



(12) **EUROPEAN PATENT APPLICATION**

(21) Application number : **93850063.4**

(51) Int. Cl.⁵ : **D04H 1/54, D04H 1/42**

(22) Date of filing : **31.03.93**

(30) Priority : **30.11.92 US 985096**

(43) Date of publication of application :
08.06.94 Bulletin 94/23

(84) Designated Contracting States :
BE DE DK FR GB NL SE

(71) Applicant : **ALBANY INTERNATIONAL CORP.**
1373 Broadway
Albany, New York 12204 (US)

(72) Inventor : **Schoppee, Meredith M.**
9 Fruit Street
Norfolk, Massachusetts 02056 (US)
Inventor : **Donovan, James G.**
19 Dana Road
Norwell, Massachusetts 02061 (US)

(74) Representative : **Berglund, Gustav Arthur et al**
AWAPATENT AB,
Box 5117
S-200 71 Malmö (SE)

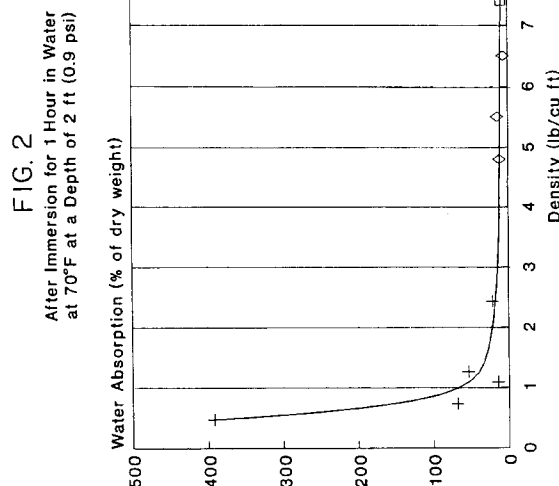
(54) **Breathable buoyant thermal insulating material.**

(57) This invention concerns a novel breathable, buoyant, thermal insulator material. The insulator material of the invention comprises an assemblage of :

(a) from about 50 to 100% by weight of spun and drawn polymeric microfibers having a diameter of from about 2 to 14 microns ; and

(b) from about 0 to 50% by weight of synthetic polymeric binder fibers having a diameter of from about 12 to 50 microns,

wherein the resulting assemblage has a density of from about 3.0 to 10.0 lb/ft³, and apparent thermal conductivity k measured by the plate to plate method according to ASTM C518 with a heat flow down of less than about 0.3 Btu·in/hr·ft²·°F in the dry condition, water absorption less than 50% of its dry weight when immersed for one hour at a depth of 2 ft. in fresh water at a temperature of 70°F, a buoyancy greater than 40 lb/ft³ after immersion for one hour at a depth of 2 ft. in fresh water at a temperature of 70°F, and an intrinsic moisture vapor transfer rate of at least 100 times greater than that of a closed-cell foam according to Military Specification MIL-P-12420C, Type II, Class 6.



The U.S. government has rights in this invention pursuant to Contract No. N00140-88-C-3056.

FIELD OF THE INVENTION

5 This invention relates to breathable, buoyant, thermally insulating material. More particularly this invention relates to breathable, buoyant, flexible, thermally efficient insulation systems which can be achieved by the use of assemblies of fine fibers.

BACKGROUND OF THE INVENTION

10

A flexible, closed-cell foam material currently used to line the multi-purpose coveralls worn by submarine crew members on deck fulfills its function of providing protection against cold and windy environments without unduly restricting the wearer's motion. In the event of accidental and prolonged immersion of the crew member in the sea, the lining retains its thermal insulation properties and provides buoyancy because it is impermeable to water. However, the wearer may suffer heat stress during periods of heavy work on deck because of the inability of the lining material to transfer moisture vapor and the consequent lack of evaporative cooling. There is, therefore, a need for a moisture vapor permeable (breathable), water penetration resistant, thermal insulating liner material for the multi-purpose coverall that will provide greater comfort to active military shipboard crew members. Such an insulating material would also provide benefits to others engaged in work or recreation in cold environments where there is some risk of accidental immersion in water, such as merchant marine crewmen, fishermen, yachtsmen, off-shore oil platform workers and ski-mobilers.

U.S. Patents Nos. 4,588,635 and 4,992,327 each describe thermal insulating materials comprising synthetic, spun and drawn, crimped microfibers and synthetic macrofiber binders, the density of the resulting batt material being less than 1.0 lb/ft³. These materials are unsuitable for the work or recreational purposes described above because of their inability to limit water absorption to acceptable levels and, as a result, to provide both buoyancy and thermal insulation value in the event of immersion.

OBJECTS OF THE INVENTION

30 It is an object of the invention to provide a novel, breathable, buoyant insulating material with thermal insulating properties that are good under dry conditions and that are superior, when immersed in water, to those of other fibrous materials.

It is also an object of the invention to provide a breathable, buoyant, thermal insulator material comprising an assemblage of:

- 35 (a) from about 50 to 100% by weight, based upon the total weight of the insulator material, of spun and drawn, polymeric microfibers having a diameter of from about 2 to 14 microns; and
(b) from about 0 to 50% by weight, based upon the total weight of the insulator material, of synthetic, polymeric binder fibers having a diameter of from about 12 to 50 microns,

wherein the resulting assemblage has a density of from about 3.0 to 10.0 lb/ft³, an apparent thermal conductivity k measured by the plate to plate method according to ASTM C518 with a heat flow down of less than about 0.3 Btu-in/hr-ft²-°F in the dry condition, water absorption less than 50% of its dry weight when immersed for one hour at a depth of 2 ft. in fresh water at a temperature of 70°F, a buoyancy greater than 40 lb/ft³ after one hour at a depth of 2 ft. in fresh water at a temperature of 70°F, and an intrinsic moisture vapor transfer rate of at least 100 times greater than that of a closed-cell foam according to Military Specification MIL-P-12420C, Type II, Class 6.

These and other objects of the invention will become more apparent in the description below.

BRIEF DESCRIPTION OF THE DRAWINGS

50 Fig. 1 is a graph of fiber diameter vs. density for particular advancing contact angles at which water at 70°F and a pressure equivalent to a depth of 2 feet is restricted from entering the average interfiber pore in a polyester fiber assembly; and
Figs. 2, 3, and 4 are each a graph showing the effect of web density on water absorption for nonwoven fiber webs according to the invention.

55

DETAILED DESCRIPTION OF THE INVENTION

The invention described herein provides an alternative to impermeable closed-cell foam material as a

buoyant insulator that has good thermal insulating performance, both wet and dry, equal or better flexibility, and much increased permeability to water vapor. This alternative insulator is comprised of either (1) all microfibers or (2) microfibers and binder fibers. The microfibers may be pre-treated with a water-repellent finish or the fiber assemblage may be treated with a water-repellent finish after formation of the fiber batt. Alternatively, the microfibers and/or binder fibers may consist of inherently water-repelling material.

There are two important physical properties that determine the level of resistance to wetting, that is, water-repellency, that an assembly of fibers can provide when immersed in water: (1) the pore size distribution and (2) the advancing contact angle between the wetting liquid, water in this case, and the fiber surface. If the fiber surfaces are hydrophilic, i.e., the contact angle between the advancing fluid meniscus and the solid surface of the fiber is less than 90°, then water will eventually wick into the assembly to fill all pores by capillary action. If, however, the surface of the fiber is hydrophobic (advancing contact angle greater than 90°), either because of its natural state or because a water-repellent finish has been applied, then positive pressure must be applied to overcome surface tension and allow water to enter the pore. The magnitude of this pressure, P , is determined by the pore diameter d_p , the cosine of the advancing contact angle, Θ_a , and the surface tension of the wetting liquid, γ , as described by the following equation (according to Laplace):

$$P = \frac{-4\gamma\cos\Theta_a}{d_p}$$

Because fibrous insulation materials are a nonhomogeneous collection of individual fibers arranged somewhat at random, they contain interfiber pores of various sizes. Although it is difficult to characterize the pore size distribution in advance, it is possible to calculate the diameter of the average pore, $\bar{d}_p$, based on the density of the insulation, ρ_0 , the compressive strain, ϵ , at the applied pressure, and the diameter, d_f , and density, ρ_f , of the fibers from which the web is constructed according to the following relationship:

$$\bar{d}_p = d_f \left[\frac{\rho_f (1 - \epsilon)}{2\rho_0} - \frac{1}{2} \right]^{1/2}$$

By use of these expressions it is possible to show, as in the attached Figure 1, that in the density range of interest, 3 to 10 lb/ft³, and for currently-known water-repellent finishing treatments, for which advancing contact angles may be as high as 120°, the range of suitable fiber diameters for an assembly of polyester fibers that will restrict the entry of water at a temperature of 70°F into the average pore at an applied pressure equivalent to a depth of 2 feet in water (0.9 lb/ft²) is between 2 and 14 microns dependant upon the web density. In the more usual range of wetting angles for water-repellent treatments, 100° to 110°, which includes the silicone and fluorocarbon polymer finishes, the fiber diameter required to prevent water absorption into the average pore of a polyester assembly must be in the microfiber range below 10 microns, as also illustrated in the attached Figure 1. For advancing contact angles below about 95°, the fiber diameter required to prevent wetting is prohibitively small in terms of current manufacturing technology.

The advantage of low water absorption during immersion on the thermal conductivity of the wet assembly can be seen from the following relationship derived from Hollies and Bogaty ("Some Thermal Properties of Fabrics Part II. The Influence of Water Content," Textile Research Journal, February 1965, pp. 187-190):

$$k_{wet} = \left(\frac{\rho_0}{1 - \epsilon} \right) \left(\frac{w}{\rho_w} \right) (k_w - k_0) + k_0$$

which relates the thermal conductivity of the wet assembly, k_{wet} , to that of the dry assembly, k_0 , and to the water absorption, w , as a fraction of the dry weight of the assembly; the "effective" thermal conductivity of water, k_w (Hollies and Bogaty use $k_w = 1.46$ Btu-in/hr-ft²-°F to account for the influence of the fiber-water arrangement in the assembly); the density of water, ρ_w ; and the density of the assembly at the hydrostatic pressure of interest, $\frac{\rho_0}{1 - \epsilon}$. For dry batt densities ρ_0 , in the range of the invention, between 3.0 and 10.0 lb/ft³, appropriate values of the compressive strain ϵ and an initial thermal conductivity of the dry assembly, $k_0 \leq 0.3$ Btu-in/hr-ft²-°F, it can be shown by means of the above relationship that water absorption of less than about

50% of the weight of the dry assembly limits the thermal conductivity of the wet assembly to less than or equal to 0.5 Btu·in/hr·ft²·°F, thereby limiting the rate of heat loss through the insulation material during immersion.

Applicants have discovered a combination of fiber selection, treatment and batt construction that utilizes an advantageous combination of the properties discussed above to provide a relatively thin, porous, thermal insulator with (1) high resistance to water penetration, (2) excellent buoyancy characteristics, (3) a high moisture vapor transmission rate, and (4) flexibility. This surprising and desirable result has not before been available. More particularly, the insulating material of the invention can be described as an assemblage of:

(a) from about 50 to 100% by weight of spun and drawn, polymeric microfibers having a diameter of from about 2 to 14 microns; and

(b) from about 0 to 50% by weight of polymeric binder fibers having a diameter of from about 12 to 50 microns,

wherein the resulting assemblage has a density of from about 3.0 to 10.0 lb/ft³, an apparent thermal conductivity k measured by the plate to plate method according to ASTM C518 with a heat flow down of less than about 0.3 Btu·in/hr·ft²·°F in the dry condition, water absorption less than 50% of its dry weight when immersed for one hour at a depth of 2 ft. in fresh water at a temperature of 70°F, a buoyancy greater than 40 lb/ft³ after one hour at a depth of 2 ft. in fresh water at a temperature of 70°F, and an intrinsic moisture vapor transfer rate of at least 100 times greater than that of a closed-cell foam according to Military Specification MIL-P-12420C, Type II, Class 6.

Water-repellency can be imparted to the assemblage of the invention by (1) pre-treating the microfibers or the microfibers and binder fibers prior to assembling, (2) treating the resulting fiber assemblage, (3) choosing fiber material that is inherently water-repellent, or (4) by a combination thereof. The pre-treatment or post-treatment can be effected by applying any of the known water-repelling agents. Typical water-repelling agents include aqueous solutions of organopolysiloxanes, such as polydimethylsiloxane, or emulsions of fluoropolymers, such as polytetrafluoroethylene. These treatments may provide the additional advantage of inter-fiber lubrication, which serves to improve the flexibility of the resulting assemblage. When the microfibers are not treated with a water-repelling agent prior to assembly or are not themselves intrinsically water-repelling, the resulting assemblage can be treated with a suitable water-repelling agent, such as SCOTCHBAN® FC-824, a fluorochemical sizing agent available from 3M. Such water-repelling agents may be applied to the fibers by spray or dip techniques well known in the art.

The resultant fiber assemblage preferably has a density of from about 3.0 to 10.0 lb/ft³. This density range is characteristic of assemblages of polyester fibers or materials of similar specific gravity. It is within the scope of the invention that the density range could be as low as about 2.0 lb/ft³ and as high as about 12.0 lb/ft³ with the selection of materials of a specific gravity different from that of polyesters.

It is preferred that the resultant fiber assemblage has an apparent thermal conductivity k measured by the plate to plate method according to ASTM C518 with a heat flow down of less than about 0.3 Btu·in/hr·ft²·°F in the dry condition, and water absorption less than 50% of its dry weight when immersed for one hour at a depth of 2 ft. in fresh water at a temperature of 70°F.

Also, the resulting assemblage preferably has a buoyancy greater than 40 lb/ft³ when immersed for one hour or less at a depth of 2 ft. in fresh water at a temperature of 70°F. The buoyancy can approach but cannot exceed the density of water (62.4 lb/ft³ for fresh water). Further, the assemblage will have an intrinsic moisture vapor transfer rate defined and measured as described herein, at least 100 times greater than that of the closed-cell foam according to Military Specification MIL-P-12420C, Type II, Class 6, incorporated herein by reference.

The invention also includes a method of forming useful thermal insulating material, which comprises the steps of

- (1) forming an assemblage of components (a) and (b) described above;
- (2) effecting connectivity between some of the fibers at their contact points; and
- (3) permanently densifying the resultant assemblage.

Microfibers and binder fibers for use in the present invention may be manufactured from polyester, nylon, rayon, acetate, acrylic, modacrylic, polyolefins, spandex, polyaramids, polyimides, fluorocarbons, polybenzimidazols, polyvinylalcohols, polydiacetylenes, polyetherketones, polyimidazols, and phenylene sulfide polymers such as those commercially available under the trade name RYTON.

The microfibers and the binder fibers may each be all the same material or different, and the binder fibers may be either the same as the microfibers or different. In an advantageous embodiment of the invention the microfibers and the binder fibers are formed from polyesters.

Component (b) may comprise single component fibers or multi-component, preferably bicomponent, fibers, where the single component or at least one component of the multicomponent binder fiber has a melting point lower than that of the microfibers of component (a), to facilitate fiber to fiber bonding. Useful two-com-

ponent binder fibers include Type K 54, a sheath/core polyester/polyester material available from Kanebo, Ltd., of Japan and Type TJ04S2, a side-by-side polyester/polyester material and Type TJ04C2, a sheath/core polyester/polyester material, the latter two available from Teijin Ltd., of Japan. Other useful two-component fibers are available under the tradename CELBOND® from Hoescht Celanese Corp., Charlotte, N.C., U.S.A.

5 Batts according to the invention can be stabilized at an appropriate density by effecting permanent connectivity between microfibers, between binder fibers, or between binder fibers and microfibers. Such connectivity, bonding, or linking can be effected by a thermal or chemical process.

 Thermal bonding of batts according to the invention can be achieved by utilizing binder fibers that have a component with a melting temperature lower than that of the material of the microfibers. Under such circumstances the binder fibers will bond to microfibers at their contact points or, optionally, to other binder fibers at binder fiber/binder fiber contact points.

 Bonding between fibers, especially between binder fibers, may be effected by use of chemical bonding agents. Certain solid, gaseous, or liquid bonding agents may cause fiber bonding. In the alternative, there are certain autologous bonding agents which would cause fiber bonding directly through the action of an intermediate chemical or physical agent.

 It is within the scope of the invention that the insulating material may be subjected to more than one procedure to cause entanglement, densification, and/or bonding between the fibers. For example, a batt comprised of microfibers and binder fibers could first be lightly needled and then the needled batt could be subjected to sufficient heating and pressure to cause the binder fiber component to bond with microfibers and other binder fibers and to cause the resultant structure to maintain its dense configuration when cooled.

 The particular method of achieving fiber connectivity, bonding and/or densification is not critical, but must be carried out under conditions such that structural integrity is imparted to the batt without appreciable immobilization of its constituent fibers. It would be appreciated by one skilled in the art that any appreciable change in the macrofibers or binder fibers during processing will effect the thermal properties and batt flexibility adversely. Therefore, this procedure needs to be conducted to maintain the physical and thermal insulating properties of the fiber components and the assemblage as much as possible.

 In a particular embodiment of the present invention bonding within the structure may be effected by heating the assemblage of fibers for a time and at a temperature and pressure sufficient to cause the fibers to bond. Heat and pressure may be applied in a hot press or between hot calender rolls, or by means of vacuum pressure in a through-air dryer/bonder. Such heating may be at, for example, a temperature of from about 260°F to 435°F for a period of from about 20 seconds to 15 minutes. After heating, the material is preferably cooled under restraint to set the densified configuration. These conditions are, of course, dependent upon the material of the microfiber and/or binder fiber components.

 The assemblage of binder fibers and microfibers may be a batt consisting of plied card-laps although other fibrous forms such as air-laid webs are equally suitable. Webs and batts of continuous filaments - whether bonded, entangled or otherwise stabilized - may be used.

 The microfibers and/or the binder fiber may optionally be crimped. Crimping techniques are well known in the art.

 In the examples below the following tests and measurements were employed:

40 Density: The volume of each insulator sample was determined by weighing samples of known areal dimensions and then measuring the thickness at approximately 0.002 lb/in² (0.014 kPa) pressure. The weight of each sample divided by the volume thus obtained is the basis for density values reported herein.

Thickness: Thickness was measured at approximately 0.002 lb/in² (0.014 kPa).

45 Flexural Rigidity: The flexural rigidity, or resistance to bending, was measured according to ASTM D1388, Standard Test Methods for Stiffness of Fabrics, Option A - Cantilever Test. In this test, a strip of fabric is advanced over the edge of a horizontal platform until the unsupported end touches a line extending from the edge at an angle of 41.5° to the horizontal. The flexural rigidity is calculated from the length of overhang, or bending length, and the weight of the sample.

50 Thermal Conductivity: The thermal conductivities of various examples of insulation material were measured according to ASTM C518, Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus. As described in this method, "The heat flow meter apparatus establishes steady state unidirectional heat flux through a test specimen between two parallel plates at constant but different temperatures." In our case, the measurements were made by Holometrix, Inc., Bedford, Mass., on 12 in. x 12 in. specimens with heat flow down from a top plate at a temperature of 100°F to a bottom plate at 50°F.

55 Water Penetration Resistance: The resistance to local penetration by water under pressure was measured as described in Federal Specification CCC-T-191b, Method 5516.1, Water Resistance of Cloth: Water Permeability, Hydrostatic Pressure Method. According to this method, a test specimen about 7 inches in diameter

is sealed against a rising column of 80°F water. When drops of water have penetrated the fabric and appear on the face of the sample opposite to the water head, the height of the column is read and converted to hydrostatic pressure. The maximum column height of the apparatus is 45 inches, which is equivalent to a water pressure of 1.6 lb/in².

5 Water Absorption : The amount of water absorbed by the materials described herein was determined by submerging samples of at least 7 in² in fresh water at a temperature of 70°F to a depth of 2 feet. The hydrostatic pressure at this depth is 0.9 lb/in². The samples were held at depth in weighted mesh bags or perforated metal holders for a period of 8 hours. The samples were removed from the water periodically, drained, and weighed. The water weight gain as a percentage of the original dry weight of the sample was thus determined after im-

10 Compression Properties: The compression properties of 3.0 to 5.0 inch diameter specimens of the materials were measured at 70°F by placing them between the hardened-steel compression platens of an Instron universal test machine and monitoring the load required to reduce their thickness until a pressure of 10 lb/in² was achieved. The thickness at a pressure of 0.9 lb/in², equivalent to the hydrostatic pressure at a depth of 2 feet, was determined from the autographic record of compression load and sample thickness. The thickness at 0.9 lb/in² was converted to compressive strain ϵ by dividing it by the original thickness of the sample measured at a pressure of approximately 0.002 lb/in².

15 Buoyancy: The buoyancy, B, of the materials in fresh water at 70°F was determined indirectly from their original density when dry, ρ_0 , the amount of water, w, absorbed at a depth of 2 feet, determined as a fraction of the dry weight as described above, and the compressive strain, ϵ , at the hydrostatic pressure corresponding to this depth according to the formula, $B = P_w - \rho_0(1+W)/(1-\epsilon)$, in units of lb/ft³, where ρ_w represents the density of fresh water at 70°F.

20 Moisture Vapor Permeability: The rate of moisture vapor transmission through the materials described herein was measured by an upright-cup water method similar to that described in ASTM E96, Standard Test Methods for water Vapor Transmission of Materials, except for the following:

- the test environment was 70°F, 65% relative humidity;
- the velocity of the air flow over the test specimens was not controlled, although all specimens saw the same, relatively static, conditions;
- the test specimens were clamped, rather than sealed, to the cup because of their thickness.

30 In this test, a specimen of the fabric of interest covers the opening of a 2.75 inch diameter, 2.0 inch deep cup which is filled with water to a depth of 1.5 inches. A layer of moisture saturated air forms above the water and permeates through the test fabric at a rate determined by the porosity of the fabric and the vapor pressure difference between the saturated layer of moisture in the cup and the external environment at the temperature and relative humidity of the test. The moisture vapor transmission rate is calculated from the rate at which weight is lost from the covered cup and may be reported directly as grams of water per m² per day, as a percentage of the rate of water evaporated from an open cup of water under the same conditions, or, more realistically, as the inverse of an intrinsic resistance R determined as follows:

$$R_{\text{intrinsic}} = R_{\text{total}} - R_{\text{extrinsic}}$$

35 where $1/R_{\text{total}}$ is the total measured moisture vapor transmission rate from the cup/water/fabric system to the external environment, and $1/R_{\text{extrinsic}}$ is the moisture vapor transmission rate measured from a cup covered by a very thin, extremely porous layer that acts only as a boundary between the internal and external environments of the cup and which contributes virtually no resistance of its own to the passage of moisture vapor. A 0.2 oz/yd² spunbonded fabric with a thickness of 0.0015 inch and approximately 65% open area was used to determine the extrinsic resistance of the cup/water system under the specific conditions of this test. Alternately, the moisture vapor transmission rate may be expressed in relative terms for comparison purposes by taking the ratio of $1/R_{\text{intrinsic}}$ for the fabric of interest to $1/R_{\text{intrinsic}}$ for a standard material, such as the closed-cell foam material of Military Specification MIL-P-12420C, Type II, Class 6, which is described in Comp. Ex. 1. The moisture vapor transmission rates for the materials described herein are compared by all of these measures in Table 2.

50 EXAMPLES

Comparative Example 1

55 Comparative Example 1 consisted of an expanded unicellular (closed-cell) elastomeric foam prepared commercially in sheet form from a blend of chlorine bearing vinyl resin and a butadiene acrylonitrile rubber according to Military Specification MIL-P-12420C, type II, class 6. This material is specified as the buoyant interlining for submarine deck exposure coveralls (buoyancy not less than 54.0 lb/ft³) according to the Military

Specification MIL-C-29109A. The closed-cell nature of this material prevents the absorption of water into its interior structure, thereby providing both buoyancy and insulation value to garments in which it is incorporated should the wearer inadvertently be submerged in water. However, the same closed-cell structure also renders the garment impermeable to the passage of moisture vapor from perspiration so that, as a result, no evaporative cooling can take place and the garment is not comfortable to wear during periods of heavy work.

Example 1

Example 1 of the invention consisted of a blend of 62% by weight of 7 micron diameter (0.5 denier), 1.5 inch, crimped, polyester microfiber treated by the fiber manufacturer with silicone slickener and water-repelling agent (polydimethylsiloxane), 19% by weight of 7 micron diameter (0.5 denier), 1.5 inch, crimped, polyester microfiber without slickener or water-repelling agent, and 19% by weight of 20 micron diameter (4.0 denier), 2.0 inch, thermally-activated, polyester binder fibers of the side-by-side type. The fiber components were blended and carded on a full-scale, commercial carding machine. The resultant web, which weighed approximately 6 oz/yd², was subjected immediately after carding to an oven exposure at 320°F for 5 minutes to create thermoplastic bonds between the microfibers and the binder fibers. Four layers of the resulting heat-set material were subsequently plied by hand to a total weight of 20 to 24 oz/yd² and a total thickness of several inches. A layer of 0.5 oz/yd² spunbonded polyester nonwoven fabric was applied to each of the two surfaces of the plied web. This assembly was densified and heat-set in its final dense configuration in a continuous process on a pilot-scale through-air bonder/drier equipped with a top restraining wire (Honeycomb Systems, Inc.). A roll of 24-inch wide material was processed on this machine at an air temperature of 375°F and a line speed of 7 ft/min in a 120° wrap configuration around a 36-inch diameter perforated steel cylinder. A vacuum pressure of 0.9 lb/in² and a restraining tension of 4 lb/inch were applied during this stage of processing. The web was cooled under restraint on a separate cooling roll before it was rolled up. The finished material was soft and flexible with a density between 8 and 9 lb/ft³ and a final thickness of 0.21 inch.

Example 2

The material of Example 2 consisted of a blend of 80% by weight of 7 micron diameter (0.5 denier), 1.5 inch, crimped, polyester microfibers treated by the fiber manufacturer with a silicone slickener and water-repellent (polydimethylsiloxane) and 20% by weight of 14 micron diameter (2.0 denier), 2.0 inch, thermally-activated, polyester binder fiber of the sheath/core type. The fibers were blended and carded on a 12-inch wide, laboratory-scale, carding machine. Layers of web removed from the carding machine were plied by hand to a final assembly weight of 21 to 23 oz/yd². These hand-ply samples, which measured about 12 inches wide by 16 inches long, were partially consolidated by light needle-punching on a laboratory-scale needling machine. The samples were further consolidated by application of heat while they were held between smooth aluminum plates spaced 0.125 inch apart. The plate/fiber assembly was heated in an oven at 350°F for 15 min. After removal from the oven, the samples were held to thickness between the plates as they cooled.

Comparative Example 2

Comparative Example 2 illustrates the effect of the absence of the water-repellent fiber finish on the wettability of the microfiber insulation material. The material of this comparative example consisted of a blend of 80% by weight of 7 micron diameter (0.5 denier), 1.5 inch, crimped, polyester microfibers to which no water-repellent was added and 20% by weight of 14 micron diameter (2 denier), 2.0 inch, thermally-activated, polyester binder fibers of the sheath/core type. The fibers were blended and carded, and the resulting card webs were plied, lightly needled, and consolidated by application of heat and pressure in the same way as that described above for Example 2.

Example 3

Example 3 of the invention illustrates the advantageous effect of the application of a water-repellent to the untreated microfiber insulation material described above as Comparative Example 2. The material of Example 3 consisted of the same blend of untreated microfibers and binder fibers as Comparative Example 2, but after light needling, a 5% solution of a fluorochemical, water-repelling, sizing agent (SCOTCHBAN® FC-824, available from 3M) was padded onto the fiber web under pressure between nip rolls in a laboratory-scale padder. A solids add-on of 1.2% of the dry weight of fiber was achieved. After being dried at 212°F, the treated web was consolidated by application of heat and pressure in the same manner as described for Example 2.

and Comparative Example 2.

Comparative Example 3

5 Comparative Example 3 was a 0.22 inch thick, 12.4 oz/yd², needled felt material that consisted of 14 micron diameter (2.0 denier), 3.0 inch, Type 450 NOMEX®, crimped staple fibers. The felt was prepared from this fiber in a continuous process on full-scale, commercial carding, cross-lapping, and needle-punching equipment. A 5% solution of a fluorochemical, water-repelling, sizing agent (SCOTCHBAN® FC-824) was padded onto 14-inch wide strips of felt in the same way as described above for Example 3. The resultant add-on of
10 solids was 1.0% of the dry weight of the felt.

Comparative Example 4

15 Comparative Example 4 was identical to Comparative Example 3 except that the felt was not treated with a water-repellent.

Example 4

20 Example 4 consisted of a blend of 62% by weight of 7 micron diameter (0.5 denier), 1.5 inch, crimped, polyester microfiber treated by the fiber manufacturer with a silicone, anti-wetting and slickening agent (polydimethylsiloxane), 19% by weight of 7 micron diameter (0.5 denier), 1.5 inch, unslickened, polyester microfiber, and 19% by weight of 20 micron diameter (4.0 denier), 1.5 inch, thermally-activated, polyester binder fiber of the sheath/core type. The fiber was blended and carded, the resulting web cross-lapped, and the binder fiber
25 activated by the application of heat in a continuous production process on commercial manufacturing equipment. The heated material was partially consolidated by passing it under a compaction roll and over a copper cooling platen as it emerged from the heat-setting oven. Samples of this material measuring 12 in. x 12 in. were compressed between and thermally bonded to two layers of a hydrophilic polyester breathable barrier film (SYMPATEX®) in one final consolidating step. The heat bonding and final densification of the membrane/fiber assembly was accomplished by holding it for 0.5 min to a thickness of 0.25 inch between aluminum
30 plates placed between the platens of a hot press at 400°F. The sample was air-cooled while held to thickness between the aluminum plates.

The properties of the Examples and of the Comparative Examples prepared as set forth above and measured in accordance with the test procedures described are summarized in the following Tables 1 and 2:

35

40

45

50

55

Table 1

	Comparative Example 1	Example 1	Example 2	Comparative Example 2	Example 3	Comparative Example 3	Comparative Example 4	Example 4
Density lb/cu ft (kg/m ³)	4.5 (72)	9.0 (144)	6.5 (104)	7.4 (119)	4.0 (64)	4.6 (74)	4.6 (74)	3.1 (50)
Thickness ^a inch (mm)	0.26 (6.6)	0.21 (5.3)	0.27 (6.9)	0.23 (5.8)	0.38 (9.7)	0.22 (5.6)	0.22 (5.6)	0.54 (13.7)
Weight oz/yd ² (g/m ²)	14.1 (477)	22.1 (751)	21.6 (731)	20.3 (689)	18.3 (622)	12.4 (420)	12.4 (420)	20.2 (685)
Flexural Rigidity ^b in-lb (g-cm)	0.0152 (17.5)	0.0069 (7.9)	0.0042 (4.8)	0.0463 (53.4)	0.0145 (16.7)	0.0154 (17.7)	0.0198 (22.8)	0.0159 (18.3)
Thermal Conductivity ^c Btu-in/m ² -hr-°F (w/m-°K)	0.22 (0.032)	0.23 (0.033)	-	-	-	-	-	0.21 (0.03)
Water Penetration Resistance ^d psi (kPa)	>1.6 (>11.0)	0.86 (5.9)	0.70 (4.8)	0.20 (1.4)	0.55 (3.8)	0.28 (1.9)	0.12 (0.8)	>1.6 (>11.0)
Water Absorption ^e % of dry weight - after 1 hr - after 4 hrs - after 8 hrs	13 17 20	14 32 41	6 11 14	757 740 745	28 58 79	461 562 548	862 928 914	48 61 83
Compressive Strain ^f %	14	28	33	20	51	(20) ^h	20	(60) ^h
Buoyancy ^g lb/m ³ - after 1 hr - after 4 hrs - after 8 hrs	57 (908) 56 (905) 56 (902)	48 (774) 46 (738) 45 (720)	52 (838) 52 (830) 51 (826)	0 (0) 0 (0) 0 (0)	52 (838) 50 (796) 48 (789)	30 (484) 24 (391) 25 (404)	7 (115) 4 (56) 4 (67)	51 (816) 50 (800) 48 (772)

- a. Measured at a pressure of approximately 0.002 lb/in².
b. Measured in accordance with ASTM D1388, Option A, Cantilever Test.
c. Measured in accordance with ASTM 518, heat flow down, T₁ = 100°F, T₂ = 50°F.
d. Measured in accordance with Fed. Spec. CCC-T-191b, Method 5516.1.
e. Submerged at a depth of 2 ft (0.9 lb/in²) in fresh water at 70°F.
f. Based on change in thickness on first cycle of compression from an applied pressure of approximately 0.002 to 0.9 lb/in².
g. At a depth of 2 ft in fresh water (0.9 lb/in²) -- calculated values obtained using the values of water absorption and comp strain given above.
h. Estimated.

Table 2

5

10

15

20

25

30

	Absolute MVTR ¹		Intrinsic MVTR ²	
	(g/m ² /24 hrs)	(% of open cup)	(g/m ² /24 hrs)	Relative to Comp. Example 1
Open cup of water	1275	100	—	—
0.2 oz/yd ² spunbonded fabric	604	47	—	—
Comparative Example 1 (closed-cell foam)	12	1	12	1
Example 1	486	38	2478	206
Example 2	439	34	1601	133
Comparative Example 2	477	37	2262	189
Example 3	451	35	1788	149
Comparative Example 3	532	42	4439	370
Comparative Example 4	489	38	2574	214
Example 4	457	36	1869	156

1. Measured by upright cup method at 70°F, 85% RH.

2. Values calculated from Absolute MVTR, see text.

35

From the data in Table 1, it is apparent that the standard foam interlining material of Comparative Example 1 provides good thermal insulation value when dry, resistance to water penetration under pressure, and both low water absorption and a high level of buoyancy when submerged in water. Unfortunately, however, this material is also virtually impermeable to the passage of moisture vapor, as indicated in Table 2. The materials of Examples 1 and 2, both of which contain a high percentage of silicone water-repellent-treated microfiber, also provide good thermal insulation, resistance to local water penetration under pressure, low water absorption, and considerable buoyancy when submerged in water, and, in addition, both are permeable to moisture vapor and more flexible than the foam material.

40

45

50

Comparative Example 2, prepared from non-water-repellent treated microfibers, illustrates the effect on water penetration resistance and absorption resistance of the absence of a water-repellent treatment, and Example 3, prepared from the same blend of fibers as Comparative Example 2, shows the effect of adding such a water-repellent treatment to batts made in the same way from the same microfiber constituents. Water readily penetrates untreated Comparative Example 2, which rapidly absorbs water to the point of saturation, in spite of its microfiber content and its relatively dense construction, and, as a result, it is incapable of providing either thermal insulation or buoyancy when it is submerged in water. Example 3, however, which is treated with a fluorocarbon anti-wetting agent, resists local water penetration at higher pressures and absorbs far less water when submerged than its untreated counterpart, Comparative Example 2, even though it is a less dense construction.

55

Neither the untreated felt of Comparative Example 4 nor its water-repellent-treated counterpart, Comparative Example 3, are particularly resistant to local water penetration under pressure or to water absorption when submerged because the water-repellent treatment is not capable by itself of providing these properties in sufficient measure to a fiber assembly in which the majority of interfiber pores are too large (because of the combination of fiber diameter and web density) to resist the ingress of water under even modest pressures. It is the combination of a microfiber construction, a web density in excess of about 3.0 lb/ft³, and treatment

with an anti-wetting agent that imparts to a fibrous insulating material the resistance to both water absorption and localized water penetration under pressure that, in turn, allows the material to provide both buoyancy and thermal insulating value in the event of water-immersion.

Example 4 of the invention illustrates the possibility of sandwiching the water-repellent-treated microfiber insulation between layers of a breathable barrier membrane to enhance its resistance to local water penetration at high pressures. The penalty for this added protection is increased weight and stiffness when dry and increased weight gain when wet due to absorption of water both by the membrane itself and within the small channels which are formed between the fibrous insulation and the membrane by the localized thermoplastic bonds. The higher percentage weight gain measured for Example 4 does not, however, represent increased absorption by the fibrous layer and does not, therefore, result in loss of insulation value of the assembly in water.

As shown in Table 2, all of the examples and comparative examples with the exception of the foam interlining material are permeable to water vapor (breathable) and are, therefore, capable of transmitting moisture vapor from perspiring skin to the environment at a rate sufficient to promote evaporative cooling and to provide greater comfort to wearers of garments containing them.

Insulating materials prepared in accordance with some of the foregoing Examples were tested to determine the effect of web density on water absorption at a pressure of 0.9 lb/in² (depth of 2 ft in water at 70°F), over periods of 1 hour, 4 hours, and 8 hours, respectively. The data points in Figs. 2 to 4 represented by the symbol "+" represent values for insulating materials prepared in accordance with the procedure of Example 4 except that there was no further consolidation of the batt after it emerged from the heat-setting oven, and no layer of breathable barrier film was added. The data points represented by the symbol "◇" represent values for insulating materials prepared according to Example 2, but due to certain processing variables the materials prepared here had different densities. The data points having the symbol "□" represent values for insulating materials essentially prepared according to the procedure of Example 1. However, the final consolidation to different densities was accomplished by heat-setting laboratory samples between aluminum plates as described for Example 2, rather than on a through-air bonder/dryer. The data points having the symbol "*" represent values for insulating materials prepared according to Example 1.

According to Figs. 2 to 4, there is an abrupt change in the amount of water absorption as the density of the batt increases. A significant decrease in this property occurs in the web density range of from about 1 to 2 lb/ft³. However, the water absorption is relatively constant as the web density increases from about 3 lb/ft³ to up to about 9 lb/ft³.

The preceding specific embodiments are illustrative of the practice of the invention. It is to be understood, however, that other expedients known to those skilled in the art or disclosed herein, may be employed without departing from the spirit of the invention or the scope of the appended claims.

Claims

1. A breathable, buoyant, thermal insulator material in the form of a cohesive fiber structure, which structure comprises an assemblage of:
 - (a) from about 50 to 100% by weight of spun and drawn polymeric microfibers having a diameter of from about 2 to 14 microns; and
 - (b) from about 0 to 50% by weight of synthetic poly-polymeric binder fibers having a diameter of from about 12 to 50 microns,
 wherein the resulting assemblage has a density of from about 3.0 to 10.0 lb/ft³, and apparent thermal conductivity k measured by the plate to plate method according to ASTM C518 with a heat flow down of less than about 0.3 Btu-in/hr-ft²-°F in the dry condition, water absorption less than 50% of its dry weight when immersed for one hour at a depth of 2 ft. in fresh water at a temperature of 70°F, a buoyancy greater than 40 lb/ft³ after immersion for one hour at a depth of 2 ft. in fresh water at a temperature of 70°F, and an intrinsic moisture vapor transfer rate at least 100 times greater than that of a closed-cell foam according to Military Specification MIL-P-12420C, Type II, Class 6.
2. The material of Claim 1, wherein the microfiber and binder fiber each independently consist of material selected from the group consisting of polyester, nylon, rayon, acetate, acrylic, modacrylic, polyolefins, spandex, polyaramids, polyimides, fluorocarbons, polybenzimidazols, polyvinylalcohols, polydiacetylenes, polyetherketones, polyimidazols, and phenylene sulphide polymers.
3. The material of Claim 1, wherein the binder fiber is a single or multi-component fiber having a moiety to

facilitate binder fiber to microfiber bonding and/or binder fiber to binder fiber bonding.

4. The material of Claim 3, wherein multi-component binder fibers are two-component fibers in a side-by-side construction or a sheath/core construction.

5

5. The material of Claim 1, wherein the microfibers or both the microfibers and binder fibers have been treated with a water-repellent.

6. The material of Claim 1, wherein the resulting assemblage has been treated with a water-repellent.

10

7. The material of Claim 5 or 6, wherein the water-repellent is selected from the group consisting of silicones, fluorochemicals, quaternary ammonium compounds, and organometallics.

8. The material of Claim 1 wherein the microfibers, the binder fibers, or the microfibers and the binder fibers are inherently water-repelling.

15

20

25

30

35

40

45

50

55

FIG. 1

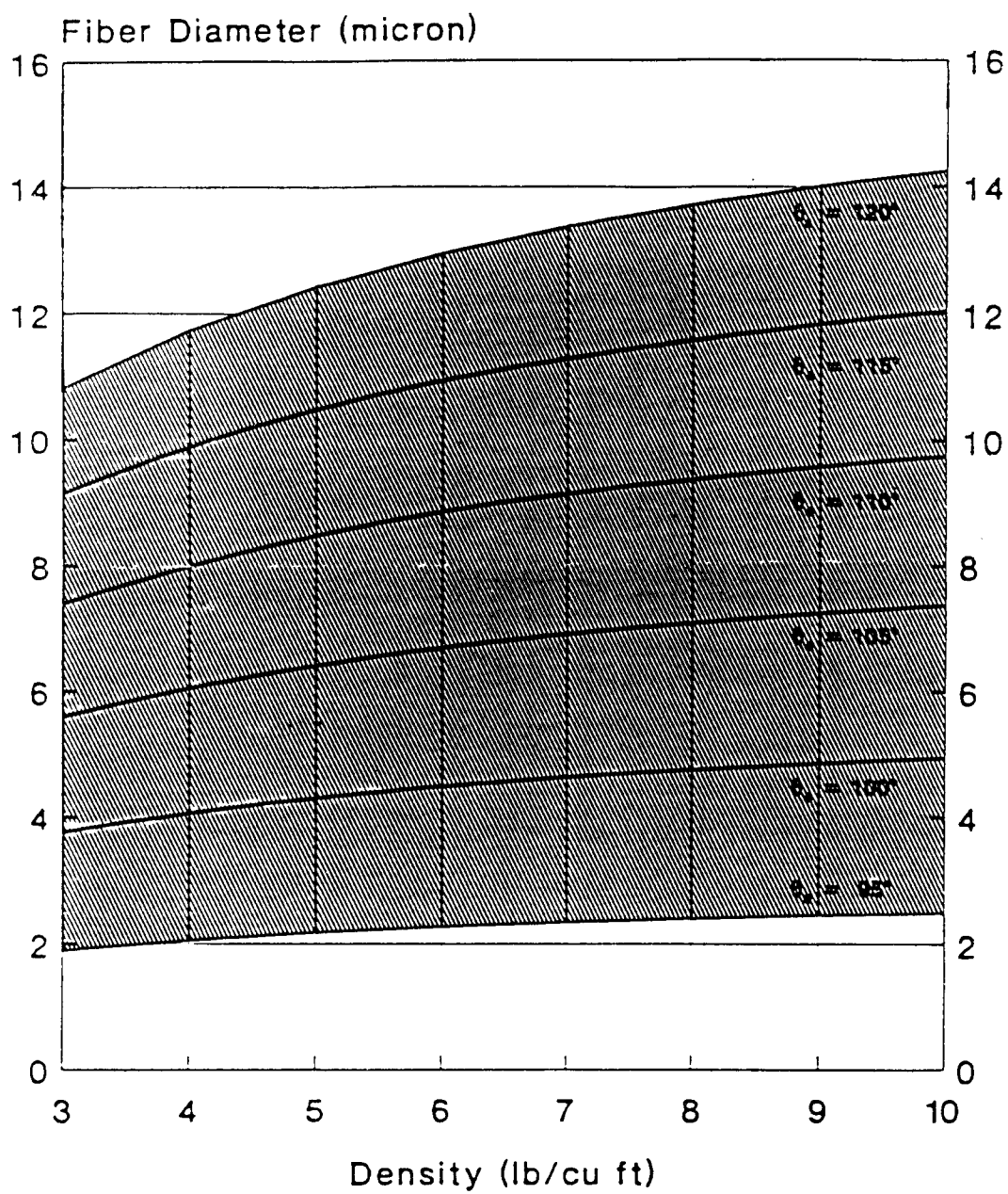


FIG. 2

After Immersion for 1 Hour in Water
at 70°F at a Depth of 2 ft (0.9 psi)

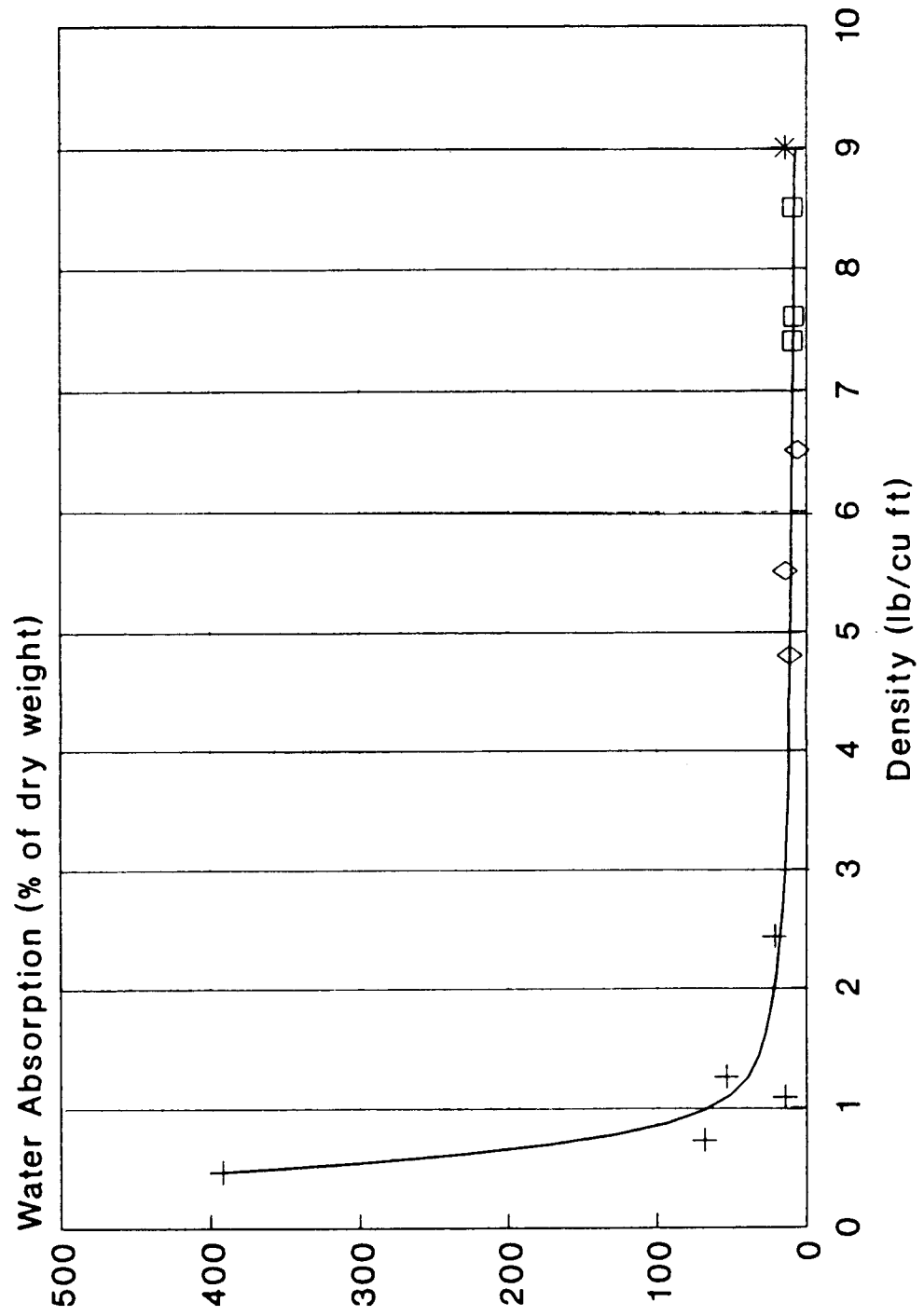


FIG. 3
After Immersion for 4 Hours in Water
at 70°F at a Depth of 2 ft (0.9 psi)

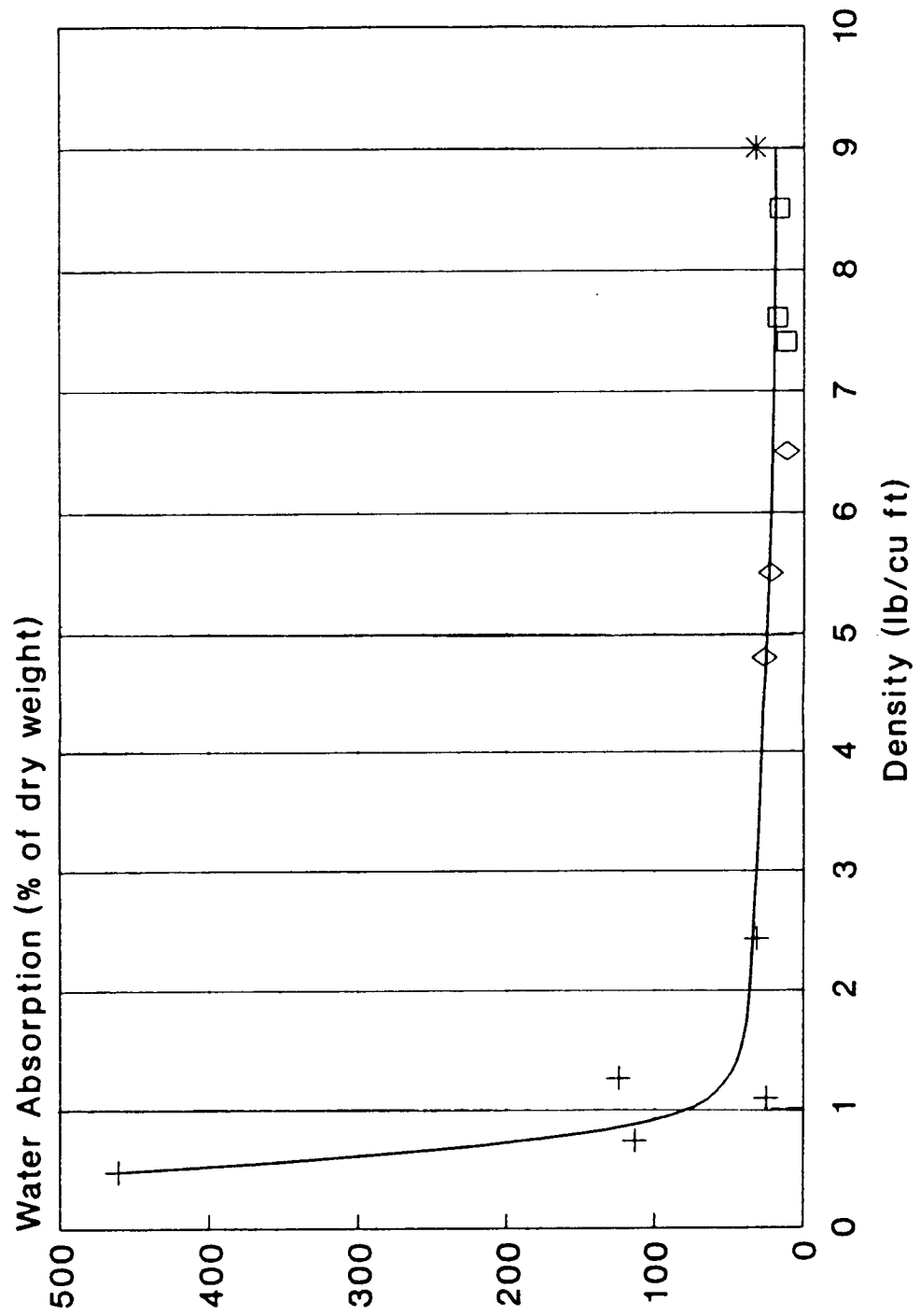
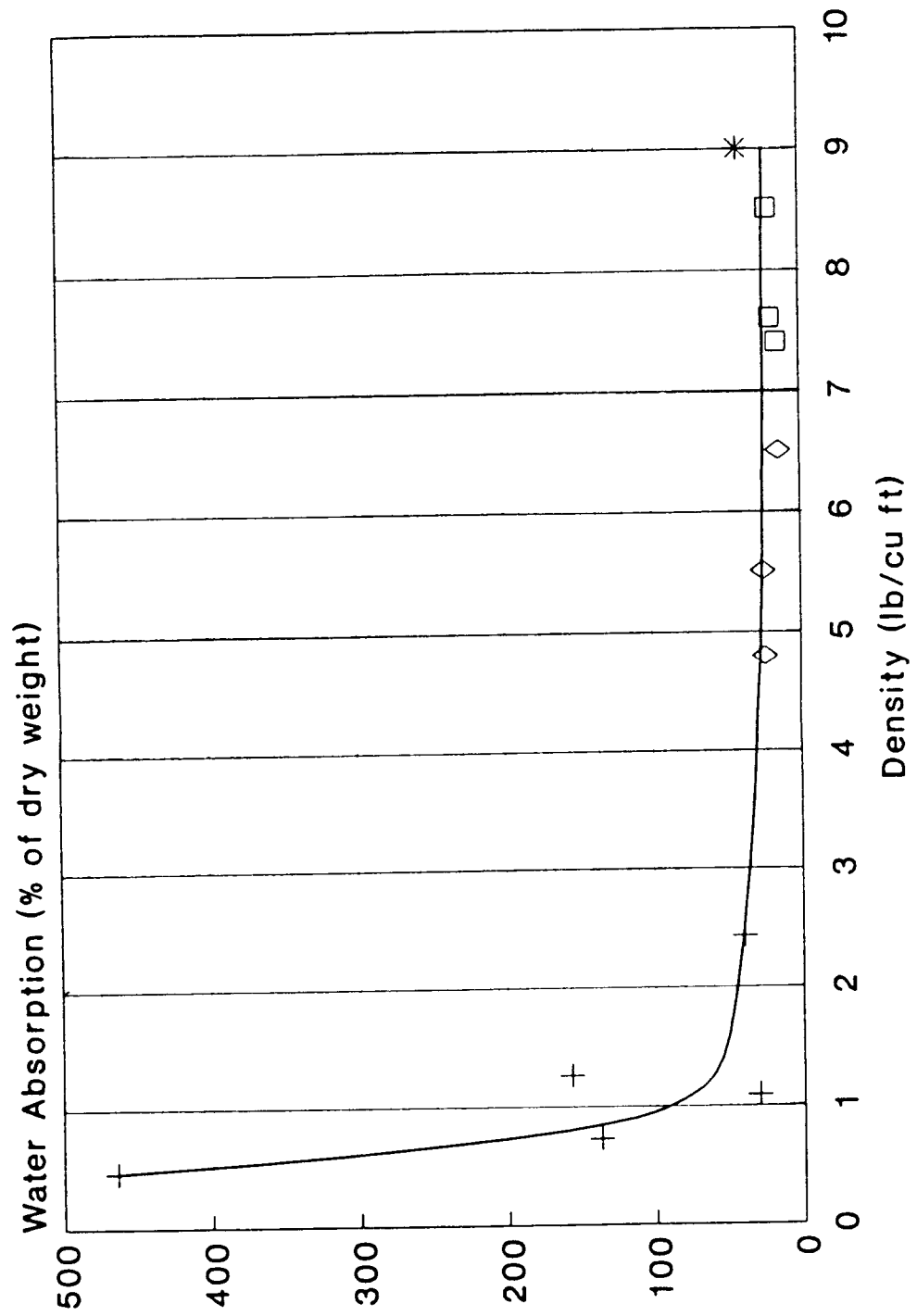


FIG. 4
After Immersion for 8 Hours in Water
at 70°F at a Depth of 2 ft (0.9 psi)





European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 93 85 0063

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
A	EP-A-0 088 191 (IMPERIAL CHEMICAL INDUSTRIES PLC.) * page 2, line 17 - page 6, line 23; example 1 *	1-5,7	D04H1/54 D04H1/42
A	US-A-4 508 775 (ADILETTA) * whole document *	1,5,8	
A	DATABASE WPI Section Ch, Week 68, Derwent Publications Ltd., London, GB; Class A, AN 68-42208Q & CA-A-828 716 (FERNANDES DJ) * abstract *	1,5,6	
			TECHNICAL FIELDS SEARCHED (Int.Cl.5)
			D04H
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 7 March 1994	Examiner VAN BEURDEN, S
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03.92 (P04C01)