

(19)



Europäisches Patentamt
European Patent Office
Office européen des brevets



(11) Publication number:

0 620 185 A1

(12)

EUROPEAN PATENT APPLICATION(21) Application number: **93304974.4**(22) Date of filing: **25.06.93**

(51) Int. Cl.⁵: **B68G 1/00**, D04H 5/08,
D02G 3/42, D02G 3/44,
D04H 1/42, D04H 3/04

(30) Priority: **16.04.93 US 48876**

(43) Date of publication of application:
19.10.94 Bulletin 94/42

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

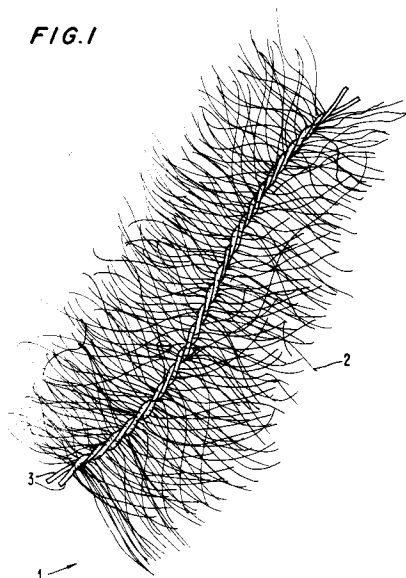
(71) Applicant: **ALBANY INTERNATIONAL CORP.**
1373 Broadway
Albany, New York 12204 (US)

(72) Inventor: **Groh, Zivile Marija**
50 Inman Street
Cambridge, Massachusetts 02139 (US)

(74) Representative: **Lowther, Deborah Jane et al**
Abel & Imray,
Northumberland House,
303-306 High Holborn
London WC1V 7LH (GB)

(54) **A thermal insulating unit and methods for manufacture thereof.**

(57) A thermal insulating unit (1) comprises an elongate support member (3) having a linear density of from about 5 to 150 mg/m and having attached thereto a generally dispersed array of discrete fine fibers (2) having diameters of from about 1.0 to 25.0 micrometers, wherein the average mass per axial unit length of fibers in the array is less than the mass per axial unit length of the support member. The units or clusters may be processed in traditional down handling equipment, an assembly of the thermal insulating units providing a very low density filling material having thermal and mechanical properties similar to that of natural down.

FIG. 1**EP 0 620 185 A1**

This invention relates to a thermal insulating unit and to methods for manufacturing such units, as well as to a thermal insulating material comprising an assemblage of such units. More particularly, this invention relates to light-weight thermal insulation systems produced using fine fibers in low density cluster assemblies.

Donovan, U.S. Patent No. 4,588,635, presents a useful discussion of the physics and mechanics of fiber assemblies and describes and claims a synthetic fiber batt thermal insulation which contains a specific intimate blend of fibers of two distinct diameters. The predominant fine microfiber species provides the thermal barrier characteristics, and the lesser proportion of large diameter macrofiber enhances the mechanical properties required in a practical insulator. The concept of providing an optimum combination of thermal and mechanical performance through the provision of a blend of fine and coarse fibers was extended in Donovan et al., U.S. Patent No. 4,992,327, which describes a bonded version of the '635 invention with even more advantageous mechanical properties.

There has been considerable activity over the past few years in the general area of high performance thermal insulation, and several other patents have issued which embody various combinations of fibers in a range of configurations, each exploiting and claiming particular advantages. Examples of such patents include U.S. Patent No. 4,118,531 to Hauser, U.S. Patent No. 4,304,817 to Frankosky, U.S. Patent No. 4,551,378 to Carey, and U.S. No. 5,043,207 to Donovan and Skelton. These patents provide a good overview of this area, which has developed to a high degree of sophistication.

One feature which most of the above patents have in common is that they provide, as an end point, a thermal insulating batt. That is, the product is available as extended sheets, and it is usually supplied to the user in roll form. This is highly beneficial to most users since the roll form is easy and convenient to handle in the layout and cutting stages of the making-up process, and the cost-effectiveness of the downstream manufacturing process is enhanced. However, it is important to realize that a considerable industry exists which is devoted to the manufacture of end-use insulating items which utilize down as a filling agent, and the manufacturing techniques employed by this traditional segment of the industry are completely different from those which utilize batts. The essential difference is that down filling is a collection of discrete individual units, and the transport and placement of large numbers of these units is normally carried out using high volume, low velocity air streams, rather than by direct manipulation of a coherent batt.

Over the past several years, enormous progress has been made in devising insulation materials based on synthetic polymeric fibers which approach or even equal the thermal performance of down, and the physical parameters which control this performance are well understood, as reflected in the above mentioned patents. There has been much less progress, however, in providing a synthetic insulator which not only exhibits the excellent thermal properties of down, but also is capable of being handled in the traditional down processing equipment. One of the above-referenced patents, U.S. No. 4,992,327, describes insulation in "cluster" form, the particular examples being small rolled balls having the same fiber characteristics and properties as the batt insulation which forms the subject of the primary claim. These clusters exhibit excellent thermal and mechanical performance, and subsequent investigations have shown that they can be processed using commercial down handling equipment. However, the clusters do not have a visual appearance which matches that of down, and they have not yet found acceptance as a viable down substitute.

Other attempts have been made to imitate the look as well as the performance of down, and some success has been claimed. U.S. Patent No. 4,418,103 describes a product and a technique for achieving this objective, in which a large number of crimped fibers are joined together at one end and are spread spherically from the joined end. Various advantageous combinations of fiber sizes and crimp densities are suggested, and the product described is similar in appearance to some down units. The thermal performance of the example described is equivalent to that of medium quality down, and the mechanical behavior is very good. The process described for the manufacture of these units does not appear to be particularly cost-effective, and there is no evidence that a commercial product made according to these claims has appeared in the U.S. market in the ten years since the patent issued.

Another attempt to provide a true "synthetic down" is reflected by U.S. Patent No. 3,892,909. Several embodiments of possible structures are described, and the principal claims describe "bodies comprising a myriad of fibers formed into a rounded configuration which is capable of being repeatedly deformed in the manner of a spring" This invention, similar to the previous one mentioned, places emphasis on achieving a rounded configuration, either cylindrical or spherical, which attempts to mimic some aspects of natural down. While this may be of value from both a performance and appearance point of view, it appears that it can only be achieved by paying a heavy penalty in terms of slow production rate, and it has not led to commercial success.

It is an object of the present invention to provide a synthetic insulator with similar thermal and mechanical behaviour to natural down.

It is a further object of the invention to provide a synthetic insulator capable of being handled in traditional down processing equipment.

5 The present invention provides a thermal insulating unit comprising an elongate support member having a linear density of from about 5 to 150 mg/m and having attached thereto a generally dispersed array of discrete fine fibers having diameters of from about 1.0 to 25.0 micrometers, wherein the average mass per axial unit length of fibers in the array is less than the mass per axial unit length of the support member.

10 The "mass per axial unit length" is measured in two distinct ways. That is, there is a first average mass per axial unit length as measured along the axes of the fine fibers and a second average mass per unit length as measured along the axes of the support members. In other words, there is a first average linear density of fine fibers as measured by the total mass of fine fibers in the array divided by the total length of fine fibers, and a second average linear density of support fibers as measured by the total mass of support members in the array divided by the total length of support members.

15 The present invention also provides a thermal insulating material comprising an assemblage of the above-mentioned thermal insulating units.

In addition, the present invention provides the use of such thermal insulating units as a low density filling material, for example, as a replacement for natural down; in particular, the present invention provides the use of such units in traditional down processing equipment to produce insulating items.

20 The present invention also provides a method of manufacturing a man-made thermal insulating cluster, which comprises the steps of:

- (a) providing a substantially planar array of dispersed fine fibers of from about 0.1 to 5.0 denier; and,
- (b) treating a linear region of the array, with or without the incorporation of additional material, so as to form an elongate support means that is attached to and disposed across the fibres, which support means

25 has a linear density of from about 5 to 150 mg/m. Furthermore, the present invention provides a method of preparing a thermal insulating unit as described above, comprising the steps of:

- (a) providing a substantially planar array of a plurality of dispersed, substantially parallel fine fibers;
- (b) treating the array of step (a) with thermal, mechanical, or chemical means or a combination thereof,
- 30 with or without the incorporation of additional material, to cause discrete, generally linear regions of attachment, adhesion, bonding, or fusion to occur within said material to form elongated support members;
- (c) cutting said material between said support members in substantially parallel lines to form elongated members; and
- 35 (d) cutting the elongated members from step (c) in linearly spaced fashion to produce discrete thermal insulating units.

In accordance with the invention, there is also provided a method of preparing discrete thermal insulating units which comprises the steps of:

- (a) preparing a substantially planar cohesive material comprising a dispersed, substantially linear array of
- 40 fibers, said cohesive material having upper and lower surfaces;
- (b) placing removable supporting surfaces in contact with the upper and lower surfaces of said cohesive material;
- (c) stitching substantially parallel linear lines on said supportive surfaces with a suitable sewing thread to cause the respective supporting surfaces to be bound to one another through the cohesive material;
- 45 (d) cutting the structure from step (c) parallel to and between the lines of stitching to form elongated members;
- (e) removing the respective supportive surfaces from the elongate members; and
- (f) cutting the elongated members from step (e) in linearly spaced fashion to produce discrete thermal insulating units.

50 The present invention further provides a thermal insulating unit obtainable by means of any of the abovementioned methods of manufacture.

The present invention provides a down-like filling material made up of an assemblage of discrete individual units, each unit having a geometric configuration designed to optimize the thermal insulating properties of the assembly. The individual units are made up of a supporting member of a predetermined

55 length, whose dimensions and mechanical properties are such that the member has sufficient rigidity to maintain its extended configuration, to which is attached an array of fine fibers whose principal function is to provide the thermal barrier properties of the assembly. The two components of the units must act cooperatively if the optimum thermal properties are to be achieved. This can be achieved if the fine fibers

form a generally dispersed array, and the distribution of fine fibers along the supporting element is generally uniform. The length of the fringe of fine fibers and the length of the support element can vary over a wide range, but there are some important limitations on the relative dimensions and proportions of the two components if an optimum assembly is required.

5 The simplest configuration which satisfies the above concept is a length of monofilament support material to which is adhesively attached a planar array of fine, more-or-less parallel fibers, with the support filament and the fibers that make up the fringe being substantially perpendicular and the support filament attachment points being located near the center line of the fringe. While this configuration is simple and symmetrical, it should not be considered as limiting, and many variations are possible which still preserve
10 the essential features of the concept.

The fine fiber array is capable of wide variation within the essential framework of this invention. One of the simplest and most direct ways of providing this array is to make use of spread multifilament tow, using a process similar to that described in U.S. Patent No. 3,423,795 to Watson, incorporated herein by reference, but it is also possible to achieve the same effect through the use of a creel or warp beam which
15 feeds individual filaments or untwisted multifilament yarns or tows through a reed in a side-by-side configuration. The essential feature that is common to these techniques is that they are capable of providing a thin layer of filaments held in a more-or-less parallel side-by-side configuration. This layer of filaments is then subsequently modified by the attachment of a multiplicity of bonding and support members which cross the array at a high angle, after which the partially bonded layer of filaments is subdivided to form a
20 number of separate sub-units, each of which consists of a finite length of bonded support member to which are attached a large number of crossing fibers and which form one of the embodiments of this invention.

The use of spread multifilament tow is a very cost-effective way of producing large quantities of the thin fiber sheet material that forms the precursor to the thermal units, and it is the preferred means of practicing the art, but under certain circumstances the other techniques are appropriate. The provision of a parallel
25 array of filamentary materials is very common in textile processing: it is found in the feed systems of weaving looms, warp knitting machines, and tufting machines, and it is also an essential component of prepreg lines for the production of impregnated yarns for composites manufacturing. All of these systems can be modified to act as the source for the fine filamentary array that provides the starting point for the production of the units according to the present invention.

30 The simple configuration described above involves a support member which is a monofilament adhesively attached to the array of fine crossing filaments. This embodiment is made by laying an adhesively coated monofilament material down in contact with the thin fiber array, so that the monofilament provides both a support and a bonding function. The actual geometrical configuration of the monofilament is not important. In its usual sense the word monofilament implies an entity with a generally circular cross
35 section, but the cross section can be of any shape, and it is possible to provide the same function with a flattened strip of polymer with a rectangular or other elongate cross section shape formed by cutting a narrow ribbon of material from a thin sheet of polymer. In this embodiment it is only necessary to have an adhesive layer on one side of the ribbon.

In the embodiments described above the monofilaments or ribbons are provided with a separate layer
40 of adhesive material, but it is possible to combine the two functions - support and bonding - into a single entity. In this embodiment a line of adhesive is laid down directly across the fine filament array from a suitable nozzle in sufficient quantity that it is capable of providing the support function in its own right when it is set, dried and cured. This is equivalent to combining the extrusion step of a melt spun filament with the laydown step and can provide a highly cost-effective way of making the product if the material type and
45 disposition are properly chosen. It is also possible to produce a bonded and supported array of fine fibers by fusing or bonding a section of the fine fiber in situ using, for example, a hot wire or an ultrasonic bonder under carefully controlled conditions. The objective is to melt and fuse an extended linear region of the fine fibers under controlled conditions so that the partially melted fibers stick together locally and the resolidified melt line has sufficient stiffness and integrity to constitute a support member. In this embodiment no
50 material additional to the fine fiber array is involved in the system and the weight penalty is minimized, but it is difficult to achieve all the mechanical requirements of the support member by this means.

In the discussion above, attention has focused on monofilament material or its analogue for the support member. This is a convenient simplification from the descriptive viewpoint, but it is not an exclusive one, and the support member can equally well be a multifilament or spun yarn, or a combination of the two. The
55 discussion has also dealt almost entirely with adhesive or other direct bonding to achieve the necessary integrity. Another way to bond the fine filament array is to use mechanical entangling to attach the support member to the fine fiber array, and this can be achieved very effectively by sewing a line of stitching across the fine fiber array. In this way the line of stitching, which may be made up of monofilament or multifilament

yarn or a combination of the two, not only provides a mechanical interlocking which holds the fine fiber array in place, it also can be made sufficiently stiff that it can act as the support member without the need for any additional adhesive. This, too, provides a mechanically efficient and cost-effective way of practicing the elements of the invention.

5 The present invention will now be described in greater detail, by way of example only, with reference to the accompanying drawings in which:

Fig. 1 is a perspective view of a thermal insulating unit constructed in accordance with the invention; and
Fig. 2 is a schematic flow chart illustrating a procedure for preparing the thermal insulating unit.

Referring to Figs. 1 and 2, a unit assembly 1 comprises an array of fine fibers 2 provided with a support
10 member 3.

The array 2 has been attached in substantially linear fashion to support member 3.

In the schematic flow chart shown in Fig. 2, material comprising substantially parallel fibers 10 is treated in step (b) to space the fibers 10 apart, and macrofibers 11 are interwoven through fibers 10 in step (c). Then, in step (d), the material is cut in the area of dotted lines 12, which are substantially parallel to
15 macrofibers 11. The assemblies 14 resulting from step (d) are cut perpendicularly, that is, perpendicular to the longitudinal axis, in step (e) to form the unit assemblies 15 shown in (f).

The materials of choice for the two components of the individual units of this invention are preferably polymeric, particularly if a thermal barrier application is contemplated, since the thermal conductivity of the materials which make up the units can be minimized by this choice. However, the concept is not limited to
20 polymeric materials, particularly for the fine fiber component, and fiber arrays of ceramic, carbon or glass materials can be used. If a polymeric assembly is required, it can be produced from any of the synthetic fiber-forming polymers in commercial use, including, without limitation, polyester, nylon, rayon, acetate, acrylic, modacrylic, polyolefins, spandex, poly-aramides, polyimides, fluorocarbons, polybenzimidazols, polyvinylalcohols, polydiacetylenes, polyetherketones, polyimidazols and phenylene sulphide polymers such
25 as RYTON. The assemblies could also be made by incorporating any of the natural fibers such as, for example, silk, cotton, wool or flax, provided that the requisite dimensional and mechanical criteria for the components are met.

The range of possible design parameters for assemblies according to the invention can be estimated by considering the geometric properties of the assemblies. Consider a unit volume of an assembly of fibers of
30 density ρ_f , denier d , and total length l : If the assembly fiber volume fraction is ν_f , then:

$$l = 9 \times 10^5 \nu_f \rho_f / d$$

and for an assembly of polyesters fibers with density $\rho_f = 1.41$ at a volume fraction $\nu_f = 0.01$, this
35 expression simplifies to:

$$l = 12690/d$$

The information inherent in this relationship is given in Table I below, which covers the entire range of
40 filament sizes that are of practical interest:

45

50

55

Table I

Dimensional Characteristics of Single-species Fiber Assemblies		
Denier	Diameter (Micrometers)	Total Length (cm)
0.1	3.2	126900
0.5	7.1	25380
1.0	10.0	12690
5.0	22.7	2538
10.0	31.6	1269
50.0	70.7	254
100.0	100.0	127
500.0	227.0	25.4
1000.0	316.0	12.7

The information in Table I is valid for unit volume of assemblies which contain fibers with a single diameter. According to the present invention, there are at least two distinct fiber species present, and this has an effect on the statistics of the assembly. The fiber units have a large number of fine fibers, which contribute the insulating properties of the material, attached to a support element, which can also be a fiber, which controls the spacial distribution of these fine fibers. In order to do this effectively, this support element must be stiffer, and hence larger in diameter than the fine-fiber array; consequently, it makes a considerable contribution to the weight of the assembly and dilutes the insulating properties of the fine-fiber array. If we are attempting to create a high performance insulator with a low value of thermal conductivity, then there is an upper limit to the amount of large denier fiber that can be tolerated. If this can be kept at less than 10% of the total fiber mass, then the thermal conductivity increase is held to an acceptable value and the assembly has adequate thermal performance. The information of Table I can be used to evaluate some features of assemblies containing both fine and coarse fibers and to determine those combinations that are practical.

Table I may be divided into two sections on the basis of diameter. Fibers falling within the range of 0.1 to 5.0 denier may be considered as insulating fibers, although the insulation performance at both ends of this range is compromised by the physics of the heat transfer process, as is explained in U.S. Patent No. 4,992,327, incorporated by reference. Filaments falling within the range of 50 to 1000 denier may be considered support fibers. Fibers with linear densities around 10 denier are not particularly effective providers either of insulation or mechanical support, and insulating assemblies containing significant components of fibers of this size exhibit mediocre all-around performance. If a mixture containing 90% of insulating fibers and 10% of support fibers is considered, then the possible combinations are shown in Table II below, together with a typical example, embodying fibers selected near the center of the available ranges. This example would have a total of approximately 20,000 cm of fine fibers attached to a total of about 10 cm of support filament contained within each cubic centimeter of fiber assembly.

Table II

Dimensional Characteristics of Mixed fiber Assemblies					
Function	Denier	Diameter (Micrometers)	Insulation Length (90%)	Support Length (10%)	Length (cm) of Fiber in Typical Combination
Insulation	0.1	3.2	114210		~20,000
	0.5	7.1	22842		
	1.0	10.0	11421		
	5.0	22.7	2284		
Transition	10.0	31.6			
Support	50.0	70.7		25	~10
	100.0	100.2		13	
	500.0	227.0		2.5	
	1000.0	316.0		1.3	

The range of these constructional parameters can be narrowed further by consideration of additional details of the structures according to the invention. One of the preferred techniques for forming the product of this invention is to attach the support fiber in a more-or-less perpendicular manner across a thin array of essentially parallel fine filaments. In order to achieve the maximum loft in the final configuration, these fine filaments should be dispersed to the maximum extent possible at the points where they attach to the supporting fiber. Optimum dispersion will occur when the fine fibers lie in a single layer at the attachment points, with the mean spacing between individual filaments being the maximum that the geometry of the system will allow. The minimum spacing occurs when this microlayer array of fine filaments is in side-by-side contact, and this represents a limiting configuration for the array. If a 2 cm length is chosen as representative for the fine fiber array, the total number of 2 cm fibers per centimeter of support filament can be calculated, as shown in Table II, and if the calculated fine fiber diameter is used to define the minimum space that a single fiber can occupy, we arrive at the minimum total length of support filament needed to satisfy the maximum dispersion requirement. Better dispersion would be achieved if the fibers were allowed to spread more than this.

It can be seen from Table III below that for fine fiber diameters in the 1.0 denier range, a fiber size that is fine enough to give good thermal properties and is at the same time large enough to be handleable by equipment designed to give a uniform spread sheet of fibers, the side-by-side configuration requires about 6 cm of support filament in each cubic centimeter of assembly, which in turn determines that the support filament can be no larger than about 200 denier. An array in which the 1.0 denier fibers are spaced apart by 1 to 2 fiber diameters will require as much as 20 centimeters of support per cubic centimeter, and according to Table III this length is not available unless the support filament is considerably smaller than about 100 denier. The need to provide a match between the space required for the array of fine fibers and the available length of the support filament effectively sets a practical upper limit to the size of the support filament. At the other end of the range an adequate level of support cannot be provided mechanically if the denier drops below the 10 denier level at which the thermal and support functions have been segregated.

From this consideration of the basic geometric parameters of the system rational selections for the range of sizes for the thermal and support elements can be made. The thermal fibers should be within the range of 0.1 to 5.0 denier, and preferably within the range 0.5 to 1.5 denier, and the support element must lie within the range 50 to 1000 denier, and preferably approximately 500 denier. If the fiber sizes show any significant digression beyond these ranges, the geometric relationships become difficult to fulfil and the thermal and mechanical performance of the assembly will be rapidly compromised.

Table III
Dimensional Characteristics of Typical Down-like Units

Function	Denier	Diameter (Micrometers)	Linear Density of Support Elements (mg/m)	Length (cm)	No. of 2 cm Lengths/ cm of Support	Side-by-Side Support Lengths
Insulation	0.1	3.2		114210	57105	18.2
	0.5	7.1		22842	11421	8.1
	1.0	10.0		11421	5710	5.7
	5.0	22.7		2284	1142	2.5
Support	50.0	70.7	5.5			25.0
	100.0	100.0	11.1			13.0
	500.0	227.0	55.0			2.5
	1000.0	316.0	111.0			1.3

The present invention will be further illustrated by means of the following examples:

Examples

Examples of down-like clusters in accordance with the present invention were prepared and their geometric, mechanical and thermal properties were evaluated. The synthetic down clusters of these particular examples were made by laying a thin uniform sheet of opened continuous filament polyester tow between two sheets of manilla paper and subsequently sewing through the paper/tow/paper assembly using parallel lines of stitching running perpendicular to the general overall direction of the filaments in the spread tow. Three different tows were used to produce the examples: Example 1 incorporated a spread tow of 0.5 denier polyester filaments; Example 2 incorporated a spread tow of 1.2 denier polyester filaments; and Example 3 incorporated a spread tow of 5.0 denier polyester filaments. In all cases the lines of stitching were made using 322 denier mercerized, cotton-covered, polyester-core sewing thread, at a stitch density of 15 to 20 stitches per inch for Example 1 and 12 stitches per inch for Examples 2 and 3. The parallel rows of stitching were spaced apart by about 33 mm in all cases.

After stitching the sandwich assemblies were cut into strips along lines located half way between the rows of stitching. The outer layers of paper were then removed from the strips to reveal long lengths of fiber fringes anchored by the lines of stitching. These fringed strips were then cut into short lengths to yield a collection of down-like clusters. The geometrical and gravimetric parameters of clusters of the three examples are given in Table IV: the measurements were made on 10 samples selected at random from the various assemblies. The information relative to the support elements (stems) was found by cutting off the fringe fibers and removing the residual fine fiber material from the lines of stitching.

Table IV
Geometrical Characteristics of Examples of Down-like Units

Example No.	Material	Length of Fine Fiber Fringe (mm)	Total Cluster Weight (mg)	Weight of Support Member (Stem) (mg)	Support Ratio (%)	Length of Support Member (Stem) (mm)	Linear Density of Cluster (mg/m)	Linear Density of Support Member (mg/m)
1	0.5 denier Polyester Tow							
	Average	33	24.3	2.9	11.9	50.3	477	59.6
2	1.2 denier Polyester Tow							
	Average	33	24.3	2.2	9.1	38.1	630	52.5
3	5.0 denier Polyester Tow							
	Average	33	31.2	2.4	7.6	46.0	674	43.4

The fine filaments in these three examples are representative of a range for the practical production of high performance insulation materials according to the invention. At linear densities significantly smaller than 0.5 denier the thermal properties of the low density fiber assemblies begin to increase because of increased radiative heat transfer; moreover, the mechanical problems associated with the production of an open more-or-less parallel array of fibers may become prohibitive. The 0.1 denier value chosen as the lower

limit of fringe fiber linear density in the tables herein represents a valid and justifiable limit for this particular concept. The fringe length (33 mm) and the length of the support element (45 mm) chosen for these examples are close to the values used in the representative calculations leading to the information that is embodied on Tables I through IV, but these values should not be considered as limiting. The fringe fiber length in the practical examples was chosen as representative of the filament length in natural down clusters, and it is well suited to the practicality of the manufacturing technique. The upper level of this parameter has not been determined, but simple order of magnitude calculations on the mechanics of deformation of fine fibers suggests that organized arrays of fine fibers (<0.5 denier) are only marginally self-supporting if the fiber length exceeds more than a few tens of millimeters.

The length of the clusters may vary. In experimental studies clusters up to 220 mm in length were investigated, but most of the work was concentrated on the range 25 to 40 mm, with the choice again driven by a desire to match the general dimensions of natural down clusters. Experience suggests that this parameter can be selected on the basis of convenience in the manufacturing process and practicality in the application stage, since there does not seem to be any fundamental physical limits to its value.

The examples of down-like materials described in Table IV have been evaluated for mechanical and thermal behavior. In general, an assembly of each of these units behaves very much like the natural down that it is intended to emulate, in that the assembly behaves in compression like a semi-coherent mass but when agitated each of the individual units is free to move with respect to its neighbor, and this provides an effective mechanism for the establishment and maintenance of a very low density assembly. The mechanical and thermal properties of these assemblies were measured under standard test conditions, and were compared with MIL-Spec down and with PRIMALOFT® insulating material, a commercial bonded batt insulator available from Albany International Corp. The test conditions are described below:

Density: The volume of each insulator sample was determined by fixing two planar sample dimensions and then measuring thickness at 0.014 kPa (0.002 lb/in²) pressure. The mass of each sample divided by the volume thus obtained is the basis for density values reported herein.

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

Apparent Thermal Conductivity was measured in accordance with the plate-sample/plate method described by ASTM Method C518. In each case the test specimen thickness was 52.9 mm (2.08 in), the test density was 8.0 Kg/m³ (0.5 lb/ft³), and the heat flow was upward with a temperature differential of 28 °C (50 °F) and a mean temperature of 23 °C (74 °F).

Compressional Recovery and Work of Compression and Recovery: Section 4.3.2 of Military Specification MIL-B-41826E describes a compressional-recovery test technique for fibrous batting that was adapted for this work. The essential difference between the Military Specification method and the one employed is the lower pressure at which initial thickness and recovered-to-thickness were measured. The measuring pressure in the Military Specification is 0.07 kPa (0.01 lb/in²) whereas 0.014 kPa (0.002 lb/in²) was used in this work.

The down used throughout the examples was actually a down/feathers mixture, 80/20 by weight, per MIL-F-43097G, Type II Class I. This mixture is commonly and commercially referred to as "down" and is referred to as "down" herein.

The three sets of samples described in Table IV were evaluated using the test methods described above. The results of the mechanical tests are given in Table V, and the results of the thermal tests are given in Table VI. Note that mechanical tests were carried out on two distinct variants of Examples 2 and 3 in which only the length of the individual units was changed; in each case the short units have a length of 25 to 40 mm and the long units have a length of 150 to 220 mm.

Table V
Mechanical Properties of Examples of Down-like Units

Example No. & Fine Fiber Denier	Unit Length (mm)	Minimum Density of Assembly (Kg/m ³)	Compression Recovery (%)
1 (0.5 denier)	25-40	5.13	105
2 (1.2 denier)	25-40 150-220	4.64 4.81	117 110
3 (5.0 denier)	25-40 150-220	4.81 4.64	120 119
Down	Approximately 25	3.85	102
PRIMALOFT Batt	Infinite Extent	6.57	98

The most noticeable feature of these results is the low minimum density and the higher compressional recovery of the downlike clusters compared with the PRIMALOFT batt, which represents good performance for fine fibers in a batt configuration. The low minimum density of the new down-like product is attributable directly to the fact that the assembly is made up of a large number of discrete, individual units which are free to move independently when they are agitated, and this permits the establishment of a very low density

assembly, exactly as is the case with down. The minimum density achieved in these examples of the new units is not quite as low as that which is achievable with down, but there is no doubt that this property could be fine-tuned by manipulation of the geometric parameters of the units. The PRIMALOFT batt contains a blend of fibers very similar to that found in Example 1, but the fibers making up the PRIMALOFT assembly are effectively bonded together to create an integral entity and this bonding, while providing excellent mechanical stability against disruptive influences, acts to prevent the establishment of a low density condition by unassisted recovery or by agitation. Another direct manifestation of the advantages of the ability of the new configuration is the high values of compressional recovery that are given in Table V. In this case the superiority of the examples over both PRIMALOFT batt and down is clear, and the values of compressional recovery that are reported in this table are extraordinarily high.

The thermal behavior of the examples is presented in Table VI, which also gives comparison data for samples of batt made from 100% of the same fiber types as were used in the fine fiber fringes for the various examples of the invention. This permits a direct evaluation of the deleterious thermal effect of the presence of the support element that was referred to in an earlier section, and it is clear that the percentage increase in thermal conductivity has been held close to the 10% level that was judged to be acceptable. In addition, thermal data is also given for the down sample of Table VI as comparison, and it can be seen that the thermal conductivity of the fine fiber sample is quite similar to that of down and that the thermal behavior is rapidly compromised if the diameter of the fringe fiber is increased. This finding is in complete agreement with the findings of previous investigations of this phenomenon as reported in U.S. Patents Nos. 4,588,635 and 4,992,327 and emphasizes that the ultimate in thermal barrier performance will only be obtained if fine fibers are used for the fringe. In many cases experience has shown that the mechanical performance of fiber assemblies is diminished as the fiber diameter decreases, but this does not seem to be a significant feature of the assemblies of the new configurations, as Table V demonstrates. The recovery from compression is certainly improved as the fiber diameter increases, but even at the smallest diameters the compressional recovery is excellent. Accordingly, the most advantageous combination of thermal and mechanical performance for these units appears to be associated with fiber at the fine end of the diameter range and the preferred embodiment would make use of fibers around 0.5 denier.

Table VI

Thermal Properties of Examples of Down-like Units		
Sample	Apparent Thermal Conductivity (W/m. K°)	Percentage Increases In Conductivity Attributable to Support Member
#1 (0.5 denier) Comparison 100% 0.5 denier Fiber	0.040 0.037	6.9
#2 (1.2 denier) Comparison 100% 1.2 denier Fiber	0.044 0.042	5.5
#3 (5.0 denier) Comparison 100% 5.0 denier Fiber	0.060 0.054	10.3
Down	0.039	

Claims

1. A thermal insulating unit comprising an elongate support member having a linear density of from about 5 to 150 mg/m and having attached thereto a generally dispersed array of discrete fine fibers having diameters of from about 1.0 to 25.0 micrometers, wherein the average mass per axial unit length of fibers in the array is less than the mass per axial unit length of the support member.
2. A thermal insulating unit as claimed in claim 1, wherein the support member is a synthetic polymeric monofilament.
3. A thermal insulating unit as claimed in claim 1, wherein the support member is a narrow strip of a polymeric material.

4. A thermal insulating unit as claimed in claim 1, wherein the support member is a polymeric multifilament or spun staple yarn or combination thereof.
- 5 5. A thermal insulating unit as claimed in claim 1, wherein the support member is formed by a line of sewing or stitching.
6. A thermal insulating unit as claimed in claim 1, wherein the support member is a narrow strip of woven fabric.
- 10 7. A thermal insulating unit as claimed in claim 1, wherein the support member is a line of adhesive.
8. A thermal insulating unit as claimed in claim 1, wherein the support member is a narrow strip of non-woven fabric.
- 15 9. A thermal insulating unit as claimed in claim 1, wherein the support member is formed by fusing or bonding a section of the dispersed fiber array.
10. A thermal insulating unit as claimed in any one of claims 1 to 9, wherein the fine fiber array is polymeric in nature.
- 20 11. A thermal insulating unit as claimed in any one of claims 1 to 9, wherein the fine fiber array is carbonaceous or ceramic in nature.
12. A thermal insulating material comprising an assemblage of thermal insulating units as claimed in any one of claims 1 to 11.
- 25 13. A method of preparing a thermal insulating unit as claimed in claim 1, which comprises the steps of:
 - (a) providing a substantially planar array of a plurality of dispersed, substantially parallel fine fibers;
 - (b) treating the array of step (a) with thermal, mechanical, or chemical means or a combination thereof, with or without the incorporation of additional material, to cause discrete, generally linear regions of attachment, adhesion, bonding, or fusion to occur within said material to form elongated support members;
 - (c) cutting said material between said support members in substantially parallel lines to form elongated members; and
 - 30 (d) cutting the elongated members from step (c) in linearly spaced fashion to produce discrete thermal insulating units.
14. A method as claimed in claim 13, in which the dispersed array of substantially parallel fibers is provided by a spread multifilament tow.
- 40 15. A method as claimed in claim 13, in which the dispersed array of substantially parallel fibers is provided by a number of low twist yarns or tows in close proximity.
16. A method as claimed in claim 13, in which the dispersed array of substantially parallel fibers is provided from a warp beam or creel.
- 45 17. A method of preparing discrete thermal insulating units which comprises the steps of:
 - (a) preparing a substantially planar cohesive material comprising a dispersed, substantially linear array of fibers, said cohesive material having upper and lower surfaces;
 - 50 (b) placing removable supporting surfaces in contact with the upper and lower surfaces of said cohesive material;
 - (c) stitching substantially parallel linear lines on said supportive surfaces with a suitable sewing thread to cause the respective supporting surfaces to be bound to one another through the cohesive material;
 - 55 (d) cutting the structure from step (c) parallel to and between the lines of stitching to form elongated members;
 - (e) removing the respective supportive surfaces from the elongate members; and

(f) cutting the elongated members from step (e) in linearly spaced fashion to produce discrete thermal insulating units.

5

10

15

20

25

30

35

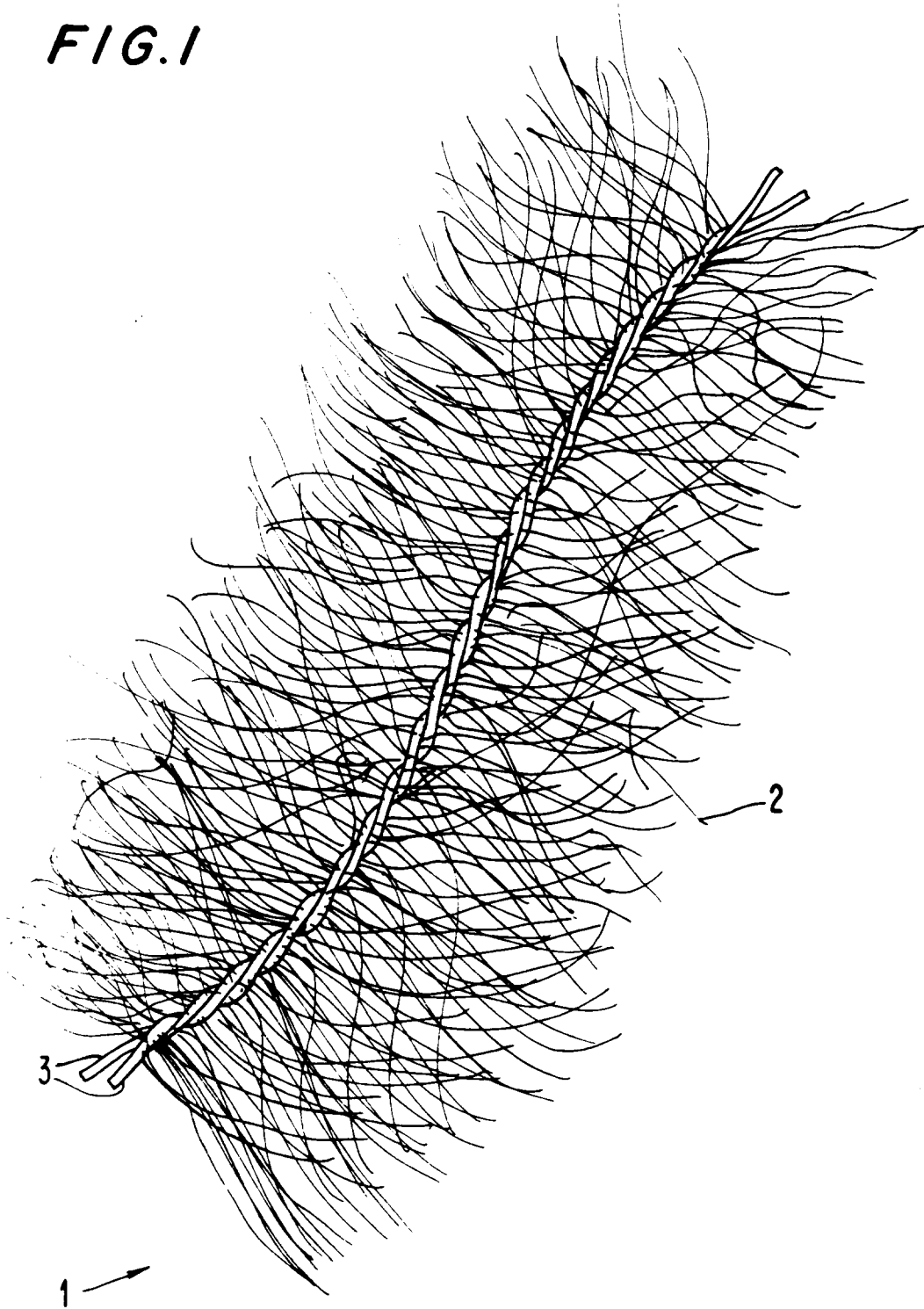
40

45

50

55

FIG. 1



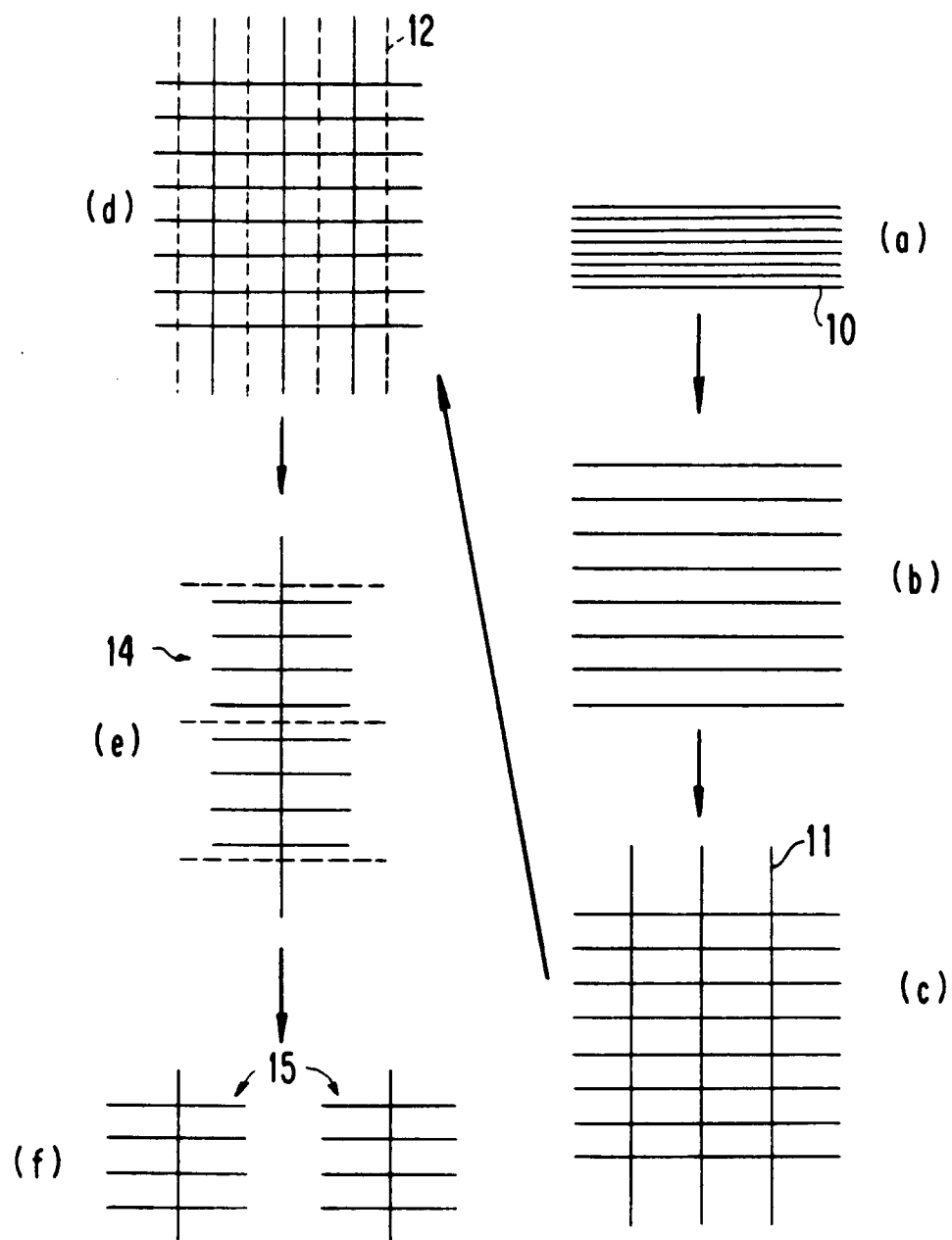


FIG. 2



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 93 30 4974

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)
Y X A	US-A-3 715 878 (CHARLES W.KIM) * the whole document * ---	1 13, 17 2-10	B68G1/00 D04H5/08 D02G3/42 D02G3/44 D04H1/42 D04H3/04
Y,D	US-A-4 588 635 (JAMES G.DONOVAN) * abstract; claims; examples * ---	1	
X A	WO-A-78 00012 (RHONE-POULENC) * the whole document * ---	13 1-10, 14-17	
A	US-H-T869020 (CHARLES W.KIM) * the whole document * ---	1-10, 14-17	
A	CH-A-358 015 (VEB) * the whole document * ---	1-8, 13, 14	
A	FR-A-2 220 606 (ETABISSEMENTS HUARD) * the whole document * ---	1, 9, 10, 13-17	TECHNICAL FIELDS SEARCHED (Int.Cl.5) B68G D04H D02G
A,D	US-A-4 992 327 (JAMES G.DONOVAN) * the whole document * ---	1-10, 13-17	
A,D	US-A-5 043 207 (JAMES G.DONOVAN) * abstract; claims * -----	1-10	
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 14 July 1994	Examiner Durand, F
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			