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Hunt

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(54) **APPARATUS FOR MOLDING THREE-DIMENSIONAL OBJECTS**

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(73) Assignee: **The United States of America as represented by the Secretary of Agriculture**, Washington, DC (US)

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(51) **Int. Cl.**[7] **B28B 1/52**

(52) **U.S. Cl.** **425/80.1**; 425/85; 425/405.1; 264/87; 162/227

(58) **Field of Search** 425/84, 85, 405.1, 425/470, 80.1; 264/87, 86; 162/223, 226, 227, 296, 382

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(57) **ABSTRACT**

A method of making a three-dimensional object from fibers includes attaching a mold made at least in part of elastomeric material to a porous support. The mold comprises a first mold member defining at least one channel in fluid communication with the porous support. Each channel has within it at least one second mold member. A mixture of fibers and fluid carrier is poured onto the mold. Thereafter, a pressure differential is created across the mold to create a flow of the mixture toward the porous support via the second mold members. This flow causes the fluid carrier to pass through the porous support, thus depositing the fibers within the recessed parts of the second mold members in the mold. Thereafter, the mold is compressed sufficiently to deform the mold and to provide uniform, normal pressure to the fibers which have been deposited in the second mold members.

42 Claims, 8 Drawing Sheets

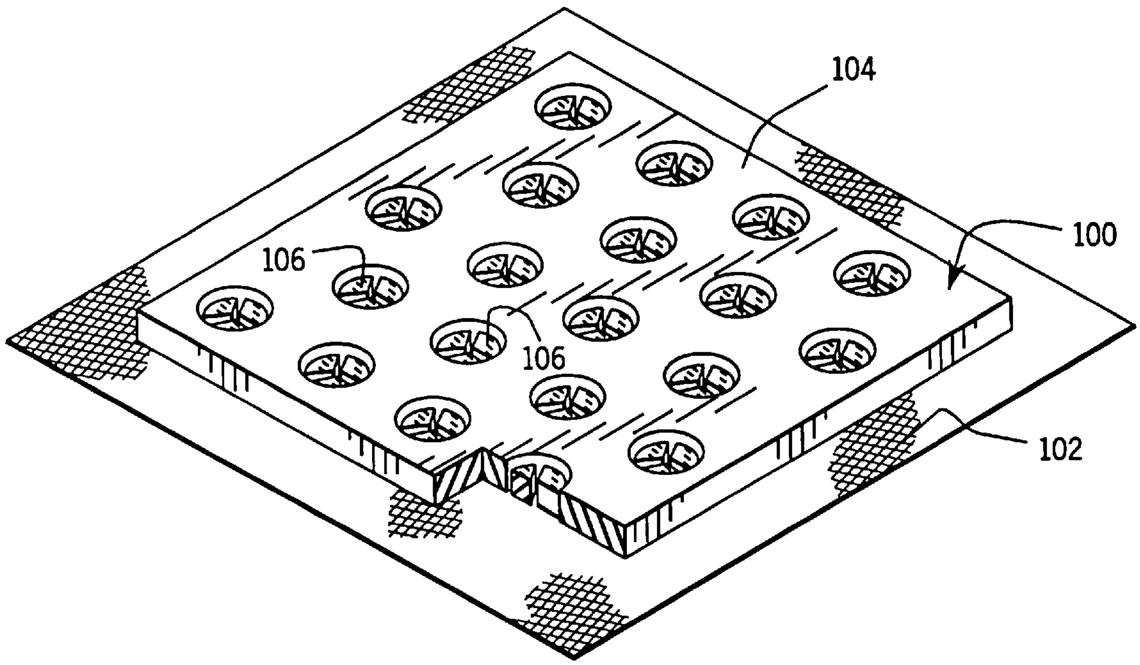
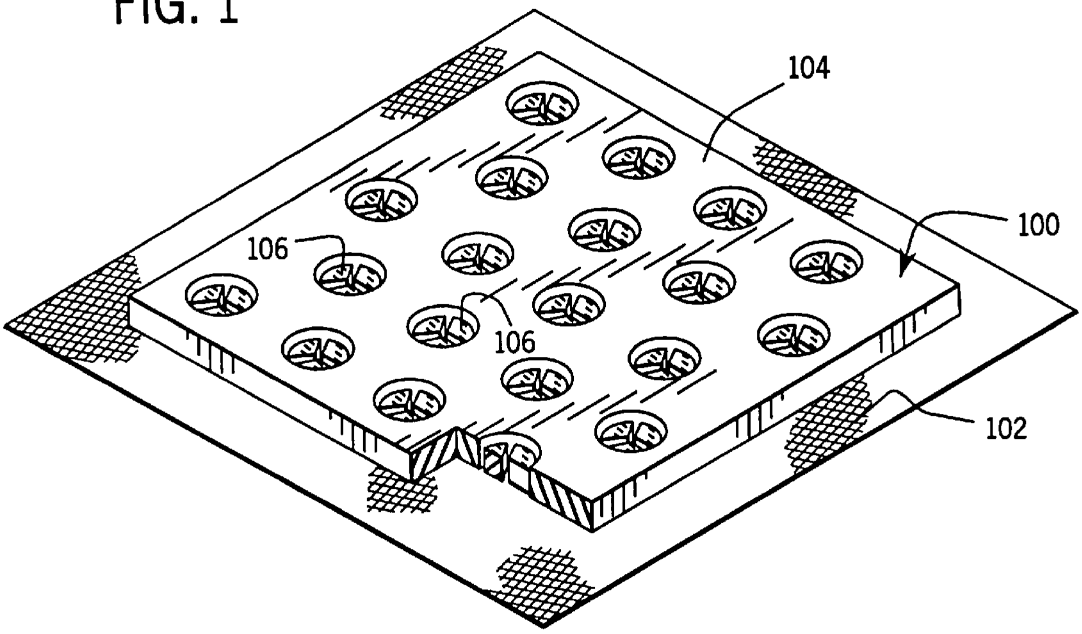


FIG. 1


104
100
106
106
102

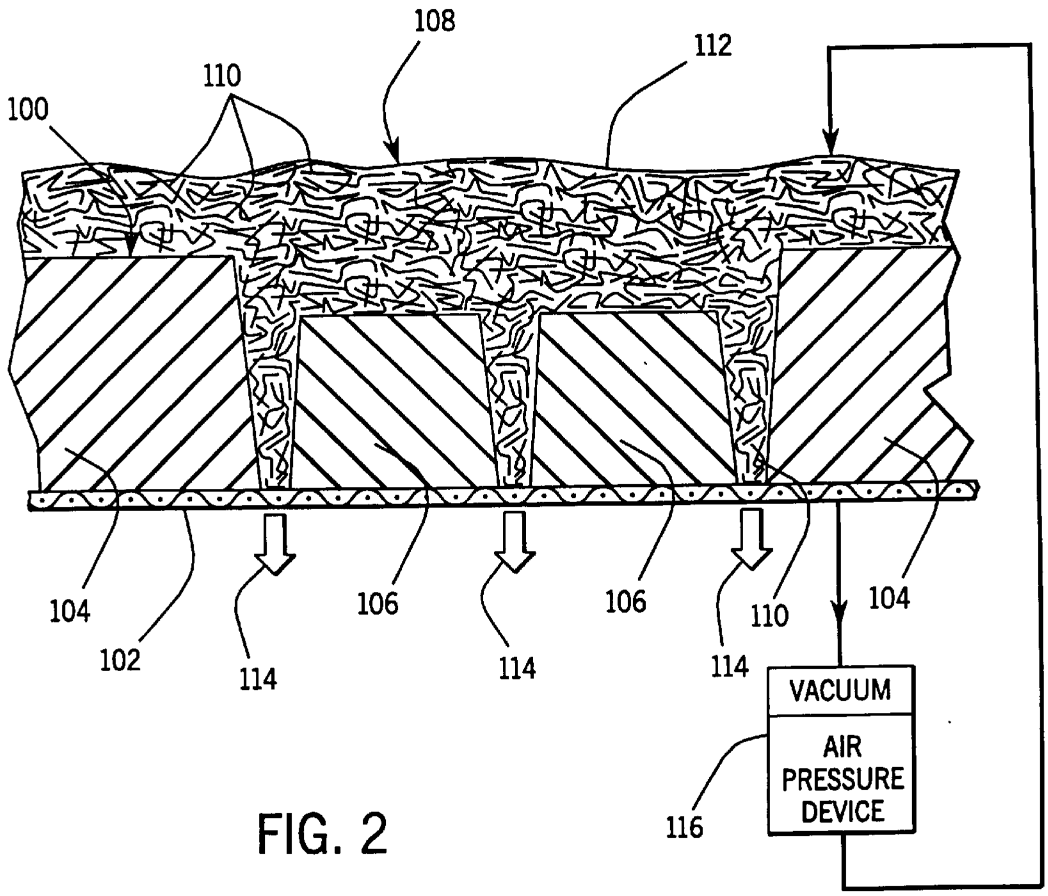

108
112
110
100
104
102
114
106
114
106
114
110
104
VACUUM
AIR
PRESSURE
DEVICE
116

FIG. 2

FIG. 3

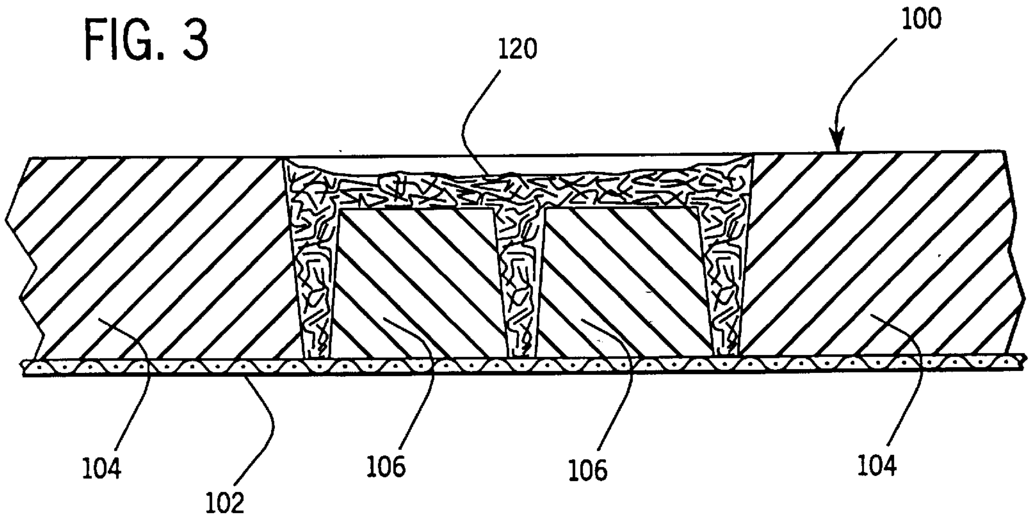


FIG. 4

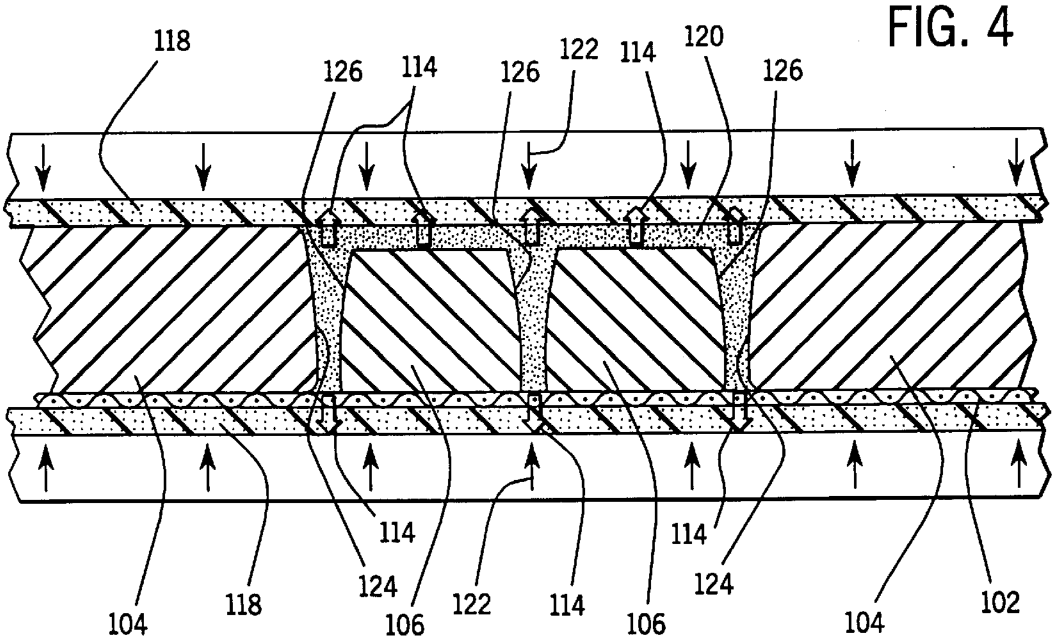


FIG. 5

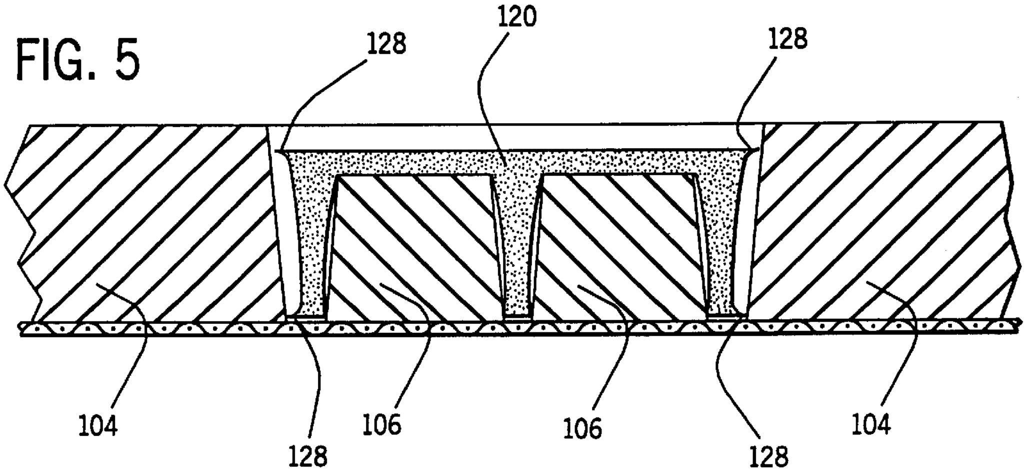


FIG. 6

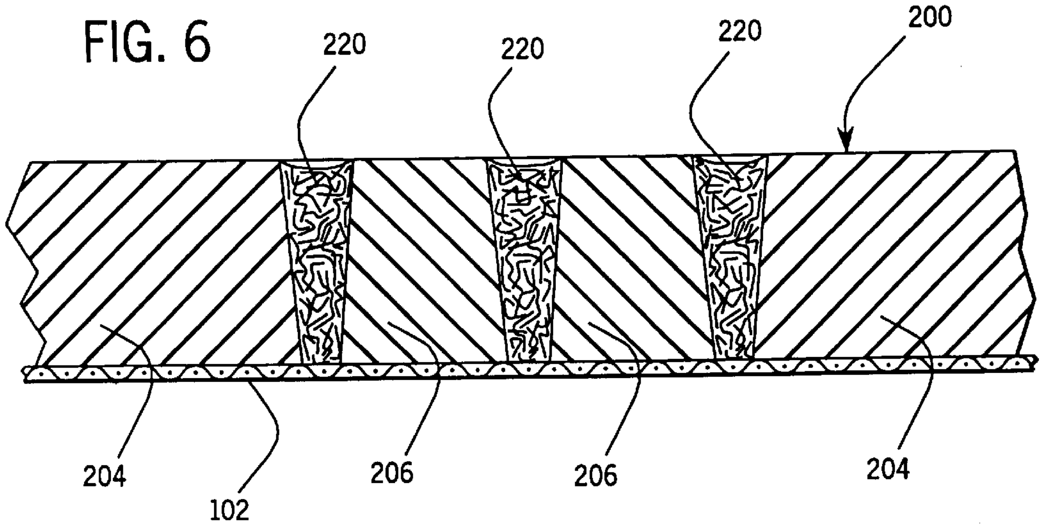


FIG. 7

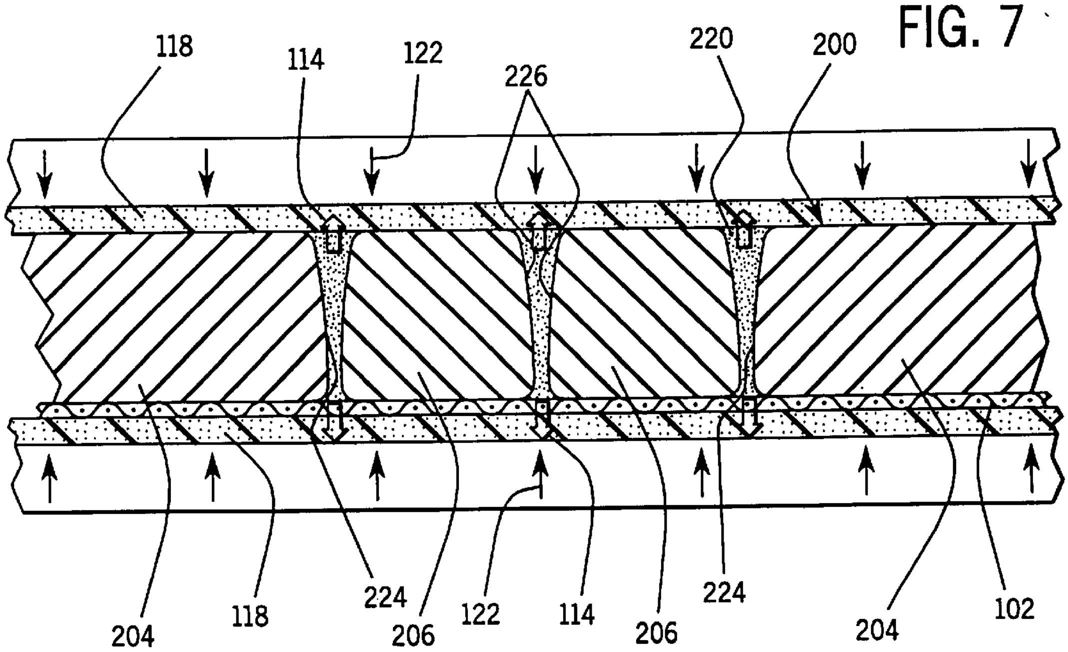


FIG. 8

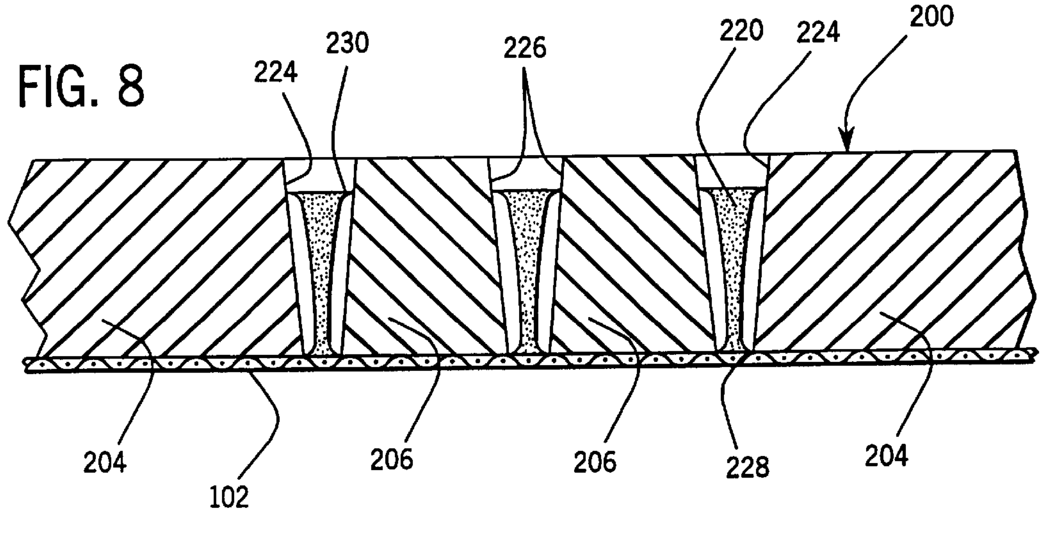


FIG. 9

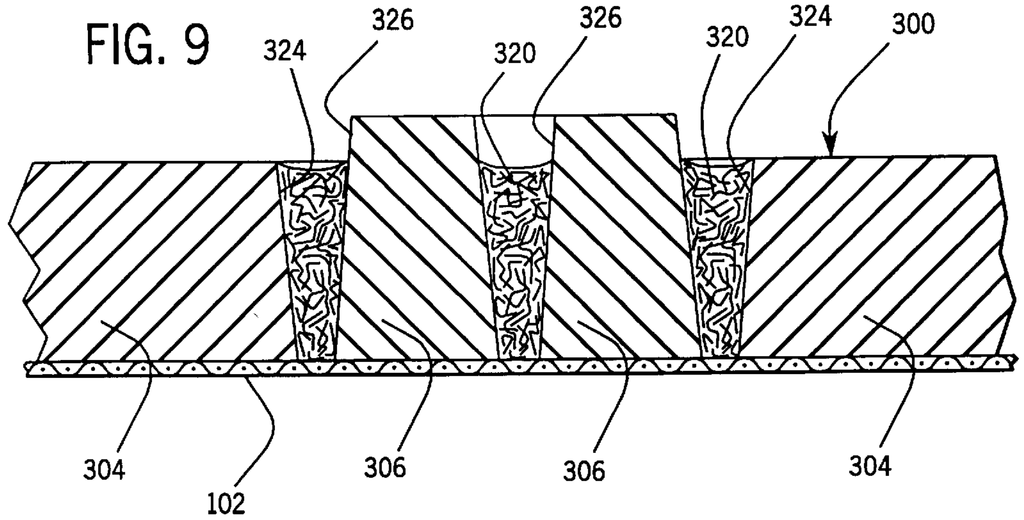


FIG. 10

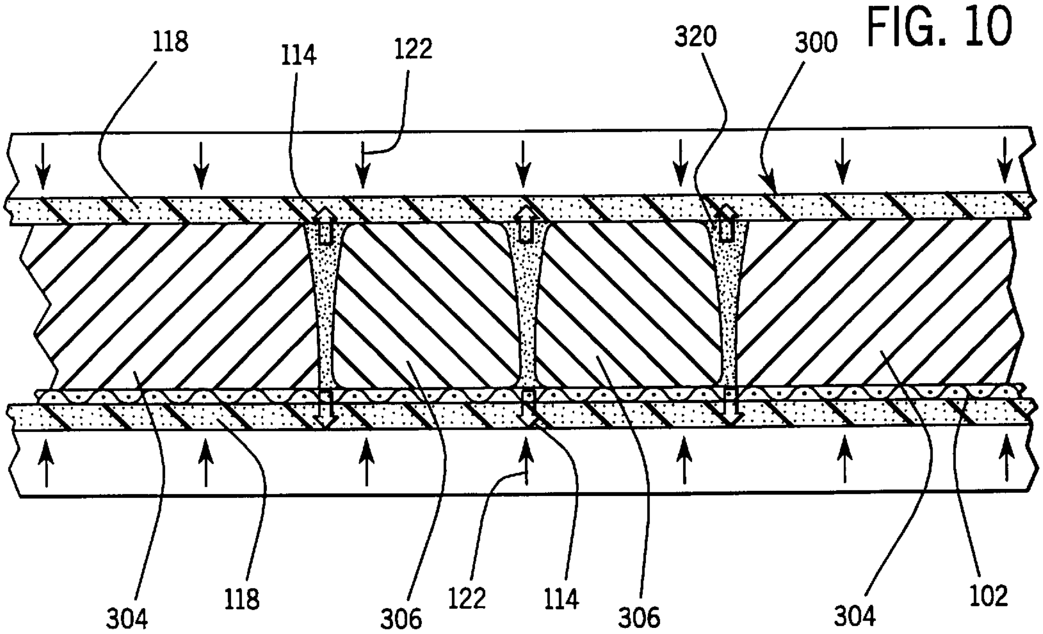


FIG. 11

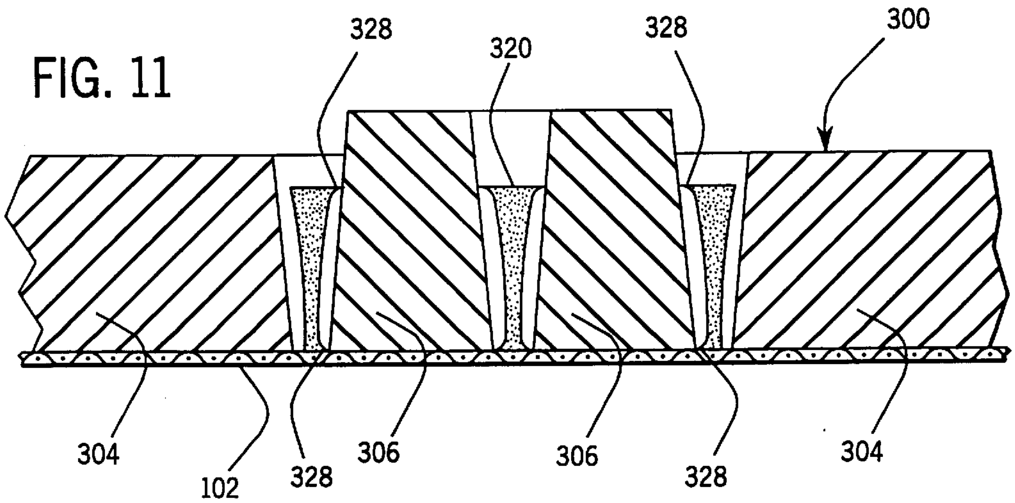


FIG. 12

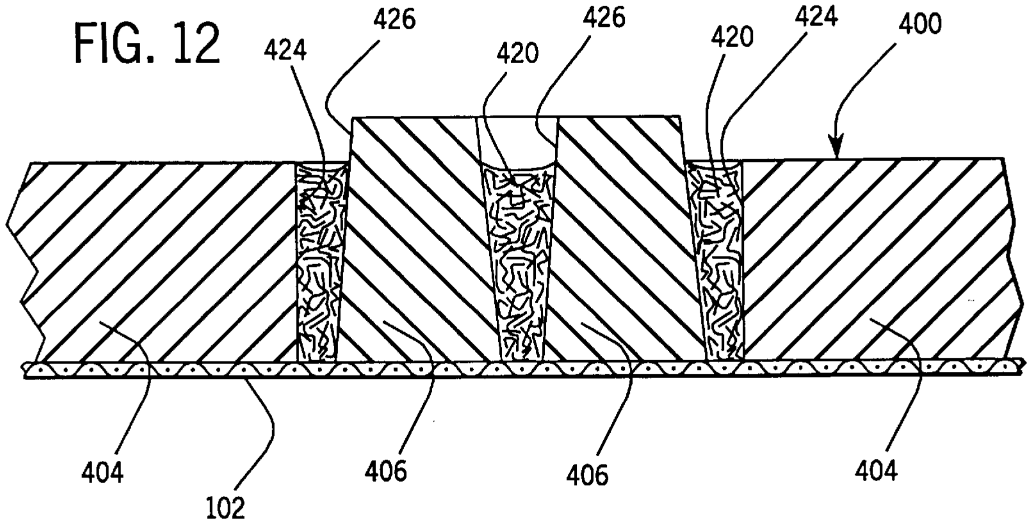


FIG. 13

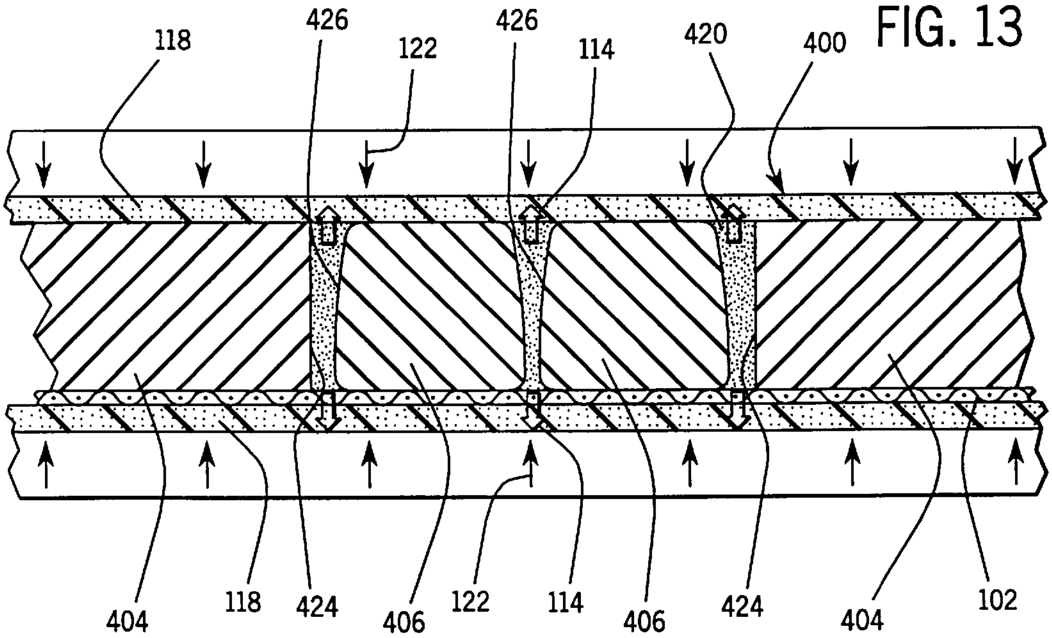


FIG. 14

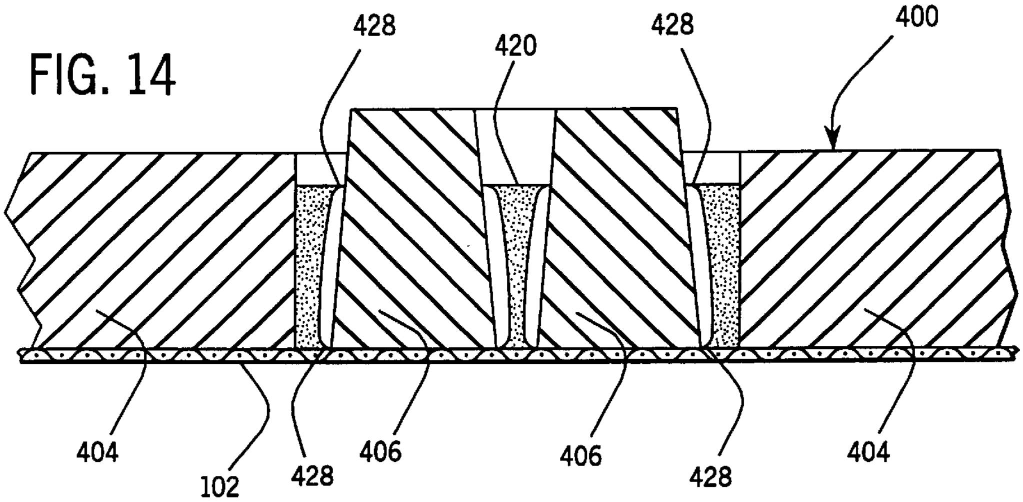


FIG. 15

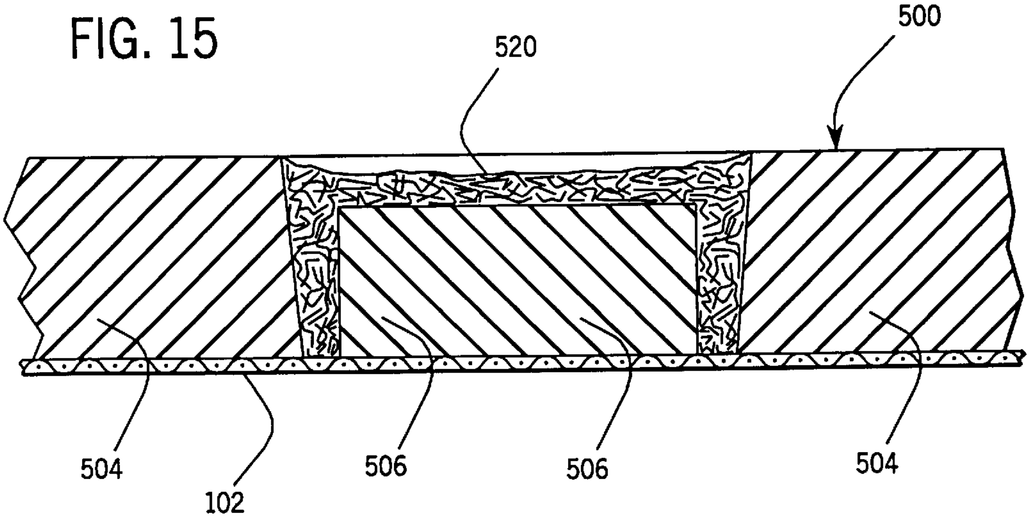


FIG. 16

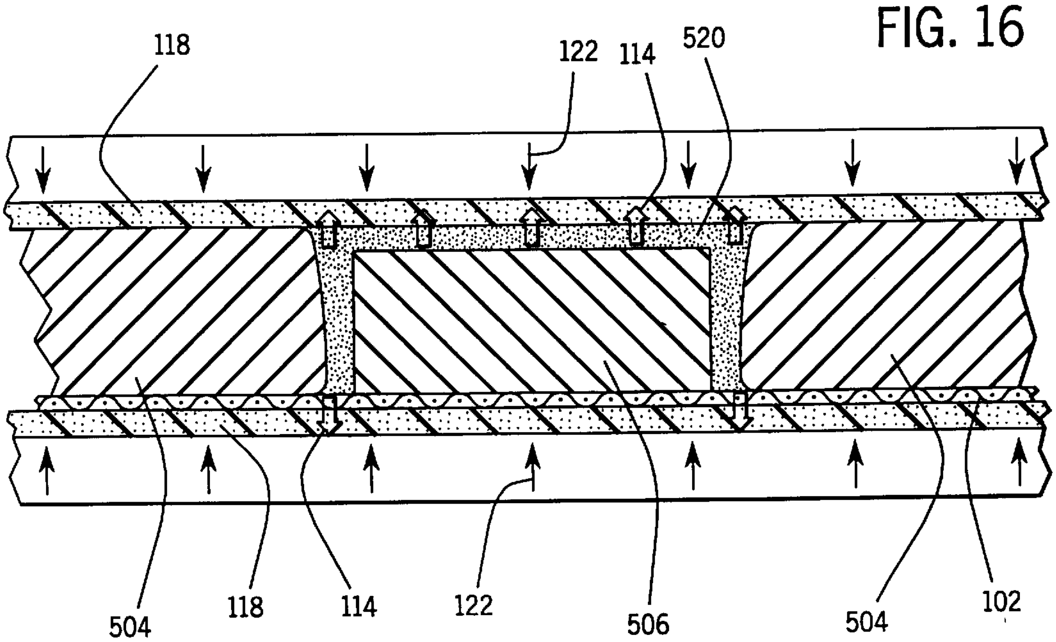
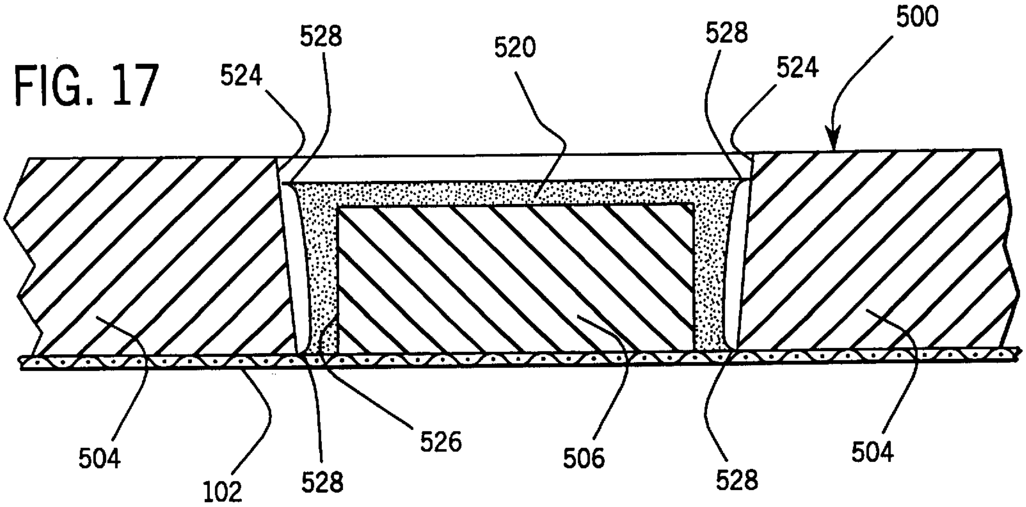


FIG. 17



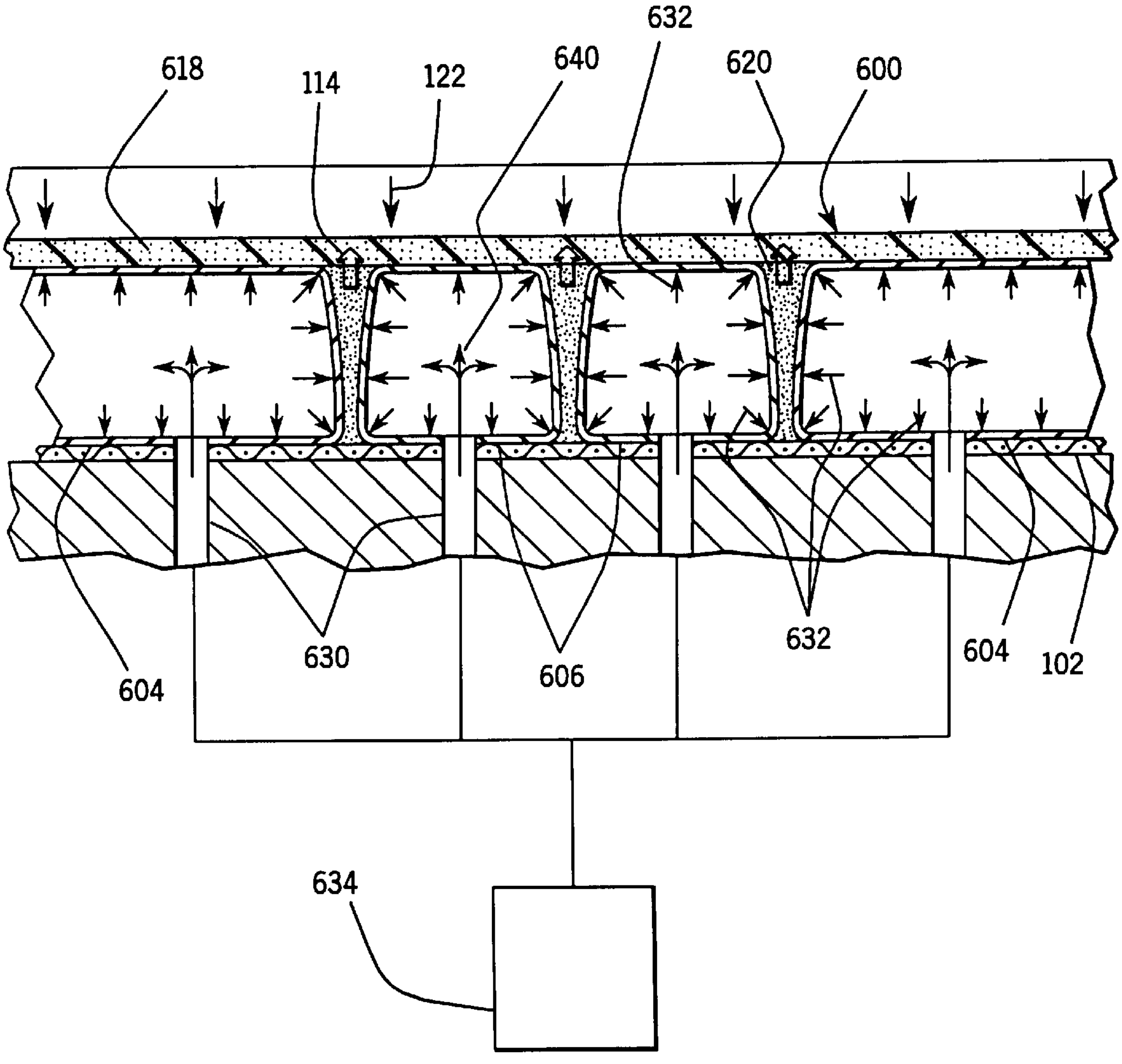


FIG. 18

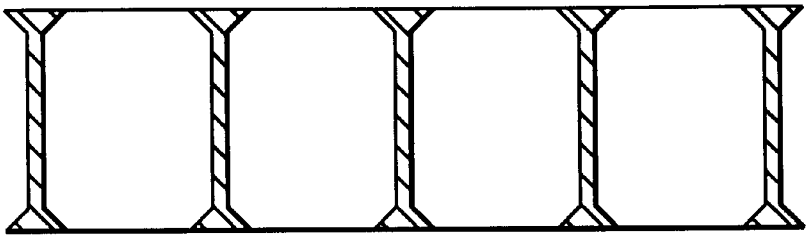


FIG. 19A

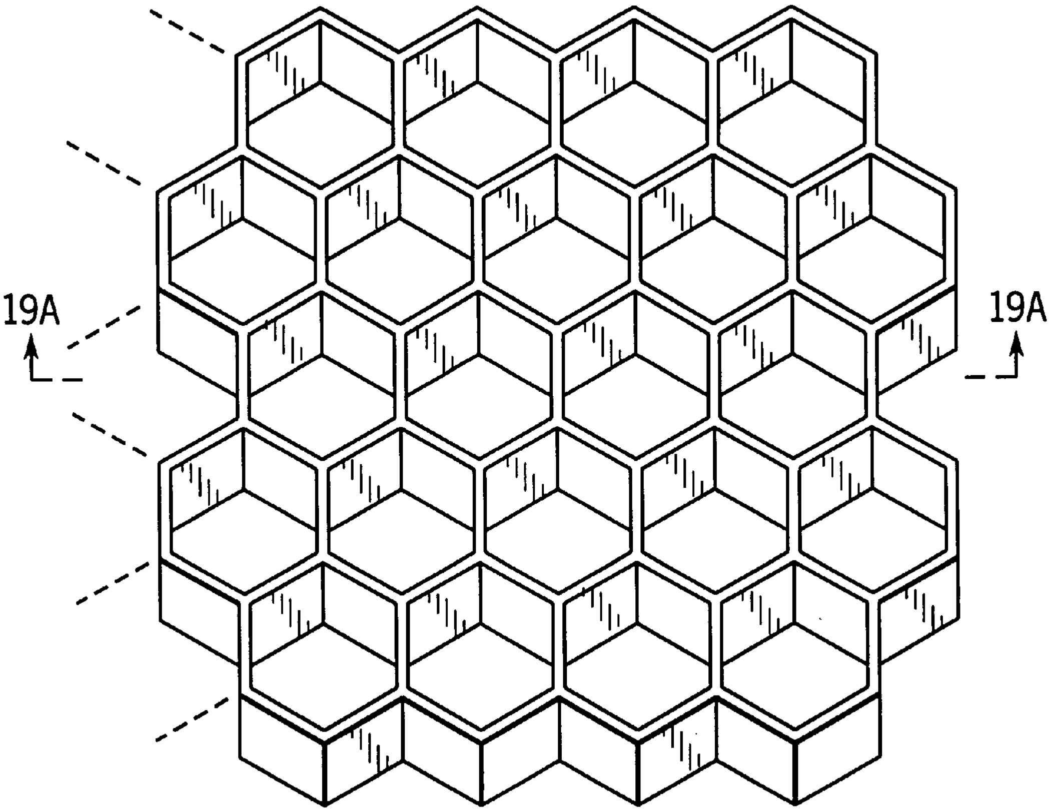


FIG. 19B

APPARATUS FOR MOLDING THREE-DIMENSIONAL OBJECTS

TECHNICAL FIELD

The present invention relates generally to the production of three-dimensional objects from fibers, and, more specifically, the present invention relates to a method and apparatus for compressing fibers in a mold made at least in part of an elastomeric material to create a three-dimensional object.

BACKGROUND OF THE INVENTION

Generally, fiber structures of the kind used for cushioning and packaging (for example, pulp packaging, peanuts, egg crates and the like) are formed from cellulose fibers using a wet forming process. The product is formed on a solid, rigid mold that is covered with a screen material on all of its surfaces. The strength of the resultant structure is due to entanglement of the fibers and hydrogen bonding. Some strength-enhancing chemical or resin may also be added.

The strength resulting from fiber entanglement depends upon the type and length of the fibers used. Bonding of cellulosic fibers depends on fiber-to-fiber contact, which is increased with increased compression of the fiber mat. Current industry use of compression of pulp-molded articles ranges from no compression to compression by mating male and female rigid molds that have close tolerances for higher consolidation of the fibers.

If the structure has any three-dimensional parts, the sides of the structure must have a draft angle, so that the compression force of the mating molds has a component force on the sides of the mold normal to the structure being formed. If the sides of the mold are substantially vertical, the mating part is not able to apply a compression force component normal to sides of the structure.

The structural performance of a pulp-molded article can be enhanced by fiber addition or by increased bonding. Increased bonding may allow for a reduction of fiber content for a given performance need. U.S. Pat. No. 4,702,870, issued to Setterholm et al. for a "Method and Apparatus for Forming Three Dimensional Structural Components from Wood Fiber" and U.S. Pat. No. 5,277,584, issued to Hunt for "Methods and Apparatus for Making Grids from Fibers" illustrate several methods and devices for forming products from the materials herein addressed.

It is an object of the invention to provide a method and apparatus for making three-dimensional structures from fibers for various structural uses.

It is another object of the invention to provide a method and apparatus for making three-dimensional structures from fibers which utilizes compressive forces normal to the surfaces of the object being formed as a result of the composition of the mold.

It is still another object of the invention to provide a method and apparatus for molding three-dimensional objects from fibers which permits the fabrication of such objects in a wide variety of structural configurations.

It is still another object of the invention to provide a method and apparatus for manufacturing three-dimensional objects from fibers where the objects consist of a plurality of interconnected ribs without integral surfaces covering the ribs.

It is a further object of the invention to provide three-dimensional objects manufactured from fibers where the objects consist of a plurality of interconnected ribs without integral surfaces covering the ribs.

It is a still further object of the invention to provide a method and apparatus for making a three-dimensional object from fibers permitting the cost effective use of both cellulosic and non-cellulosic fibers to create such three-dimensional objects.

DISCLOSURE OF THE INVENTION

These and other objects of the present invention are accomplished as explained in the detailed description of the embodiments of the invention in connection with the Figures.

Generally, however, the objects of the invention are accomplished in a method of making a three-dimensional object from fibers which includes attaching a mold made at least in part of elastomeric material to a porous support. The mold comprises a first mold member defining at least one channel in fluid communication with the porous support. Each channel has within it a second mold member structure. A mixture of fibers and fluid carrier is poured onto the mold. Thereafter, a pressure differential is created across the mold to create a flow of the mixture toward the porous support via the channels containing the second mold members. This flow causes the fluid carrier to pass through the porous support, thus depositing the fibers within the recessed portions and generally across the top of the second mold members in the mold. Thereafter, the mold is compressed sufficiently to deform the mold and to provide substantially uniform pressure to the fibers which have been deposited in and on top of the second mold members. In a number of the embodiments, the first mold member and second mold members have different relative heights to achieve various structural features in the formed object. Moreover, the mold may be made of different materials to provide a variety of structural features in the formed object. The apparatus of the present invention is the mold described above.

The invention further provides three-dimensional objects manufactured from fibers where the objects consist of honey comb-like structure including a plurality of interconnected ribs without integral surfaces covering the ribs. Additionally, the invention provides such objects where the ribs include integrally-molded flanges to impart strength and other desirable structural characteristics to the objects.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of an embodiment of the present invention;

FIG. **2** is a cross-sectional view of the embodiment of FIG. **1** depicting a fiber and fluid carrier mixture poured onto the mold of the invention;

FIG. **3** is a cross-sectional view of the embodiment of FIG. **1** depicting fibers deposited in the recessed portions of the mold formed around the second mold members, after application of a pressure differential across the mold and porous support;

FIG. **4** is a cross-sectional view of the embodiment of FIG. **1** depicting compression of the mold and second mold members by a press and the resulting consolidation of the fibers;

FIG. **5** is a cross-sectional view of the embodiment of FIG. **1** depicting the consolidated formed fiber object in the mold of the present invention;

FIG. **6** is a cross-sectional view of a second embodiment of the invention depicting fibers deposited in the recessed portions of the mold formed around the second mold members, after application of a pressure differential across the mold and porous support;

FIG. **7** is a cross-sectional view of the embodiment of FIG. **6** depicting compression of the mold and second mold members by a press and the resulting consolidation of the fibers;

FIG. **8** is a cross-sectional view of the embodiment of FIG. **6** depicting the consolidated formed fiber object in the mold of the invention;

FIG. **9** is a cross-sectional view of a third embodiment of the invention depicting fibers deposited in the recessed portions of the mold formed around the second mold members, after application of a pressure differential across the mold and porous support;

FIG. **10** is a cross-sectional view of the embodiment of FIG. **9** depicting compression of the mold and second mold members by a press and the resulting consolidation of the fibers;

FIG. **11** is a cross-sectional view of the embodiment of FIG. **9** depicting the consolidated final formed fiber object in the mold of the present invention;

FIG. **12** is a cross-sectional view of a fourth embodiment of the invention depicting fibers deposited in the recessed parts of the mold formed around the second mold members, after application of a pressure differential across the mold and porous support;

FIG. **13** is a cross-sectional view of the embodiment FIG. **12** depicting compression of the mold and second mold members by a press and the resulting consolidation of the fibers;

FIG. **14** is a cross-sectional view of the embodiment of FIG. **12** depicting the consolidated formed fiber object in the mold of the invention;

FIG. **15** is a cross-sectional view of a fifth embodiment of the invention depicting fibers deposited in the recessed parts of the mold formed around the second mold members, after application of a pressure differential across the mold and porous support;

FIG. **16** is a cross-sectional view of the embodiment of FIG. **15** depicting compression of the mold and second mold members by a press and the resulting consolidation of the fibers;

FIG. **17** is a cross-sectional view of the embodiment of FIG. **15** depicting the consolidated formed fiber object in the mold of the invention;

FIG. **18** is a cross-sectional view of a sixth embodiment of the invention showing compression of fibers and the inflated mold of the present invention by a press; and

FIG. **19** depicts the embodiment of FIG. **8** wherein FIG. **19**A is a crosssectional view and FIG. **19**B is a perspective view depicting the consolidated formed fiber object of the invention consisting of ribs without integral stressed skins covering the ribs.

In the Figures, like reference numerals refer to like elements.

DETAILED DESCRIPTION OF THE INVENTION

The present invention provides a method and apparatus for molding three-dimensional objects from fibers, as well as certain unique objects produced . The fibers may be cellulosic, non-cellulosic or a combination thereof. Cellulosic fibers, whether virgin or recycled, have natural bonding potential and can be recycled. For some applications, it may be desirable to incorporate synthetic fibers. However, for purposes of illustration, a system for molding three-dimensional objects from cellulosic fibers will be described herein.

An embodiment of the present invention is shown in FIGS. **1–5**. In FIG. **1**, a mold **100** is mounted on a porous support **102**, which can be a metal or composite screen or the like. Preferably mold **100** is made of a low durometer elastomeric material, possessing high deformability and resilience. Silicone rubber has generally desirable elastomeric properties, is readily available, is stable in an aqueous environment, and can withstand relatively high environmental temperatures. Mold **100** is mounted on porous support **102** by suitable means, for example, by an adhesive, a mechanical fastener or by direct molding. Mold **100** is comprised of a first mold member **104** which is depicted as a sheet of elastomeric material such as silicone rubber. The upper surface of first mold member **104** is in fluid communication with porous support **102** via at least one, and preferably a plurality of channels in first mold member **104**. That is, fluid poured onto the mold **100** will pass through the channel(s) and into the porous support **102**. At least one second mold member **106** will occupy the channel(s) defined in first mold member **104**.

Although the invention is described herein generally with reference to a single channel in first mold member **104** containing a single second mold member **106**, it will readily be recognized that a plurality of channels can be formed in first mold member **104**, each such channel containing at least one second mold member **106**, or a second mold member comprising a plurality of separate components, thereby facilitating the formation of a plurality of three-dimensional objects from a single mold **100**, and in a single operation. Each of the objects thus-formed can be substantially similar, or a range of objects can be formed from a single mold **100** by appropriate configuration of the first and second mold members **104** and **106**. Likewise, the formed objects may be a series of interconnected ribs of a honey comb configuration without integral stressed skins covering the ribs.

As seen more clearly in FIGS. **2** and **3**, each second mold member is comprised of recessed structure(s) **106** whose upper surfaces are below the level of the upper surface of the first mold member **104**, for reasons which will be explained in greater detail below. The second mold members **106** are generally isolated from one another so that a natural separation of the molded objects is accomplished upon formation.

To initiate the forming process, a mixture **108** of fibers **110** and fluid carrier **112** is poured over the mold. In many embodiments, water acts as the fluid carrier. Water temperatures typically will range from 50° to 140° F. when forming objects with cellulosic fibers. In some applications, it may be desirable to add a resin or adhesive to the fluid carrier. However, such an addition may degrade the recyclability of the fiber objects, and thus should be used judiciously.

As seen in FIG. **2**, the fibers **110** are carried within the fluid carrier **112**. Once the mixture **108** is poured onto the mold **100**, the mixture **108** flows over the mold and toward and into the recessed portions of the mold **100**. Fluid **112** begins to pass through the porous support **102** in a direction generally as designated by arrows **114**, depositing fibers **110** over the mold faces and within the spaces defined by the first mold member **104** and second mold members **106**.

A pressure differential is then created across the mold **100** and the porous support **102**, for example by an air pressure control device **116**. Preferably the pressure differential is in the range of 1 to 20 inches Hg of vacuum below the mold **100** so as to cause fluid flow through porous support **102**. Alternatively, or in conjunction, a head of air pressure above mold **100** can also be used. This pressure differential further enhances the flow of the fluid carrier **112** out of the mold **100** through porous support **102** generally in the direction of arrows **114**. This flow of fluid **112** also deposits additional fibers **110** over the mold faces and within the second mold member recesses.

At this point, additional fluid, typically the same as fluid carrier **112**, may be sprayed on the mold **100** to "clean" the mold by washing additional fibers into the recessed portions of second mold members **106**. As can be seen in FIG. **3**, at this stage of the forming process, the three-dimensional object **120** begins to take shape, and the fibers **110** are somewhat condensed and entangled within the recessed spacing of each second mold member **106**.

FIG. **4** illustrates the next step in the forming process. A generally flat press **118** is applied to both the top of mold **100** and the bottom of porous support **102**. Pressure sufficient to deform the mold **100** to a preselected degree is applied by the press **118** in the direction of arrows **122**. In embodiments disclosed herein, this pressure typically is on the order of 25 to 2000 psi, depending on the product being formed.

Preferably, the press **118** is made of porous material, such as is found in a wet felt press or screen material, permitting fluid carrier **112** to flow generally in the direction of arrows **114**, as shown in FIG. **4**.

Deformation of the first mold member **104** and second mold member **106** permits application of compressive forces generally normal to the surfaces of the object **120** being formed, irrespective of the orientation of those surfaces relative to the press **118**.

The three-dimensional object **120** being formed is thus further compressed, and acquires preselected structural features, due to the unique structure and composition of mold **100**. As seen in FIG. **4**, surface **124** of first mold member **104** has a greater curvature than the sidewalls **126** of second mold member **106**. As suggested previously, this effect is due to the difference in height of the first mold member **104** and the second mold member **106**. The surface **124** and walls **126** preferably are angularly displaced from vertical, as seen in FIGS. **2** and **3**. This angular displacement facilitates removal of the formed object after pressing and contributes to the formation of preselected structural features in the object **120**.

In this embodiment, the first mold member **104** is thicker than the second mold member **106**. Thus, during pressing, the thicker material of first mold member **104** deforms more than the components of the second mold member **106**, causing greater curvature of the first mold member surfaces. Such structural characteristics can also be influenced by appropriate selection of the materials used to form the various components of the mold **100**.

The object **120** may also be hot pressed for further processing in mold **100**. In some circumstances, fiber-to-fiber bonding can be enhanced when an object is held under pressure while heat is applied. It may also be desirable to remove the object **120** and position it on a second mold similar to molds **104** and **106** yet having tolerances and dimensions closer to the final requirements of the finished object, where the object is held under pressure while heat is applied.

The forming process described herein may be conducted in a batch, semicontinuous or continuous operation. Such processing is well known in the art and can be adapted easily to the present invention by those of ordinary skill in the art. Generally, the mold for batch or semi-continuous operation would have a selected length and width and an array of separate second mold members. The mold for a continuous operation would be a belt or rotary drum having selected dimensions.

When pressure is removed from the mold **100**, as seen in FIG. **5**, the forming surfaces of mold **100** retract from the object **120**, facilitating release of the object **120** from the mold **100**. Air pressure may be applied under the mold **100** by device **116** to assist in removing the object **120** from the mold **100**.

After pressing, the object **120** may be removed for subsequent drying in a convection oven or other drying apparatus. It may also be desirable to remove the object **120** and position it on a second mold similar to molds **104** and **106** yet having tolerances and dimensions closer to the final requirements of the finished object, where the object is held under pressure while heat is applied. Typically, drying temperatures should not exceed 400° F. for cellulosic fibers. For applications using synthetic fibers, other pressing and drying or heating parameters may prove useful and desirable.

As seen in FIG. **5**, the present invention permits fabrication of an object **120** possessing features which could not be realized in earlier designs. For example, flanges **128** can be created in the object **120** as a result of the deformation of the elastomeric material in the mold **100**. One or more structural ribs with integrally-formed flanges in the top surface can be constructed, including a flange oriented toward the inside of object **120**, or, as shown in FIG. **5**, a flange to the outside of the object **120**. In addition, an "I" beam structure also can be created. It is well known that such "I" beam structures have superior strength-to-weight characteristics, a desirable attribute in certain structural and cushioning applications.

A second embodiment of the present invention is shown in FIGS. **6–8**, which illustrate processing steps similar to those shown in FIGS. **3–5**. FIG. **6** shows a mold **200** mounted on porous support **102**. Mold **200** again is comprised of a first mold member **204** which defines at least one channel in the mold **200** in fluid communication with porous support **102**. Second mold member **206** occupies the channel (s) defined in first mold member **204**. Again, the surfaces **224** of first mold member **204** and the surfaces **226** of second mold member **206** are angularly displaced from vertical.

As seen more clearly in FIG. **6**, each second mold member **206** is comprised of structures whose uppermost surfaces are substantially even with the upper surface of the first mold member **204**. The mixture **108** of fibers **110** and fluid carrier **112** is poured over the mold **200**, in a manner similar to that shown in FIG. **2**, flowing toward and into the channels of the mold **200**. The fluid carrier passes through porous support **102**, depositing fibers within the spaces only defined by the first mold member **204** and second mold member **206**. A pressure differential is created across the mold **200** and porous support **102** by air pressure control device **116**.

As seen in FIG. **7**, press **118** is applied to the top of mold **200** and the bottom of porous support **102**. Mold **200** is deformed, again permitting application of compressive forces substantially normal to the surfaces of the object **220** being formed, irrespective of the orientation of those surfaces relative to the press **118**. Preferably, the press **118** is made of porous material, such as is found in a wet felt press or screen material, permitting fluid carrier **112** to flow generally in the direction of arrows **114**, as shown in FIG. **4**.

The honey comb-like three-dimensional object **220** being formed is further compressed, and acquires preselected structural features due to the unique construction of mold **200**. As seen in FIGS. **7** and **8**, the angular orientation of the surface **224** and walls **226** of first mold member **204** and second mold member **206**, respectively, create honey comb or cellular-like connected ribs with flange structures **228** and

230 having no integrally-molded face surfaces. FIG. **8** illustrates that the upper flanges **230** may differ slightly from the lower flanges **228**. These unique objects consisting of ribs with flanges, which can be specially shaped depending upon the desired application or use, will provide a much stronger honey comb structure than any comparable honey comb structure heretofore known in the prior art.

Again, when pressure is removed from the mold **200**, the forming surfaces of mold **200** retract from the object **220**, permitting easy release of the object **220** from the mold **200**. Air pressure may be applied under the mold **200** by device **116** (FIG. **2**) to assist in removing the object **220** from the mold **200**. As seen in FIG. **8**, this alternate embodiment permits fabrication of an object **220** possessing an augmented "I" beam structure, without integral top or bottom surface as previously described and depicted in FIG. **5**.

A third embodiment of the present invention is shown in FIGS. **9–11**, which illustrate processing steps similar to those shown in FIGS. **3–5**, but without an integrally-formed top surface. In FIG. **9**, a mold **300** is mounted on a porous support **102**. In this embodiment, the surfaces **324** of first mold member **304** and the walls **326** of second mold member **306** are again angularly displaced from vertical, however the second mold member structures may also be rounded.

As seen more clearly in FIG. **9**, the upper surfaces of second mold member **306** are higher than the upper surface of the first mold member **304**. After processing generally in accordance with the description above, the three-dimensional object **320** formed with mold **300** possesses honey comb or cellular-like connected ribs with flanges **328**. In this case, the flanges **328** are oriented inwardly. In addition, there is no top or bottom surface; the object consists of the interconnected rib structure.

A fourth embodiment of the present invention is shown in FIGS. **12–14**, which again illustrate processing steps similar to those shown in FIGS. **3–5**, except that there is no integrally-formed top or bottom surface. In FIG. **12**, mold **400** is mounted on porous support **102**. Mold **400** again is comprised of a first mold member **404** which defines at least one channel in the mold **400** in fluid communication with porous support **102**. Second mold member **406** occupies the channel(s) defined in first mold member **404**. In this embodiment, the surfaces **424** of first mold member **404** are substantially vertical and the walls **426** of second mold member **406** are angularly displaced from vertical.

In this embodiment, unlike the previously disclosed embodiments, first mold member **404** and second mold member **406** are made of different materials. Here, first mold member **404** is made of a much harder material than the elastomeric material used to make second mold member **406**. This harder material may be elastomeric, with a higher durometer rating, or may be another type of material, such as metal.

As seen in FIG. **12**, the softer second mold member **406** will have upper surfaces which are higher than the upper surface of the first mold member **404**. After the mixture **108** of fiber **110** and fluid carrier **112** has been poured onto spaces between the mold **400**, a pressure differential is again created across the mold **400**, for example by air control device **116**.

As seen in FIG. **13**, press **118** is applied to the top of mold **400** and the bottom of porous support **102**. In this embodiment, however, only the second mold member **406** is deformed to a substantial degree. Therefore, significant compressive forces are not applied by the surfaces **424** of the first mold member **404**. Instead, such forces are applied only by the walls **426** of the deformed second mold member **406**. However, the compressive forces applied normal to the object **420** still apply pressure to the surfaces **424** of the first mold member **404**.

As seen in FIG. **14**, the honey comb-like rib three-dimensional object **420** thus formed has outside dimensions substantially equal to the first mold member **404**. This embodiment permits fabrication of three-dimensional objects of a honey comb-like structure having specific outside dimension limitations. However, the internal edges of object **420** have flanges **428** to enhance the object's strength for various applications.

A fifth embodiment of the present invention is shown in FIGS. **15–17**, which illustrate processing steps similar to those shown in FIGS. **3–5**, with ribs and integrally-molded top surface. In FIG. **15**, mold **500** is mounted on porous support **102**. Mold **500** again is comprised of a first mold member **504** which defines at least one channel in the mold **500** in fluid communication with porous support **102**. Second mold member **506** occupies the channel defined in first mold member **504**. In this embodiment, the surfaces **524** of first mold member **504** are angularly displaced from vertical and the walls **526** of second mold member **506** are substantially vertical.

In this embodiment, first mold member **504** and second mold member **506** are also made of different materials. Here, however, second mold member **506** is made of a much harder material than the elastomeric material used to make first mold member **504**. This harder material also may be elastomeric or may be another type of material, such as metal.

As seen in FIG. **15**, the softer first mold member **504** has an upper surface which is higher than the upper surfaces of the second mold member **506**. After the mixture **108** of fiber **110** and fluid carrier **112** is poured onto the mold **500**, a pressure differential is again created across the mold **500**, for example by air control device **116**.

As seen in FIG. **16**, press **118** is applied to the top of mold **500** and the bottom of porous support **102**. In this embodiment, however, only the first mold member **504** is deformed. Therefore, compressive forces are not applied by the walls **526** of the second mold member **506**. Instead, such forces are applied only by the surfaces **524** of the deformed first mold member **504**. However, compressive forces are generated by deformation of the surfaces **524** of first mold member **504**. These forces are applied normal to the object **520**, and therefore apply pressure to the surfaces **524** of the first mold member **504** via the object **520**.

As seen in FIG. **17**, the three-dimensional object **520** formed has final internal dimensions substantially equal to the second mold member **506**. This embodiment permits fabrication of objects having specific inside dimension limitations. However, the outside edges of object **520** have ribs with flanges **528** to enhance strength for various applications.

A sixth embodiment of the present invention is shown in FIG. **18**, which illustrates a processing step similar to that shown in FIG. **4**. In FIG. **18**, mold **600** is mounted on porous support **102**. Mold **600** again is comprised of a first mold member **604** which defines at least one channel in the mold **600** in fluid communication with porous support **102**. Second mold member **606** occupies the channel defined in first mold member **604**. In this embodiment, both the first mold member **604** and second mold member **606** are thin walled, inflatable structures connected by passages **630** to a source

634 of pressurizing fluid, such as air. Pressurizing fluid inflates each member **604**, **606** of the mold **600**, causing the members **604**, **606** to deform generally in the directions of arrows **632**. Further pressure is applied to the object **620** being formed by press **618** applied to the top of mold **600**.

It will also be appreciated that the separate members **604**, **606** of the mold **600** can be individually and separately inflatable, and thereby provide the differential deformability aspects of the invention depicted in various other embodiments.

As seen in FIG. **19**, the invention also provides three-dimensional object **220** which comprises a honey comb-like object consisting of a series of interconnected ribs with flanges, but without the top or bottom faces which characterize the molded objects heretofore molded in accordance with the prior art. These objects and their flanges can be specially shaped depending upon the desired application or use, and will provide a much stronger honey comb-like structure than any comparable honey comb-like structure heretofore known in the prior art.

Thus it can be seen that the present invention provides method and apparatus for forming three-dimensional objects having ribs with flanges made from fibers which provides a variety of structural features which enhance the strength and versatility of the objects. In addition, both the internal and external dimensions of the objects can be rigidly controlled by selecting the appropriate materials for construction of the various components of the present molds.

All patents and patent applications cited in this specification are hereby incorporated by reference as if they had been specifically and individually indicated to be incorporated by reference.

Although the foregoing invention has been described in some detail by way of illustration and example for purposes of clarity and understanding, it will be apparent to those of ordinary skill in the art in light of the disclosure that certain changes and modifications may be made thereto without departing from the spirit or scope of the appended claims.

What is claimed is:

1. An apparatus for making a plurality of independent three-dimensional objects from fibers comprising:

a) a porous support;

b) a first mold mounted on said porous support, said first mold comprising:

i) a first mold member composed of a first material and having an upper surface, said first mold member defining a plurality of channels permitting fluid communication between said first mold member upper surface and said porous support, wherein said first mold member upper surface is at a preselected height above said porous support; and

ii) at least one second mold member composed of a second material, each of said second mold members occupying one of the channels in said first mold member and comprising a structure having a second mold member upper surface; and

c) a press for compressing and deforming said first mold to form a three-dimensional object from each channel.

2. The apparatus of claim **1** wherein the press comprises of a means for drying the three-dimensional object on said first mold.

3. The apparatus of claim **1** further comprising:

d) a second mold for compressing, de forming, and drying the three-dimensional object created on said first mold.

4. The apparatus of claim **3** wherein said second mold includes at least one mold member having dimensions which are closer to the final dimensions of the dried three dimensional object than the dimensions of the first mold.

5. The apparatus of claim **1** wherein said first material is a first elastomeric material and said second material is a second elastomeric material.

6. The apparatus of claim **5** wherein said first elastomeric material is less resilient than said second elastomeric material.

7. The apparatus of claim **6** wherein said first mold member upper surface is higher than said second mold member upper surface.

8. The apparatus of claim **5** wherein said second elastomeric material is less resilient than said first elastomeric material.

9. The apparatus of claim **8** wherein said second mold member upper surface is higher than said first mold member upper surface.

10. The apparatus of claim **1** wherein said second mold member upper surface is at a different height above said first porous support than the height of said first mold member upper surface.

11. The apparatus of claim **10** wherein said first mold member upper surface is above said second mold member upper surface.

12. The apparatus of claim **10** wherein said first mold member upper surface is below said second mold member upper surface.

13. The apparatus of claim **1** wherein said first material is the same as said second material.

14. The apparatus of claim **1** wherein said mold members are inflatable structures which deform in response to changes in pressure.

15. An apparatus for making a plurality of independent three-dimensional objects from fibers comprising:

a) a porous support;

b) a first mold mounted on said porous support, said first mold comprising:

i) a first mold member composed of a first material and having an upper surface, said first mold member defining a plurality of channels permitting fluid communication between said first mold member upper surface and said porous support, wherein said first mold member upper surface is at a preselected height above said porous support; and

ii) at least one second mold member composed of a second material, each of said second mold members occupying one of the channels in said first mold member and comprising a structure having a second mold member upper surface;

c) a fiber directing device that directs fibers from the upper surface of the first mold member and into the channels; and

d) a press for compressing and deforming said first mold to form a three-dimensional object from each channel.

16. The apparatus of claim **15** wherein the press comprises of a means for drying the three-dimensional object on said first mold.

17. The apparatus of claim **15** further comprising:

e) a second mold for compressing, deforming, and drying the three-dimensional object created on said first mold.

18. The apparatus of claim **17** wherein said second mold includes at least one mold member having dimensions which are closer to the final dimensions of the dried three dimensional object than the dimensions of the first mold.

19. The apparatus of claim **15** wherein said first material is a first elastomeric material and said second material is a second elastomeric material.

20. The apparatus of claim 19 wherein said first elastomeric material is less resilient than said second elastomeric material.

21. The apparatus of claim 20 wherein said first mold member upper surface is higher than said second mold member upper surface.

22. The apparatus of claim 19 wherein said second elastomeric material is less resilient than said first clastomeric material.

23. The apparatus of claim 22 wherein said second mold member upper surface is higher than said first mold member tipper surface.

24. The apparatus of claim 15 wherein said second mold member upper surface is at a different height above said porous support than the height of said first mold member upper surface.

25. The apparatus of claim 24 wherein said first mold member upper surface is above said, second mold member upper surface.

26. The apparatus of claim 24 wherein said first mold member upper surface is below said second mold member upper surface.

27. The apparatus of claim 15 wherein said first material is the same as said second material.

28. The apparatus of claim 15 wherein said mold members are inflatable structures which deform in response to changes in pressure.

29. An apparatus for making a plurality of independent three-dimensional objects from fibers comprising:

a) a porous support;

b) a first mold mounted on said porous support, said first mold comprising:

i) a first mold member composed of a first elastomeric material and having an upper surface, said first mold member defining a plurality of channels permitting fluid communication between said first mold member upper surface and said porous support, wherein said first mold member upper surface is at a preselected height above said porous support; and

ii) at least one second mold member composed of a second elastomeric material, each of said second mold members occupying one of the channels in said first mold member and comprising a structure having a second mold member upper surface, wherein said second elastomeric material is more resilient than said first elastomeric material; and

c) a means for compressing and deforming said first mold to form a three-dimensional object from each channel.

30. The apparatus of claim 29 wherein said first mold member upper surface is higher than said second mold member upper surface.

31. An apparatus for making a plurality of independent three-dimensional objects from fibers comprising:

a) a porous support;

b) a first mold mounted on said porous support, said first mold comprising:

i) a first mold member composed of a first elastomeric material and having an upper surface, said first mold member defining a plurality of channels permitting fluid communication between said first mold member upper surface and said porous support, wherein said first mold member upper surface is at a preselected height above said porous support; and

ii) at least one second mold member composed of a second elastomeric material, each of said second mold members occupying one of the channels in said first mold member and comprising a structure having a second mold member upper surface, wherein said second elastomeric material is less resilient than said first elastomeric material; and

c) a means for compressing and deforming said first mold to form a three-dimensional object from each channel.

32. The apparatus of claim 31 wherein said second mold member upper surface is higher than said first mold member upper surface.

33. An apparatus for making a plurality of independent three-dimensional objects from fibers comprising:

a) a porous support;

b) a first mold mounted on said porous support, said first mold comprising:

i) a first mold member composed of a first material and having an upper surface, said first mold member defining a plurality of channels permitting fluid communication between said first mold member upper surface and said porous support, wherein said first mold member upper surface is at a preselected height above said porous support; and

ii) at least one second mold member composed of a second material, each of said second mold members occupying one of the channels in said first mold member and comprising a structure having a second mold member upper surface, wherein said second mold member upper surface is at a different height above said first porous support than the height of said first mold member upper surface; and

c) a means for compressing and deforming said first mold to form a three-dimensional demensional object from each channel.

34. The apparatus of claim 33 wherein said first mold member upper surface is above said second mold member upper surface.

35. The apparatus of claim 33 wherein said first mold member upper surface is below said second mold member upper surface.

36. An apparatus for making a plurality of independent three-dimensional objects from fibers comprising:

a) a porous support;

b) a first mold mounted on said porous support, said first mold comprising:

i) a first mold member composed of a first elastomeric material and having an upper surface, said first mold member defining a plurality of channels permitting fluid communication between said first mold member upper surface and said porous support, wherein said first mold member upper surface is at a preselected height above said porous support; and

ii) at least one second mold member composed of a second elastomeric material, each of said second mold members occupying one of the channels in said first mold member and comprising a structure having a second mold member upper surface, wherein said second elastomeric material is more resilient than said first elastomeric material; and

c) a fiber directing device that directs fibers from the upper surface of the first mold member and into the channels; and

d) a means for compressing and deforming said first mold to form a three-dimensional object from each channel.

37. The apparatus of claim 36 wherein said first mold member upper surface is higher than said second mold member upper surface.

38. An apparatus for making a plurality of independent three-dimensional objects from fibers comprising:

a) a porous support;

b) a first mold mounted on said porous support, said first mold comprising:

i) a first mold member composed of a first elastomeric material and having an upper surface, said first mold member defining a plurality of channels permitting fluid communication between said first mold member upper surface and said porous support, wherein said first mold member upper surface is at a preselected height above said porous support; and

ii) at least one second mold member composed of a second elastomeric material, each of said second mold members occupying one of the channels in said first mold member and comprising a structure having a second mold member upper surface, wherein said second elastomeric material is less resilient than said first elastomeric material; and

c) a fiber directing device that directs fibers from the upper surface of the first mold member and into the channels; and

d) a means for compressing and deforming said first mold to form a three-dimensional object from each channel.

39. The apparatus of claim **38** wherein said second mold member upper surface is higher than said first mold member upper surface.

40. An apparatus for making a plurality of independent three-dimensional objects from fibers comprising:

a) a porous support;

b) a first mold mounted on said porous support, said first mold comprising:

i) a first mold member composed of a first material and having an upper surface, said first mold member defining a plurality of channels permitting fluid communication between said first mold member upper surface and said porous support, wherein said first mold member upper surface is at a preselected height above said porous support; and

ii) at least one second mold member composed of a second material, each of said second mold members occupying one of the channels in said first mold member and comprising a structure having a second mold member upper surface, wherein said second mold member upper surface is at a different height above said first porous support than the height of said first mold member upper surface; and

c) a fiber directing device that directs fibers from the upper surface of the first mold member and into the channels; and

d) a means for compressing and deforming said first mold to form a three-dimensional object from each channel.

41. The apparatus of claim **40** wherein said first mold member upper surface is above said second mold member upper surface.

42. The apparatus of claim **40** wherein said first mold member upper surface is below said second mold member upper surface.

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