine at a consistency of 6–8 percent. This pulp was then used as described below.

Regular strawboard pulp, prepared by cooking whole straw with 6 percent lime and 1.5 percent caustic soda for 5 hours at 140° C., was washed and beaten to a freeness of 410 cc. Schopper-Riegler. This beaten stock was then mixed in various proportions with the long hair-like, springy fiber-bundle stock described. The mixtures were formed into boards 11'' in diameter, using a laboratory board-forming machine. The wet pulp boards were dewatered to approximately 75 percent moisture content by pressing in a

hydraulic press at room temperature. The boards were then placed between 16-mesh copper screens and dried between hot platens (50 pound steam pressure) of a hydraulic press until dry. A steel bar ½'' thick was placed between the platens to maintain a definite separation of the platens during the drying operation.

The physical properties of these boards as related to the percent of hydrated fiber are shown in the table below. Ballistic tests made on shotgun shell wads punched from these boards are also reported in this table. Board 44 was judged the best and was of superior character.

*Table 1.—Small boards*

| Sample | Hydrated pulp, Percent | Density, g./cc. | Impact strength, Ft.-lbs. per inch² | Flexural strength, p. s. i. | Tensile strength, p. s. i. | Thickness, Inch | Ballistic tests | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Pressure at desired velocity, 100 p. s. i. | Confetti results | Rating |
| 36 | 20 | 0.294 | 3.21 | 805 | 417 | 0.412 | 83 | Laminated | 7 |
| 38 | 25 | 0.302 | 3.00 | 951 | 474 | 0.397 | 86 | No lamination | 2 |
| 44 | 30 | 0.354 | 3.15 | 1146 | 540 | 0.388 | 91 | do | 1 |
| 45 | 35 | 0.389 | 3.30 | 1296 | 798 | 0.375 | 87 | do | 1 |

EXAMPLE 2

Using the procedures for the preparation of the two different fibers as described in Example 1, other lots of wheat straw were cooked. From these, boards 3-feet square were formed on a pilot-plant board machine and dried as described with a protective screen on each side. The effect of using different amounts of pulp per 3-foot board on the physical properties of the board is shown in the table below. These boards were punched into wads, using commercial shotgun shell wad machinery, and the ballistic tests on the wads so produced were excellent.

*Table 2.—Three-foot boards*

| Sample | Long fiber pulp, pounds | Hydrated pulp, pounds | Hydrated pulp, per cent | Thickness, inch | Density, g./cc. | Impact strength, Ft.-lbs. per inch² | Flexural strength, p. s. i. | Tensile strength, p. s. i. | Ballistic tests |
|---|---|---|---|---|---|---|---|---|---|
| 3 | 15.75 | 1.90 | 30 | 0.432 | 0.309 | 2.81 | 685 | 564 | Satisfactory. |
| 7 | 19.40 | 2.15 | 30 | 0.428 | 0.355 | 2.54 | 811 | 811 | Do. |

Obviously, the thickness of the sheet may be decreased or increased, with corresponding increase and decrease in the density, by using bars less than or greater than ½'' thick. The density may be varied over a wide range.

Having thus described our invention, we claim:

1. A firearm cartridge wad comprising a cylinder of felted and pressed vegetable fibers, said fibers comprising a mixture of no less than about 60 percent of hair-like, springy plant-fiber bundles substantially free from pith particles, a majority of which fiber bundles have the approximate thickness of animal hair and extend unbroken through the planar dimension of the wad, mixed with and held together by beaten and chemically hydrated paper-making fibers, said plant-fiber bundles being the chemically unaltered, lengthwise-split stems of mature hollow-stemmed, annual plants selected from the group consisting of cereal straws and grasses.

2. The product defined in claim 1 in which the plant-fiber bundles constitute from 65 to 75 percent of the mixture of plant-fiber bundles and the chemically hydrated paper-making fibers, the stems being precut to length prior to lengthwise splitting, the lengthwise splitting being by a rubbing action such that there is no substantial reduction in length.

3. The product defined in claim 1 in which the annual plant stems are wheat straw.

4. The process of making a shock-resistant product comprising preparing hair-like, springy plant-fiber bundles from wheat straw, comprising cutting the straw into lengths between about ¾ to 1¼ inches, subjecting the cut stems to non-chemical cooking while submerged in at least several parts by weight of liquid water to soften the fibers and render them flexible and to remove water solubles and after draining and washing subjecting the cooked drained stems at a temperature not substantially higher than room temperature to a rubbing action to split them lengthwise into a plurality of hair-like, springy fiber bundles having the approximate thickness of animal hair, the rubbing action being limited to such that there is no substantial reduction in length, forming a mixture of said plant-fiber bundles with beaten and chemically hydrated paper-making fibers, and pressing the mixture into shape.

5. The process of making a shock-resistant product comprising preparing hair-like, springy plant-fiber bundles from wheat straw, comprising cutting the straw into lengths between about ¾ to 1¼ inches, subjecting the cut stems to non-chemical cooking while in water, in a weight ratio of about 7 of water to 1 of straw at a temperature corresponding to about 40 pounds' gauge steam pressure, to soften the fibers and render them flexible and to remove water solubles and after draining subjecting the cooked stems at a temperature not substantially higher than room temperature to a single pass rubbing action, between grid plates having a clearance between about 0.018 to 0.030 inch, to split them lengthwise into a plurality of hair-like, springy fiber bundles having the approximate thickness of animal hair, the rubbing action being limited to such that there is no substantial reduction in length, forming a mixture of said plant-fiber bundles with beaten and chemically hydrated paper-making fibers, and pressing the mixture into shape.

6. The process of preparing hair-like, springy plant-fiber bundles from wheat straw, comprising cutting the straw into lengths between about ¾ to 1¼ inches, subjecting the cut stems to non-chemical cooking while submerged in several

parts by weight of liquid water to soften the fibers and render them flexible and to remove water solubles and after draining and washing subjecting the cooked stems at a temperature not substantially higher than room temperature to a rubbing action to split them lengthwise into a plurality of hair-like, springy fiber bundles having the approximate thickness of animal hair, the rubbing action being limited to such that there is no substantial reduction in length.

7. The process of preparing hair-like, springy plant-fiber bundles from wheat straw, comprising cutting the stems into lengths between about ¾ to 1¼ inches, subjecting the cut stems to non-chemical cooking while immersed in water, in a weight ratio of about 7 of water to 1 of straw at a temperature corresponding to about 40 pounds' gauge steam pressure, to soften the fibers and render them flexible and to remove water solubles and after draining and washing with cold water subjecting the cooked stems at a temperature not substantially higher than room temperature to a rubbing action to split them lengthwise into a plurality of hair-like, springy fiber bundles having the approximate thickness of animal hair, the rubbing action being limited to such that there is no substantial reduction in length.

8. The process of making a shock-resistant firearm cartridge wad comprising preparing hair-like, springy plant-fiber bundles from mature annual plants having hollow nodular stems carrying leaf sheaves and having little or no associated pith particles, comprising cutting the stems into lengths between about ¾ to 1¼ inches, subjecting the cut stems to non-chemical cooking while submerged in several parts by weight of liquid water to soften the fibers and render them flexible and to remove water solubles and after draining and washing subjecting the cooked stems at a temperature not substantially higher than room temperature to a rubbing action to split them lengthwise into a plurality of hair-like, springy fiber bundles having the approximate thickness of animal hair, the rubbing action being limited to such that there is no substantial reduction in length, forming a mixture of said plant-fiber bundles with beaten and chemically hydrated paper-making fibers, and forming the mixture into cartridge wad shape.



9. The process of claim 4 in which the non-chemical cooking is carried out at 40 pounds' gauge pressure, and the rubbing action is accomplished by a single pass through an attrition-type refining mill having good plates with a clearance between about 0.018 to 0.030 inch.

10. The process of claim 4 in which the stems are selected from the group consisting of cereal straws and grasses.

11. The process of preparing hair-like, springy plant-fiber bundles from mature annual plants having hollow nodular stems carrying leaf sheaves and having little or no associated pith particles, comprising cutting the stems into lengths between about ¾ to 1¼ inches, subjecting the cut stems to non-chemical cooking while submerged in several parts by weight of liquid water to soften the fibers and render them flexible and to remove water solubles and after draining and washing subjecting the cooked stems at a temperature not substantially higher than room temperature to a rubbing action to split them lengthwise into a plurality of hair-like, springy fiber bundles having the approximate thickness of animal hair, the rubbing action being limited to such that there is no substantial reduction in length.

ELBERT C. LATHROP.
THEODORE R. NAFFZIGER.

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