

[54] **EXCHANGE PACKING ELEMENT**

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[*] Notice: The portion of the term of this patent subsequent to May 23, 1989, has been disclaimed.

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 768,995, Oct. 21, 1968, Pat. No. 3,664,095, and a continuation of Ser. No. 767,681, Oct. 15, 1968, abandoned.

[52] U.S. Cl. **55/387, 55/498, 55/524, 162/181**

[51] Int. Cl. **B01d 53/04**

[58] Field of Search **55/163, 387-389, 55/496, 524; 210/502, 506, 490, 491, 498; 162/181 C**

[56]

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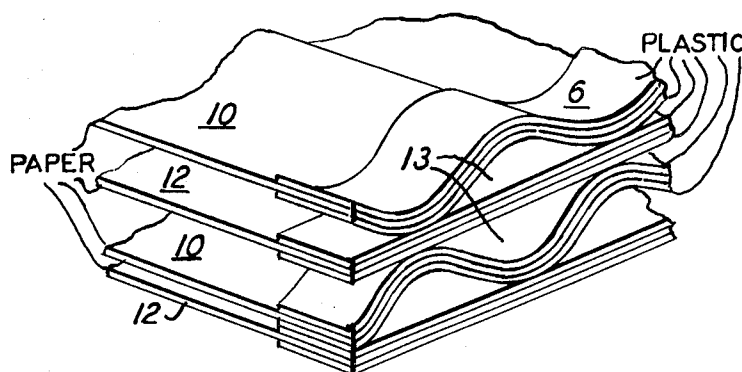
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[57]

ABSTRACT

A moisture adsorbent packing is formed as a laminated cellular structure of paper in which the pores of the paper have been filled with an inorganic moisture adsorbent substance, the packing being strengthened and reenforced using some minor hard resin coating at the cellular inlets and outlets of the packing without, however, coating of the moisture adsorbent surfaces.

2 Claims, 6 Drawing Figures



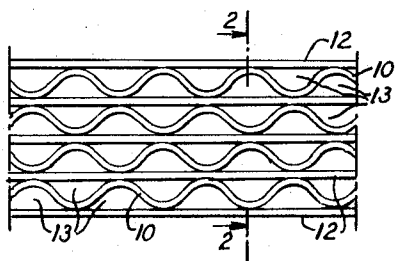


FIG. 1

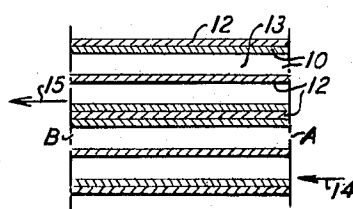


FIG. 2

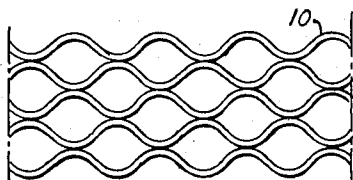


FIG. 3

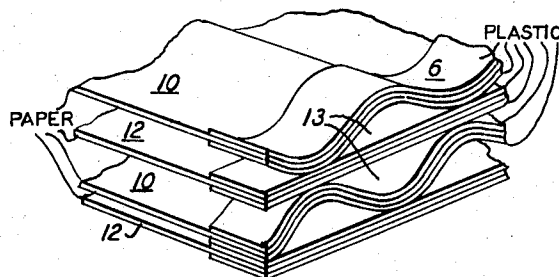


FIG. 4

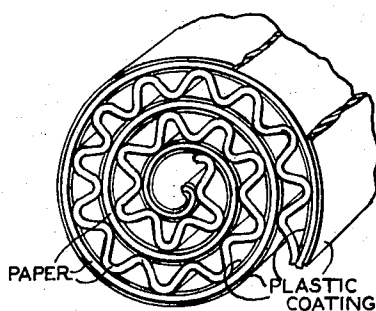


FIG. 5

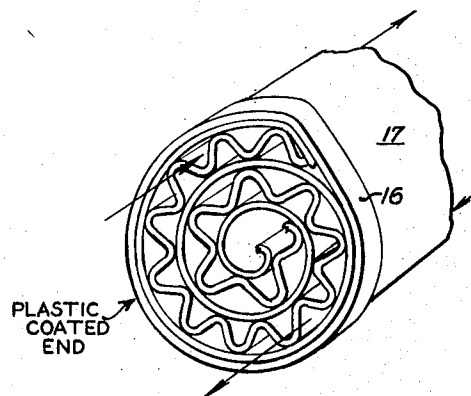


FIG. 6

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EXCHANGE PACKING ELEMENT

This application is a continuation-in-part of my co-pending application serial number 768,995, filed Oct. 21, 1968, and now allowed, to be issued as U.S. Pat. No. 3,664,095, May 23, 1972; and is a streamline refiled continuation of my parent application serial number 767,681, filed Oct. 15, 1968, and now abandoned.

This invention relates to a moisture exchange packing element formed of porous paper impregnated with moisture-adsorbent substances, corrugated and laminated into a cellular body, and secured and stiffened, usually at its outer edges, by a hard-bonding resin or plastic.

More particularly, this invention relates to a porous paper body of cellulosic fiber which may comprise a strong, heavy, but absorbent sulfite or sulfate cellulose fiber converted to a porous paper which may be impregnated with a moisture-adsorbent substance in substantial quantity, either before or after forming into paper sheets.

In one aspect of the invention, the porous cellulosic paper is dipped in a soluble form of a hydrous oxide which is then precipitated in the pores of the paper by a suitable precipitating agent, thus converting the soluble form of the hydrous oxide in the paper into an insoluble form of hydrous oxide. Upon ultimate drying of the paper and activating hydrous oxide therein, the paper becomes highly moisture adsorbent. Such adsorbent paper is corrugated and laminated into a moisture-adsorbent cellular body.

In a second aspect of this invention, the wet paper pulp may be mixed with the soluble hydrous oxide, and the pulp either before or after forming into wet porous sheets is treated with a precipitating agent to precipitate the hydrous oxide so that the hydrous oxide is evenly distributed with the wet fibers of the cellulose and both are then dried in sheet form to a moisture-adsorbent paper.

It is preferred before drying and sometimes before precipitating the soluble form of the hydrous oxide, to first corrugate at least some of the paper sheets, assembling the corrugated sheets into lamina, whereby a laminated cellular body of paper is formed in which each corrugation is an air permeable cell.

Then, after drying of the porous paper and activating the impregnated hydrous oxide to moisture-adsorptive form, the assembled laminated body may have its open cellular ends dipped in a hard resinous material penetrating only a short distance inward, such as from about one-eighth to one-half inch, whereby the resinous material upon hard setting greatly reinforces the laminated corrugated paper body. It is then a strong, useful moisture-adsorbent packing material, capable of adsorbing moisture from gases such as air. The air is dried by passing through the corrugations formed by cells extending from side to side of the cellular body, and the moisture is adsorbed from the air by the moisture adsorptive hydrous oxide contained in the pores of the paper. In this manner a strong packing material is formed, having great economy.

The body when intended for use in rotary form may have the corrugated sheets coiled spirally into a cylindrical body in which a plane sheet of paper which is not corrugated may be assembled and coiled together with the corrugated paper, and both corrugated and uncorrugated sheets are simultaneously coiled into a

rotary body in which the cells of the corrugations are separated in each layer by the flat uncorrugated sheets of paper.

In alternate constructions, it is possible either to impregnate with moisture adsorbent hydrous oxide both the flat sheet of paper and the corrugated paper; or merely to use, as the flat sheet of paper, ordinary paper which is not moisture adsorbent; and, as a further alternative, the flat sheet may be further coated with a strong reinforcing resin coating which is hard setting. When the resin coating upon the flat sheet has only partially set and is still tacky, the flat sheet of coated paper is then assembled with the uncoated corrugated moisture adsorbent sheet of paper and the assembly is then coiled into a cylindrical body. When the cellular body is not to be used by rotation, then the assembly need be merely a laminated tier of sheets, corrugated sheet alternating with flat sheets of paper, of which the latter need not be moisture adsorbent and may even be resin coated sheets with only the corrugated sheets being moisture adsorbent. The tacky, hard-setting resin coated flat sheets serve to bind the corrugated sheets into a strongly cohered laminated body.

The invention is further described with relation to the drawings wherein:

FIG. 1 shows an end view of a laminated assembly of corrugated paper alternating and adhered to intermediate flat sheets of paper as an overall structure;

FIG. 2 is a section through FIG. 1 taken on line 2—2 of FIG. 1;

FIG. 3 is a modification of a cellular laminate in which the intermediate flat sheet of FIG. 1 is omitted, but the bottom of each dip of a corrugation is adhered to the top of the rise of the next corrugated sheet to form a laminated cellular structure;

FIG. 4 illustrates the edge of a laminate showing that the laminated body, for a short distance inward, has been dipped in a hard setting resin whereby the laminate is reinforced only at its outer edges with a resin;

FIG. 5 shows a rotary type of packing comprising a corrugated paper, alternating with a flat, non-corrugated insulation paper, and with a detail indicating that the flat sheet of paper per se may be coated with a hard resin; and

FIG. 6 is a modification of FIG. 5 which is the flat sheet of paper coated or non-coated and coiled into a cylindrical body as in FIG. 5 which may be further reinforced by a metallic or cellular reinforcing ring or band mounted about the outer cylindrical surface thereof.

As stated, in forming the hydrous oxide impregnated paper, one common method will be to add a hydrous oxide forming chemical, typically water glass, sodium aluminate, ferrous sulfate or aluminum sulfate to the wet pulp to form a wet hydrous oxide salt-impregnated paper pulp. This chemically impregnated paper pulp is then distributed on a paper forming foudrinier screen to form a sheet, dewatered of excess chemical solution, and at least partially dried into a paper sheet, usually without substantial rolling, pressing or calendaring; that is, without expulsion of the impregnating chemical. The paper then has the hydrous oxide precipitated, which usually as in the case of water glass, will be by wetting the impregnated paper with a mineral acid, typically dilute hydrochloric or sulfuric acids to precipitate the silica; or with similar acid to precipitate hydrous

alumina from a sodium aluminate impregnated sheet when that is the chemical impregnating agent; or with soluble alkali such as sodium or alkali earth metal or ammonium hydroxide, for example, aqueous barium hydroxide solution, when the impregnating chemical is soluble acidic ferrous salt or aluminum salt. Such treatments produce a hydrous oxide precipitate evenly secured and distributed among the paper pulp fibers such as of silica, alumina, or ferrous hydroxide. Other known moisture adsorptive hydrous oxides can be similarly precipitated as distributed in the paper pulp.

Usually the hydrous oxide is formed in quantity of about 10 to 60 percent by weight of the impregnated paper body. The paper in a moist state can be corrugated, or it may be merely dried and then corrugated.

The same kind of impregnation can also be effected by first forming the paper into a porous fibrous sheet, dipping the preformed porous paper into the first treating chemical solution such as water glass, sodium aluminate, ferrous sulfate or the like, and then immediately treating the impregnated paper with a precipitating chemical to form the insoluble hydrous oxide in the pores of the preformed paper. Whichever way is followed, the paper may be formed either in flat sheets for flat sheet, moisture-adsorbent purposes, or it may be corrugated to form the cells of the assembled body.

In a final treatment, usually after corrugation or after assembly into a laminated body, it is heated from 225° to 300°F to activate the hydrous oxide into moisture-adsorptive form.

Referring first to FIG. 1, the laminated body may consist of corrugated paper 10 impregnated with the moisture adsorbent hydrous oxide as described, alternating with flat plane sheets of paper 12, to form cellular spaces 13 by each corrugation in the corrugated sheet. The cells extend from one side A, where the moisture-containing gas may enter, according to the arrows 14 of FIG. 2, and the gases pass freely through the cellular body being emitted from the side B, according to arrows 15. In passing through the cells, the moisture-adsorbent hydrous oxide adsorbs moisture from the gas as it passes, thus being emitted from the side B as a dried gas. The cellular hydrous oxide impregnated paper laminate may be assembled as a laminate in plane stacks as shown in FIG. 1, to any height or width useful for gas treatment, and the stacks may be shaped similar to various moisture adsorbent beds such as shown in prior patent Nos., 3,204,388, 3,119,673, and 3,159,354, wherein granular silica gel was used as a bed shaped to a useful structure to adsorb moisture from gases passed therethrough.

In an alternate structure, each corrugated sheet impregnated with moisture adsorbent hydrous oxide, as described, may be coiled into a laminated structure as shown in FIGS. 5 and 6. In the structure of FIG. 5 a portion of the gas may pass axially through the cells formed by the corrugations from end to end as shown in FIG. 2, but for moisture adsorption in the structures of FIGS. 5 and 6 the gas will pass near one radial side of the cylindrical laminated body for removal of moisture therefrom. Simultaneously, scavenging gas which can be ordinary ambient air, but heated sufficient to drive the adsorbed moisture out of the hydrous oxide, is passed through the opposite radial side of the cylindrical body to remove the adsorbed moisture as it

passes axially through the cells of the laminated structure from end to end of the cylindrical body, often in an opposite direction to that of the gas passing for moisture adsorption. The whole coiled body of FIGS. 5 and 6 are rotated between the two gaseous streams so that cold ambient air passes axially near one radial side for moisture adsorption while heated air is passed through the opposite radial side, and often in an opposite axial direction, to remove the adsorbed moisture continuously as the laminated body rotates between the two streams. Thus, two fluids are simultaneously passed through the cellular rotary packing near opposite radial sides, one to be dried and the other to remove the adsorbed moisture from the hydrous oxide continuously regenerating it for drying of the gas. Obviously the scavenging gas is disposed of separately and away from the gas to be dried, so that the dried gas is not admixed with the ambient gas upon being emitted by structures known in the art and not here shown.

FIG. 3 shows a simple modification in which the flat separating sheets are omitted and the cellular structure is formed by adhering the corresponding bottom dips of the corrugations to the top dip of the adjacent corrugations of the adjacent lamina, and so on, to build up a cellular body with direct adhesion between the corrugated hills and depressions adhered to the corresponding hills and depressions of the next adjacent corrugated sheet of the laminate. Usually the adhesion is effected by a hard, resinous bonding agent applied to the outer dips and tops of the corrugated hills and depressions of the corrugated sheets so that adhesion can be effected to each other.

However, as shown in FIG. 1, in an alternate modification, it is possible, as stated, to substitute ordinary flat paper sheet 12 for a porous adsorptive sheet. The flat sheet is dipped in a hard-setting resin, such as an epoxy resin, and before the resin is cured and is still tacky, the assembly of packing is formed by adhering each uncoated corrugated sheet containing the hydrous oxide therein, as described, between two resin-coated ordinary flat sheets, and the laminate is thus formed to the desired height using as many layers as desired for the structure.

As shown in FIG. 5, the preferred structure results where a plane sheet and a corrugated sheet, each of which may be impregnated with moisture adsorbent hydrous oxide, as described, are coiled layer upon layer into a cylindrical body. The ends of the cylindrical body are then usually dipped into a hard-bonding resin, such as an epoxy resin, for a short distance such as one-eighth to one-half inch in depth, and allowed to set, with the adsorbent body held in coiled position so that the hard-bonding resin applied to each opposite end of the coiled body greatly reinforces and secured it in the coiled structure, as shown. It is also useful to merely assemble corrugated hydrous oxide impregnated and plane sheets in a stack, as shown in FIG. 4, and impregnate only the ends of the stack 16 with a hard-bonding resin, such as epoxy which, upon setting, secures the stack into a strong, moisture-absorbent, laminated body of which both the plane sheets and the corrugated sheets are moisture adsorbent. It will be understood in each of the figures, the corrugations form cells preventing lateral communication between cells and allow only axial passage of gas through each cell formed by a corrugation from end to end of the laminated body.

Where a stack of corrugated sheets are assembled in a tier with or without intermediate plane sheets, such body is first used to adsorb moisture in a dry cycle and in an alternate regeneration cycle hot gases may be passed through the cells in the same or opposite direction to the gas that was first dried, so that in the regeneration cycle the adsorbed moisture will then be removed by a hot scavenging gas, regenerating the laminated cellular body for further use in air drying.

In a further modification, as shown in FIG. 6, the structure of FIG. 5 may be further strengthened by mounting a metallic ring 17 around the outside, strongly reinforcing and securing the coiled laminate into the cellular body as shown.

The following examples illustrate the practice of this invention:

EXAMPLE I

Sulfite paper pulp substantially dewatered by removal of excess water is wet with a 45 percent solution of sodium silicate in water (water glass), centrifuged, passed over a foudrinier screen to remove excess sodium silicate. Some of the sheets are then dried and other sheets are corrugated, both assembled alternately into a laminated stack, a flat sheet separating a corrugated sheet as a cellular bed of substantial depth as desired, such as 5, 10 or 20 inches up to several feet, depending upon the volume of gas to be treated by that cellular body. The green assembled laminate is then further dried in an air-drying oven with warm air at 75°C. The stack is then dipped, first one half, then the other, in a 10 percent solution of hydrochloric acid to precipitate the water glass as silica gel, again dipped in water to remove excess acid and dried to a hard, moisture-adsorbent body. The ends are then dipped in liquid epoxy resin, in this case Shell Epon 834, having an epoxy equivalent of about 250, the resin being dissolved as a 70 percent solution in butyl carbitol to which about 5 weight per cent of metaphenylene diamine was added just prior to use. The edges of the laminate are thus resin coated to a depth of about one-half inch at the cellular ends and the non-cellular sides are merely dipped to a depth sufficient to coat. The assembled body after evaporating the solvent and curing of the epoxy resin, which sets hard in a short two-hour storage period, is quite strong structurally and is useful as a packing through which gas may be passed for moisture adsorption and alternate regeneration.

EXAMPLE II

Example I is repeated except that the corrugated sheets and flat porous paper sheets impregnated with about 60 weight per cent of acid precipitated silica gel are assembled as a pair of sheets and rolled into a coil of about 10 inches in diameter, held temporarily in that shape by a banding member such as a string, and each cellular end is then dipped to a depth of one-fourth inch in the same epoxy resin solution as in Example I, the resin being allowed to set hard for two hours. The coiled cellular body is found to be quite strong structurally and is useful for mounting as a packing as a rotary member for drying gas passed through one radial side, while simultaneously regenerating the adsorbed moisture by passing a hot scavenging gas through an opposite radial side to expel the moisture that was adsorbed, the regenerating gas being heated to about 200°C for expulsion of the moisture. Thus, as the coiled body ro-

tates, a portion adsorbs moisture near one side, and the adsorbed moisture is expelled near the opposite side.

EXAMPLE III

In a modification of Example II, the coiled laminate of flat sheet alternating with corrugated sheet has a metal sleeve fitted thereabout to support and tightly contain the coil laminate formed as described and shown in FIG. 6, the sleeve being applied either before or after dipping in the epoxy resin to apply the resin only to a shallow depth, but at the entrance and emission end of each cell, the resin extending about one-fourth inch inward of each opposite cell end.

EXAMPLE IV

In a further modification the hydrous silica gel impregnated in the sheet following corrugation, is assembled with an ordinary sheet of kraft paper, the kraft paper being without corrugation and being dipped in epoxy resin. The wet, tacky, coated kraft sheet is then assembled with the dry corrugated, uncoated, adsorbent sheet as a pair of sheets which are then coiled into a laminate while the coated sheet is still tacky. Such structure is illustrated in FIG. 5. The coil extends to the desired diameter which may be further secured by a metal sleeve as shown in FIG. 6, or not, as desired, mounted about the cylindrical body. Again, while the structure described is highly adsorbent, the adsorbency exists only in the corrugated sheet of FIG. 5. Nevertheless, the structure is quite strong and may be even further reinforced by coating each axial end of the cellular body by dipping to a depth of one-eighth to one-fourth inch with more epoxy resin as shown in FIG. 4. In that manner a very rugged rotary packing body is formed.

EXAMPLE V

Highly porous paper is corrugated, and assembled alternately in a pair of a plane sheet and a corrugated sheet, both of equal porosity and coiled to desired diameter. The coiled porous laminated paper packing is secured in a metal sleeve as shown in FIG. 6. The entire body is first dipped in water glass, allowed to drain and substantially dry in an air drying oven for a period of two hours with warm air at 75°C. The entire body is then dipped into a dilute solution of inhibited hydrochloric acid which will not corrode the sleeve, and finally dipped in rinsing water solution, and then returned to the air drying oven and again dried by heating to about 275°F, whereby both the plane and corrugated paper in the laminated coils as described have silica gel impregnated in the porous paper and is supported in a highly porous, active, moisture-adsorbent state. The opposite axial ends of the cylindrical body may then also be dipped to a depth of about one-fourth inch in a hard setting liquid epoxy resin and allowed to set. In that manner again a strong rotary cellular body is formed in which the hydrous oxide silica gel is supported as a rotary air drying packing and is useful as described above.

EXAMPLE VI

Porous paper is corrugated, the outer bends (peaks) at each side only being coated with a strip of wet epoxy resin. The corrugated sheet is then assembled with an uncorrugated sheet, and both are rolled into a coiled, cylindrical body, whereby the resin bonds the sheets

together at the points of contact of the corrugated and flat sheets and upon setting of the epoxy resin the cylindrical body becomes internally reenforced at the juncture of each corrugation with the flat paper sheet. The cylindrical body, after setting of the resin, is then dipped in 15 percent aluminum sulfate, dried at 70°C in an air drying oven, and is then dipped in a dilute 5 percent caustic soda solution whereby hydrous alumina is precipitated in the pores of the assembled cylindrical body. Thereafter, the wet body is dried in an air drying oven at 70°C and then further heated to 275°F to expel any adsorbed moisture and to effect an activation of the hydrous oxide to a moisture adsorbent state. Finally, the cellular ends of the cylindrical body are each dipped in the hard setting liquid epoxy resin to a depth of about one-fourth inch at each axial end which is then allowed to set. The rotary packing may be further reenforced about its cylindrical outer surface by a metal cylindrical tight-fitting sleeve and then used as a rotary cellular packing material for adsorbing moisture.

Various modifications will occur to those skilled in the art. Thus, known methods for forming paper impregnated with a moisture-adsorbing substance may be substituted. The paper may be corrugated and laminated as corrugations with or without separating the sheets; and portions of the laminated assembly, such as the outer axial ends of the cells, may be coated with a hard-setting resin sufficient to both impart great strength and to bond the laminate into a coherent laminated body without coating over the moisture adsorbing cellular surfaces to reduce their moisture adsorption capacity. The laminar body may be further reen-

forced at its ends, perimeter, or periphery, as desired.

Accordingly, it is intended that the description and examples herein be regarded as exemplary and not limiting except as defined in the claims appended hereto.

What is claimed is:

1. A moisture-adsorbent cellular packing body comprising a laminated cellular structure formed of alternate layers of plane sheets and corrugated porous cellulosic paper sheets, the corrugated sheets having a substantial exposed surface content of moisture-absorbent desiccant material distributed in and filling the pores of the paper to convert the corrugated paper sheets to gas impermeable form, said plane sheets having a coating thereon of a hard-setting adhesive, the adhesive coated plane sheet being hard bonded in alternate layers to the dry corrugated sheets in the assembly as a unitary body in which the uncoated corrugations form open cells extending from one side of the body to an opposite side through which gases may pass for moisture adsorptive contact with the surface exposed desiccant contained in the paper sheets, said adhesive coated plane sheet along bonding the assembly into a unitary reenforced packing body.

2. A moisture adsorbent cellular packing as defined in claim 1 where the body comprises an assembly of a corrugated sheet and a plane sheet, only said plane sheet having an adhesive coating bonding said uncoated moisture adsorbent corrugated cylindrical coiled sheet into a laminated body.

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