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(71) Applicant *(for all designated States except US)*: **PRINCE SPORTS, INC.** [US/US]; One Advantage Court, Bordentown, NJ 08505 (US).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **GAZZARA, Roberto** [IT/IT]; Via Fiume, 4/C, I-30171 Mestre (VE) (IT). **PINAFFO, Mauro** [IT/IT]; Via Cordenons, 4, I-35012 Camposampiero (PD) (IT). **PEZZATO, Mauro** [IT/IT]; Via K2, 11, I-31100 Treviso (IT). **POZZOBON, Michele** [IT/IT]; Via Fiume, 10, I-31050 Fossalunga Di Vedelago (TV) (IT). **DAVIS, Stephen J.** [US/US]; 18 Hansel Road, Newtown, PA 18940 (US).

(74) Agents: **ZANOLI, Enrico** et al.; Via Melchiorre Gioia 64, I-20125 Milano (IT).

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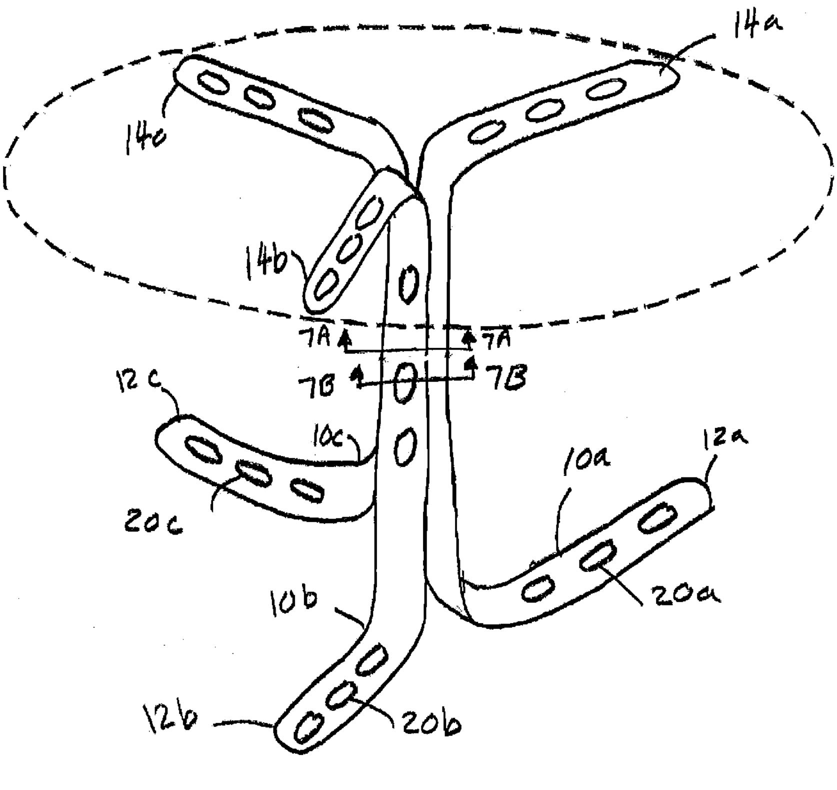

FIG. 7

(57) Abstract: A article of furniture is formed of multiple composite tubes bonded to one another along a common wall, wherein apertures, or "ports," are molded between the tubes to improve the stiffness, strength, resiliency, and aesthetics of the furniture.

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FURNITURE HAVING A MULTIPLE TUBE STRUCTURE

DESCRIPTION

Background of the invention

The present invention relates to furniture made preferably of composite material.

Furniture products such as tables, chairs, sofas, benches, light fixtures, etc., require a structure to support the loads placed on the furniture. For example, a table generally has a flat surface onto which objects are placed, with legs or other means to support that flat surface. A chair, sofa or bench generally has a frame to support people's weight. Such a frame may have fabric or cushioning means attached. A light fixture needs a structure to house the lighting means. Shelving or other storage means require a supporting structure.

These structures have traditionally been constructed of wood, metal, plastics or a combination thereof. This is because these materials are readily available and are economical to produce.

However, there are limitations to these traditional materials. Wood, for example, is available in a variety of species, but is limited in terms of strength, availability, and is susceptible to changes in temperature and humidity. In addition, there are limited shapes and designs that are possible with wood.

Metal materials offer some opportunities beyond wood, but also have limitations. Steel alloys are very stiff and strong materials, but are very heavy and susceptible to corrosion. Aluminum alloys offer lighter weight, but due to their lower stiffness and strength, require larger frame cross sections. Titanium and magnesium offer even lighter weight with increased strength, but the material cost is too high. In addition, with all metals, the process to produce the raw materials limits the designs which can be made.

Plastic materials are a good alternative using a low cost method such as injection molding to produce a variety of intricate shapes. However, the properties of injection molded plastics have lower strengths and the mold costs can be very high.

Long fiber reinforced composite materials offer an excellent alternative to the traditional materials used. The term "long fiber" is used to distinguish from the short fibers used in injection molding processes. In general, long fibers are longer than 0.5 inches in length have orientations that maximize the anisotropy fiber reinforced composites can offer.

Examples of long fiber reinforced composites are carbon fiber reinforced epoxy. Other fibers such as glass, aramid (Kevlar), boron and liquid crystal polymer (Vectran) can be used. Other resins may also be used including other thermoset resins such as polyester and vinylester among others. Thermoplastic resins may also be used such as polyamide, abs, peek, and acrylic among others. More details about the composite materials and processing will be covered later in this document.

The use of composite materials in furniture has been limited in the prior art. Examples of carbon fiber composite reinforcement to enhance wood structures are U.S. Pat. No. 6,287,677 to Ishihara et. al., U.S. Pat. No. 6,378,948 to Macher and Zorn, U.S. Pat. No.6,565,959 to Tingley, U.S. Pat. No.6,701,550 to Baeriswyl, U.S. Pat. No.6,994,032 to Conely and Rudisilli, and U.S. Pat. No. 7,128,960 to Walz and Walz.

Carbon fiber reinforcement to injection molded structures is shown in U.S. Pat. No. 5,253,888 to Friedrich, U.S. Pat. No. 6,536,841 to Pearce, et. al., and U.S. Pat. No. 6,786,548 to Pearce, et. al.

Examples which list carbon composites as an alternative material are U.S. Pat. No. 4,975,994 to Barmettler, U.S. Pat. No. 5,695,244 to Gillern and Hare, U.S. Pat. No. 6,857,696 to Usagani, U.S. Pat. No. 7,069,608 to Failor and Fox, and U.S. Pat. No. 7,118,172 to Pattison-Sheets.

Examples of light weight structures for chairs are U.S. Pat. No. 5,045,849 to Hoff and U.S. Pat. No. 7,014,261 to Haney. The light weight is achieved by the design using a minimum of frame members. U.S. Pat. No. 5,709,428 to Hugghins uses carbon fiber composite tubular legs to achieve a light weight design.

Summary of the invention

The present invention relates to a composite structure for an article of furniture, and more particularly, where the structure is comprised of multiple continuous tubes, preferably a pair of tubes fused together along their facing surfaces to provide an internal reinforcing wall as well as apertures, or "ports," between the tubes to provide specific performance and aesthetic advantages.

In particular, the basis of the design is to replace the traditional structure with a multiple, e.g., double tube design. This provides a structure with an internal wall between the tubes which has strength and stiffness advantages. In addition, the tubes can be separated at various locations to form apertures or ports between the tubes which act as opposing arches which provide improved stiffness, strength, attachment means, and aesthetics over conventional designs.

There exists a continuing need for an improved article of furniture that has the combined features of light weight, improved bending stiffness, improved strength, improved aesthetics and improved design. In this regard, the present invention substantially fulfills this need.

The present invention is a structure for an article of furniture made with multiple tubes which are fused together along much of their lengths. The tubes preferably are separated from one another at selected locations to form apertures that act as double opposing arches, providing improved means of adjusting stiffness, resiliency, and strength.

The present invention is designed to provide a combination of light weight, tailored stiffness, greater strength, and improved aesthetics over the current prior art.

The furniture system according to the present invention substantially departs from the conventional concepts and designs of the prior art and in doing so provides an apparatus primarily developed for the purpose of reducing weight while providing tailored stiffness, greater strength, as well as improved appearance.

In view of the foregoing commonality inherent in furniture of known designs and configurations now present in the prior art, the present invention provides an improved furniture system.

There has thus been outlined, rather broadly, the more important features of the invention in order that the detailed description thereof that follows may be better understood and in order that the present contribution to the art may be better appreciated. There are, of course, additional features of the invention that will be described hereinafter and which will form the subject matter of the claims attached.

In this respect, before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not limited in its application to the details of construction and to the arrangements of the components set forth in the following description or illustrated in the drawings. The invention is capable of other embodiments and of being practiced and carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein are for the purpose of descriptions and should not be regarded as limiting.

It is important, therefore, that the claims be regarded as including equivalent constructions insofar as they do not depart from the spirit and scope of the present invention.

The present invention provides a new and improved furniture system which may be easily and efficiently manufactured.

The present invention provides a new and improved furniture system which is of durable and reliable construction.

The present invention provides a new and improved furniture system which may be manufactured at low cost with regard to both materials and labor.

The present invention provides a furniture system that can provide specific stiffness zones at various locations along the length of the furniture.

The present invention provides an improved furniture system that has improved strength and fatigue resistance.

The present invention provides an improved furniture system that has a unique look and improved aesthetics.

For a better understanding of the invention and its advantages, reference should be made to the accompanying drawings and descriptive matter in which there are illustrated preferred embodiments of the invention.

Brief description of the drawings

Figure 1 is an isometric view of a table constructed in accordance with an embodiment of the present invention.

Figure 2 is an isometric view of a table leg constructed in accordance with an embodiment of the present invention.

Figure 2A is a cross sectional view of the table leg taken along lines 2A-2A of Figure 2.

Figure 2B is a cross sectional view of the table leg taken along lines 2B-2B of Figure 2.

Figure 2C is an isometric view of a portion of the table leg shown in Figure 2.

Figure 3 is a longitudinal sectional view of a portion of the table leg.

Figure 4 shows an alternative example of a table leg constructed using multiple tubes.

Figure 4A is a cross sectional view along the lines 4A-4A of Figure 4.

Figure 4B is a cross sectional view along the lines 4B-4B of Figure 4.

Figure 5 shows an alternative example of a table leg.

Figure 6 shows an alternative example of a table leg.

Figure 7 shows an alternative example of a table leg.

Figure 7A shows an assembly technique for the table legs of Figure 7.

Figure 7B shows an alternative assembly technique for the table legs of Figure 7.

Figure 7C shows an alternative technique for the table legs of Figure 7.

Figures 8A – 8E show various table leg designs.

Figure 9 is an isometric view of a table leg constructed with a multiple tube design.

Figure 9A is a cross section of the table leg in Figure 9 taken along lines 9A-9A.

Figure 9B is a cross section of the table leg in Figure 9 taken along lines 9B-9B.

Figure 9C is an isometric cutaway view of a portion of the table leg shown in Figure 9.

Figure 10 is an isometric view of a chair constructed in accordance with an embodiment of the present invention.

Figure 11 shows an alternative example of a chair constructed in accordance with an embodiment of the present invention.

Figure 12 shows an alternative example of a chair constructed in accordance with an embodiment of the present invention.

Figure 13 shows a light fixture constructed in accordance with an embodiment of the present invention.

Figure 14 is an isometric cutaway view of an alternate embodiment of a frame member made with a multiple tube construction with all ports in the same location.

Figure 14A is a cross sectional view along the lines 9A-9A of Figure 14.

Figures 15A-15D show various shapes of ports.

Figures 16-17 are perspective views illustrating a process for forming a frame member to a single tube portion.

Figure 18 is a longitudinal sectional view of an example of a frame member structure prior to molding.

Figure 19 is an isometric view of a shelf structure constructed in accordance with an embodiment of the present invention.

Figure 20 is an isometric view of an alternative design for a shelf structure.

The same reference numerals refer to the same parts throughout the various Figures.

Detailed description of the invention

As described below, the furniture system is formed of two or more tubes which are molded together to form a common wall (or walls, in the case of more than two tubes). This common wall improves the strength of the frame member by acting as a brace to resist compression of the cross section resulting from bending loads.

However, at selected locations, the facing surfaces of the tubes are kept apart during molding, to form openings. On either side of the openings, the tubes are joined together. The openings so formed are referred to herein as "ports". These ports are formed without drilling any holes or severing any reinforcement fibers.

The resulting structure is found to have unique performance characteristics for several reasons. The ports are in the shape of double opposing arches which strengthen the structure while allowing deflection. As a result, the ports allow greater bending flexibility than would traditionally be achieved in a tubular design. The internal wall between the hollow tubes adds strength to resist compressive buckling loads generated from the bending of the frame members.

The added strength allows for a lighter weight design. This is a desirable feature in furniture because it is easier to move. In addition, the light weight expands the usefulness of the furniture to outdoor activities including camping and backpacking.

The molded ports can facilitate the assembly of frame members by providing an attachment means. The ports also facilitate the design of collapsible furniture.

New and different design shapes can be molded to give the furniture a unique and fresh appearance.

Figure 1 illustrates a partial view of a table 8 with a frame member, which is referred to generally by the reference numeral 10. The frame member 10 includes feet portions 12 and 12a that connect to the table top attachment area 14, at which the flat surface (represented with a dotted line for the sake of clarity) of the table 8 is connected to the frame member 10.

Figure 2 shows a preferred embodiment wherein the frame member 10 contains openings, or "ports" 20, oriented in line and with axes oriented in a vertical direction. The ports 20 may be located along the length of the frame member 10.

Figure 2A, taken along the lines 2A-2A of Figure 2, shows the two hollow tubes 22 which form the structure of the frame member in this embodiment. The hollow tubes 22 are joined together to form an internal wall 24. The preferred location of the internal wall 24 is near the central axis of the frame member. Both of the hollow tubes 22 should preferably be about the same size and, when molded, form a rectangular shape.

Figure 2B, taken along the lines 2B-2B of Figure 2, shows that, at the locations of the ports 20, the hollow tubes 22 are separated from one another to form the walls defining the ports 20. It is advisable to have a radius (i.e., rounded edges 26) leading into the port so to reduce the stress concentration and to facilitate the molding process.

Figure 2C is an isometric view of the frame member 10 isolated to one port which shows the two hollow tubes 22 and internal wall 24. Also shown is the port 20 formed by curved wall 30 which may have the shape of a portion of a cylinder.

Figure 3 is a longitudinal section view along the frame member 10 that shows at locations other than the ports, the hollow tubes 22 are positioned side-by-side and are fused together along much of their lengths to form a common wall 24 that extends along the centerline of the frame member, i.e., bisects the frame member interior. At selected locations, e.g., where ports 20 are to be formed, the facing surfaces 30a and 30b of the tubes 22 are separated during molding to form apertures 20 in the shape of double opposing arches which act as geometric supports to allow deformation and return. In addition, the internal wall 24 provides structural reinforcement to resist cross section reduction and buckling failures.

Figure 4 shows an alternative embodiment of the frame member 10. In this "W" shape design, there are 3 attachment locations to the table top denoted as 14a,b,c. There exist 2 feet denoted as 12a,b. In this case the frame member 10 is designed using a multiple tube construction with allows for ports 20 and ports 20a to be positioned along 2 different rows.

In order to form ports in multiple rows, multiple tubes are needed. Figure 4A shows a cross sectional view of the frame member 12 taken along the lines 4A-4A in Figure 4. In this example, 3 tubes(42,43,44) are used to create the frame member which creates walls 46 and 48 in between.

Figure 4B, taken along the lines 4B-4B of Figure 4, shows that, to form the ports 20, tubes 43 and 44 are separated from one another to form the walls defining such ports. Similarly, to form ports 20a, tubes 42 and 43 are separated from one another to form walls defining such ports. Again, it is advisable to have a radius (i.e., rounded edges 26 and 26a) leading into the port so to reduce the stress concentration and to facilitate the molding process.

Figure 5 shows an alternative design for the frame member 10. This "X" shaped frame member is constructed of frame member 10a and frame member 10b. Frame members 10a and 10b are symmetrical to each other about a horizontal plane through the connection area 16. Feet 12 and 12a are formed in frame member 10a, and table top attachment areas 14 and 14a are formed in frame member 10b. Ports 20a molded in frame member 10a are in the same respective position as ports 20b molded in frame member 10b. The frame members 10a and 10b are connected with fasteners going through ports 28a and 28b on frame member 10b, and through corresponding ports(not shown) in frame member 10a. It is also possible to mold frame member 10 as a single piece unit.

Figure 6 shows an alternative design for the frame member 10. This "Figure 8" shaped frame member has table top attachment areas 14 and 14a, and feet 12 and 12a. The frame member 10 is preferably molded as a one piece unit. The frame member 10 can also be constructed of 2 frame members 10a and 10b similar to Figure 5 using connection areas 16a,b,c.

Figure 7 shows an alternative tripod style design using identical frame members 10a,b,c arranged so that the table top attachment points 14a,b,c and feet 12a,b,c are angled equally between each other. Each frame member has a general "U" shape and has ports 20a,b,c molded in line in each respective frame member 10a,b,c. Also in this case the flat surface of the table is represented by a dotted line.

Figure 7A is a cross section taken along the lines 7A-7A in Figure 7. For simplicity, only frame member 10a will be discussed because it is similar to frame members 10b and 10c. Frame member 10a is constructed using two tubes 22a to form a center wall 24a there between. The triangular cross section creates mating surfaces 32a which match the corresponding surfaces of the other frame members. An adhesive can be used to bond all 3 frame members to each other along these mating surfaces.

Figure 7B is a cross section taken along the lines 7B-7B in Figure 7 shows that, at the locations of the ports 20a,b,c, the hollow tubes 22a,b,c are separated from one another to form the walls defining the ports 20a,b,c. A “Y” shaped fastening means 34 is inserted into each of the ports 20a,b,c and secured to the frame members using a threaded fastener 36. This fastening means may be used as needed to stabilize the structure.

An optional fastening means is shown in Figure 7C. In this example, blind ports 20a,b,c are formed on the interior sides of frame members 10a,b,c. A “Y” shaped fastener 34 is bonded to the frame members using a high strength adhesive such as epoxy. This method provides a cleaner exterior appearance.

Figures 8A – 8E show a variety of frame member shapes that are possible with the present invention. Each example has a table top attachment area 14 and foot area 12. Ports are molded throughout each frame member for aesthetic purposes. Ports in the table top area 14 may also be used for attaching to the table top using a fastening means.

Figure 9 shows an alternative embodiment of the frame member. In this case the frame member 10 is designed using a multiple tube construction with allows for ports 20 and ports 20a to be oriented at different angles.

In this particular example, the ports 20 have axes oriented horizontally, and ports 20a have axes oriented vertically. This design allows the ports to be seen from all angles. It is possible arrange the ports in any desirable sequence, orientation and location. In this example, ports 20a in table top area 14 could be used to attach to the table or to attach to another frame member such as shown in Figure 5.

In order to form ports in multiple directions, multiple tubes are needed. In the example of Figure 9A, 4 tubes (42,43,44,45) are used to create the frame member 10 shown in Figure 9 which creates an internal wall 46 in the form of an “X”.

The Figure 9B cross section is in the region of port 20a which has an axis oriented vertically. In this example the hollow tubes 42 and 43 have remained together as well as hollow tubes 44 and 45. The tubes 42 and 43 are separated from the tubes 44 and 45 during molding to create the port 20a.

Figure 9C is an isometric view of a cutaway portion of the frame member 10 of Figure 9 showing ports 20 with axes oriented horizontally, and ports 20a with axes oriented vertically. As described above in connection with Figures 9A and 9B, ports may be formed by separating two tubes from the other two tubes. In this example, to form port 20, hollow tubes 42 and 45 have remained together as well as hollow tubes 43 and 44. To form port 20a, hollow tubes 42 and 43 have remained together as well as hollow tubes 44 and 45.

Molding the parts using multiple tubes allows greater design options. For example, separating the hollow tubes at selected axial locations along the frame in order to mold large oval shaped openings between the tubes, allows the characteristics of the frame member to be varied as desired.

Figure 10 shows a chair 11 with ports molded along the frame members. The chair is comprised of frame member 54a and 54b which are attached at locations 56a and 56b to form an "X" shaped structure. Ports 20a are formed in frame member 54a and ports 20b are formed in frame member 54b. The ports are located at regular spacings in between for this example, but can be located at any location or orientation and the size and shape of the ports may vary as well. Ports are located at the joint locations 56a and 56b to facilitate attachment between the frame members 54a and 54b.

Ports located in the vertical portions 56a and 56b may be used to attach string between the ports to create a support structure for the back. Other materials may also be used such as fabric strips, a fabric panel, elastomeric tubing, or other suitable materials. Similarly, such materials may attach between ports molded in horizontal members 58a and 58b to create a sitting area.

Figure 11 is a view of a folding chair 13 with ports formed in the frame members. In this example, ports 20 located in frame member 59 are arranged along the length with a particular port located at joint 56 to facilitate attachment to the frame member 58.

Figure 12 is a view of a beach or backpacking type chair 15 with ports formed in the frame members. The arm 57 has a particular port 21 formed with an irregular shape to allow adjustment means of the chair.

Figure 13 is a view of a light fixture 17 comprised of frame member 19 with a lighting area 23 and a base area 12. Ports 20 are formed in line along the length of frame member 19. A larger port 20a is formed near the foot 12.

Figure 19 is a view of a shelf structure 120 comprised of frame members 122a,b and transparent shelves 124. In each frame member are large decorative ports 126 and smaller ports 128 for attachment to the shelves.

Figure 20 is a view of an alternative shelf structure 130 that takes advantage of the ported tubular construction. Frame member 132 is constructed of multiple tubes to create ports 134 on the front face and ports 136 on the side face. The base frame 140 is constructed of tubes 142 and 144 to form the ported base structure 140. For example, tube 142 starts at the connection point 146 and proceeds around the perimeter region 148 until reaching the rear point 154 where it returns back to the connection point 146. Ports 150 and 152 are formed by tube 142 molded around a male portion in the mold. Tube 144 forms the other half of the base structure 140 in a symmetrical fashion. Port 156 is formed by separating tube 142 from tube 144. Frame member 132 connects to base frame 140 at the connection point 146 by using adhesive or other attachment means. It is also possible to produce the combined structure of frame member 132 and base frame 140 as a single one piece unit.

An option is to form ports in multiple directions at the same location. Figure 14 is an isometric cutaway view of a four tube structure 52 with ports for all tubes located in the same location. In this example, hollow tubes 47, 48, 49, and 50 are all separated in the same location to form four ports 51 there between.

Figure 14A is a cross sectional view of the tube structure 52 in Figure 14 taken along the lines 14A-14A. Here it can be seen that because all hollow tubes are separated, there results in an open port 51 that has four openings 51a-d. This particular embodiment would provide more flexibility and visibility for both in 2 directions at the same location.

In a multiple tube design, there can be any number of ports and orientations of ports depending on the number of hollow tubes used and how many are separated to form these ports. In addition, for example with a 3 tube design, the axis of the port would not necessarily have to pass through the center of the frame member.

Figures 15A-15D illustrate some examples of the variety of shapes possible to be used for the ports. Depending on the performance required of the structure at a particular location, more decorative port shapes can be used.

In all orientations, the quantity, size, and spacing of the ports can vary according to the performance desired. In addition, the internal wall assists in resisting the buckling of the tubular construction. This is an excellent application of where a multiple tube construction such as using 3 tubes therefore creating 2 internal walls will better resist these stresses.

The preferred embodiments of the present invention use multiple continuous composite tubes which are separated to form apertures in the form of double opposing arches at various locations in the frame member.

The invention allows the frame member to be custom tuned in terms of its stiffness and strength by varying, in addition to the material used and the geometry of the frame member itself, the size, number, orientation and spacing of the ports in the frame member.

The present invention will require a specific molding technique because the use of multiple tubes and forming ports requires internal pressure to consolidate the prepreg plies. For example when molding the frame member using two prepreg tubes, each tube should be approximately half the size of the cross section of the frame member. A polymer bladder is inserted into the middle of each prepreg tube and is used to generate internal pressure to consolidate the plies upon the application of heat. The mold packing process consists of taking each prepreg tube and internal bladder and position into a mold cavity and an air fitting is attached to the bladder. The process is repeated for each tube depending on how many are used. Care should be taken for the position of each tube so that the internal wall formed between the tubes is oriented properly, and that pins can be inserted between the tubes in order to form the ports during pressurization. The pins are secured into portions of the mold and are easily removed.

The mold is designed with a cavity that will form the shape of the molded part. The mold is pressed closed in a heated platen press and air pressure for each tube should be applied simultaneously to retain the size and position of each tube and the formed wall in between. Simultaneously, the tubes will form around the pins to form the ports. As the temperature rises in the mold, the viscosity of the epoxy resin decreases and the tubes expand, pressing against each other until expansion is complete and the epoxy resin is cross linked and cured. The mold is then opened, the pins removed, and the part is removed from the mold.

If multiple tubes are used, they may be a continuing part of one of the other tubes which have reversed direction. The additional tubes could also be a separate tube construction using internal air pressure for consolidation or have an expanding internal foam core to provide such pressure.

The orientation of the wall in the frame member can be positioned to take advantage of the anisotropy it offers. If more bending flexibility is desired, the wall can be positioned along the neutral axis of bending. If greater stiffness is needed, then the wall can be positioned like an “I Beam” at 90 degrees to the neutral axis to greatly improve the bending stiffness.

Molding in of apertures, or ports, at selected locations results in a double opposing arch construction. What is contributing to the structure, is the “double arch effect” of the ports, which are oval in shape creating two opposing arches which allow the tubular part to deflect, while retaining the cross sectional shape of the tube because of the three dimensional wall structure provided by the port. For example, a ported double tube structure has a combination of exterior walls, which are continuous and form the majority of the structure, and ported walls, which are oriented at an angle to the exterior walls, which provide strut like reinforcement to the tubular structure. The cylindrical walls of the ports prevent the cross section of the tube from collapsing, which significantly improves the strength of the structure.

The stiffness and resiliency of the ported double tube structure can be adjusted to be greater or less than a standard single hollow tube. This is because of the option of orienting the internal wall between the tubes as well as the size, shape, angle and location of the ports. The ports can be stiff if desired, or resilient allowing more deflection and recovery, or can be designed using different materials or a lay-up of different fiber angles in order to produce the desired performance characteristics of the structure.

The structure can be further refined by using more than two tubes. For example, using three tubes allows for apertures to occur in 120 degree offsets, providing specific stiffness tailoring along those directions. Using four tubes provides the possibility of having apertures at ninety degree angles to each other and alternately located along the length of the tubular part to achieve unique performance and aesthetic levels. Another option is to locate the multiple ports in the same location to achieve more of an open truss design.

Another option is to combine a single composite tube with a multiple tube composite design. In this example, the single composite tube can be a portion of the frame member and co-molded with the multiple tubes to produce a lighter weight alternative to a 100 % multiple tube construction.

In this example, the composite single tube can be a portion of the frame member and fused or co-molded with the multiple prepreg tubes which form the frame members. This can produce a lighter weight structure that can still achieve the performance and aesthetic requirements of the product.

Referring to Figures 16-17, in order to make this construction, the forward ends 62 of a pair of prepreg tubes 60a, 60b, each having an inflatable bladder 64, are inserted into one end 65 of a composite single tube 66. The unit is placed inside a mold, which should have a shape, on either side of the juncture 70 of the prepreg tubes 60a, 60b and the composite single tube 66, so that the outside surface of the unit is continuous. A pin or mold member (not shown) is placed between the prepreg tubes 60a, 60b where a port 20 is to be formed. The mold is then closed and heated, as the bladders 64 are inflated, so that the prepreg tubes assume the shape of the mold, the mold member keeping the facing walls 71a, 71b apart so as to form the port 20. As shown, the tubes 60a, 60b will form a common wall at seam 72. After the prepreg tubes have cured, the frame member 74 is removed from the mold, and the mold member or pin is removed, leaving the port 20. In this embodiment, the seam 70 between the composite portions 60a, 60b of the frame member 74 and the composite single tube portion 66 should be flush.

The tube portion 66 may also be made of metal to produce a less expensive product than using 100% composite materials.

Yet another option is to construct a double opposing arch structure using 100% metal materials. The preferred method to produce this structure is to start with a metal tube with a "D" shaped cross section. The tube can then be formed with a half arch bend along a portion of its length. A similar operation can be done with another metal tube. The two tube halves can then be attached by fixing the flat sides of the D shaped cross section so that the two half arches oppose each other. The tubes can be welded or bonded together resulting in a structure with an internal reinforcing wall and a double opposing arch shaped aperture.

An alternative method to produce a multiple tube structure out of metal is to start with a metal tube such as aluminum, titanium, steel, or magnesium for example, and deform the tube in local areas to create dimples or craters in the surface of the tube on opposing sides. The centers of these dimples can be removed leaving a circular aperture through the tube. A tubular section can then be positioned through these circular apertures and fixed to the edges of this dimple area of the primary tube using a welding process to create the 3D structure. The result will be a structure with the primary tube being a single hollow tube with other single hollow tubes attached in a transverse manner internal to the primary tube.

Another advantage of the invention is vibration damping. Vibrations are damped more effectively with the opposing double arch construction. This is because the movement and displacement of the arches absorbs energy which damps vibrations. As the tubular parts deflect, the shape of the ports can change, allowing a relative movement between the portions of the tube either side of the port. This movement absorbs energy which damps vibrations. This can provide an advantage for use on or near loud machinery, for example as a seat used in an automobile or tractor.

Finally, there is a very distinguished appearance to an article of furniture made according to the invention. The ports are very visible, and give the tubular part a very light weight and high tech appearance. The ports can also be painted a different color, to further enhance the signature look of the technology.

There are unlimited combinations of options when considering a double opposing arch structure. The ports can vary by shape, size, location, orientation and quantity. The ports can be used to enhance stiffness, resilience, strength, and aesthetics. For example in a low stress region, the size of the port can be very large to maximize its effect and appearance. If more deflection or resilience is desired, the shape of the aperture can be very long and narrow to allow more flexibility. The ports may also use designer shapes to give the product a stronger appeal.

If more vibration damping is desired, the ports can be oriented and shaped at a particular angle, and constructed using fibers such as aramid or liquid crystal polymer. As the port deforms as a result of bending deflection, its return to shape can be controlled with these viscoelastic materials which will increase vibration damping. Another way to increase vibration damping is to insert an elastomeric material inside the port.

Figure 18 illustrates generally a process which may be used to make the frame member. A pair of prepreg tubes 100, 102 extend side-by-side from the butt end 29 towards the tip end 116. At the tip end, the inside, common wall 104 of the tubes 100, 102 is cut out, the outside walls of the prepreg tubes 100, 102 are folded over one another, so as to close off the forward end and create a space 106 between the outside walls 108 and the forward end 105 of the common wall 104.

An inflatable bladder 110 extends through the interior of one prepreg tube 100, through the space 106 at the forward tip 116, and back through the other prepreg tube 102, so that opposite ends 112, 112a of the bladder 110 extend out of the open butt end 29 of the tubular layup. A mold pin 114 is inserted between the facing walls 104 of the tubes 110, 112 to form a port. This structure is then placed in a mold which is heated, while the bladder 110 is inflated, to form the frame member. After molding a cap may be secured by any suitable means to close off the butt end 29 of the frame member.

Alternately, the frame member can be molded with the butt end 29 closed and the tip end 116 open (i.e., the opposite of Figure 18), in which case the frame member tip is secured after molding. Or, the frame member can be molded with both ends open, using a pair of inflatable bladders. In either such case, the tip and/or butt may, if desired, be closed off after molding by securing a tip and/or butt piece, respectively, to the frame member. In such a case, the ends of the tubes would not be folded over one another.

The prepreg tubes used to make the frame member, or its various parts, may be formed by rolling up sheets of prepreg, in which unidirectional reinforcement fibers (such as carbon fibers) are embedded in an uncured resin (such as epoxy). Alternately, the prepreg tubes may be formed of reinforcement fibers and a thermoplastic material, using a technique similar to that disclosed in U.S. patent No. 5,176,868.

With respect to the above description then, it is to be realized that the optimum dimensional relationships for the parts of the invention, to include variations in size, materials, shape, form, function and manner of operation, assembly and use, are deemed readily apparent and obvious to one skilled in the art, and all equivalent relationships to those illustrated in the drawings and described in the specification are intended to be encompassed by the present invention.

Therefore, the foregoing is considered as illustrative only of the principles of the invention. Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation shown and described, and accordingly, all suitable modifications and equivalents may be resorted to, falling within the scope of the invention.

CLAIMS

1. A frame member for an article of furniture formed of at least two hollow tubes, said tubes being formed of composite material;
wherein said frame member has a longitudinal axis and a cross sectional dimensions which vary along said axis;
wherein first portions of said tubes form an outer wall of said frame member and define a frame member interior; and
wherein second portions of said tubes extend across the interior of said frame member and are bonded to one another, at least along much of the length of said frame member, thereby to form an internal reinforcing wall.

2. A frame member as defined in claim 1, wherein said frame member is formed of a double tube construction.

3. A frame member as defined in claim 1, wherein said frame member is formed of a triple tube construction.

4. A frame member as defined in claim 1, wherein said frame member is formed of four tubes.

5. A frame member formed of at least two hollow tubes, said tubes formed of composite material; wherein said frame member has a longitudinal axis; wherein first portions of said tubes form an outer wall of said frame member and define a frame member interior; wherein second portions of said tubes extend across the interior of said frame member and are bonded to one another along much of the length of said frame member, thereby to form an internal reinforcing wall; and wherein said second portions are separated from one another at at least one axial location so as to form at least one port.

6. A frame member as defined in claim 5, wherein said at least one port has a double opposing arch structure.

7. A frame member as defined in claim 6, wherein said frame member has multiple double opposing arch shaped ports.

8. A frame member as defined in claim 5, wherein said second portions are separated from one another at selected locations to form multiple ports.

9. A frame member as defined in claim 5, wherein said ports have an axis therethrough, and wherein at least two of said ports have different axial orientations.

10. A frame member as defined in claim 5, wherein said frame member includes ports which vary in size.

11. A frame member as defined in claim 5, wherein said frame member includes at least three ports, wherein each port has a central axis therethrough, and wherein the axes of said ports are spaced apart from one another by at least two distances.

12. A frame member as defined in claim 1, wherein one or more tubes are added to a single tube structure in a local area.

13. A frame member as defined in claim 1, wherein the frame member comprises a metal tube for a portion of its length.

14. A frame member as defined in claim 1, wherein at least a portion comprises a single metal tube joined to a multi-tube member.

15. A frame member as defined in claim 14, wherein said multi-tube member includes a port.

16. A frame member component which is metal and produced using a multiple tube construction in which the tubes have facing surfaces which are bonded to one another along at least much of their lengths.

17. A frame member as defined in claim 1, wherein said frame member is the frame of a table.

18. A frame member as defined in claim 1, wherein said frame member is the frame of a chair.

19. A frame member as defined in claim 1, wherein said frame member is the frame of a light fixture.

20. A frame member as defined in claim 1, wherein said frame member is the frame of a shelf fixture.

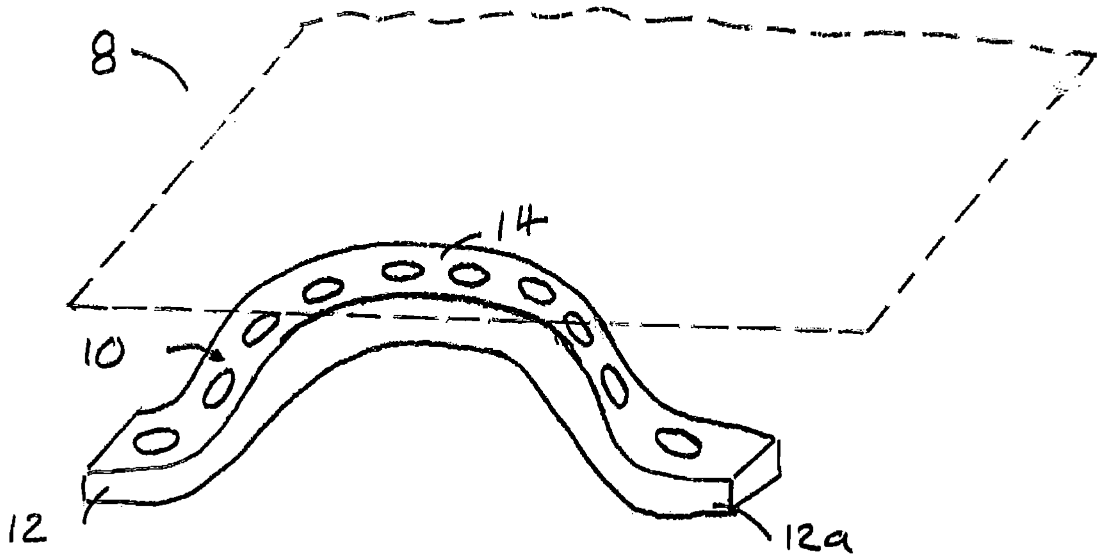


FIG.1

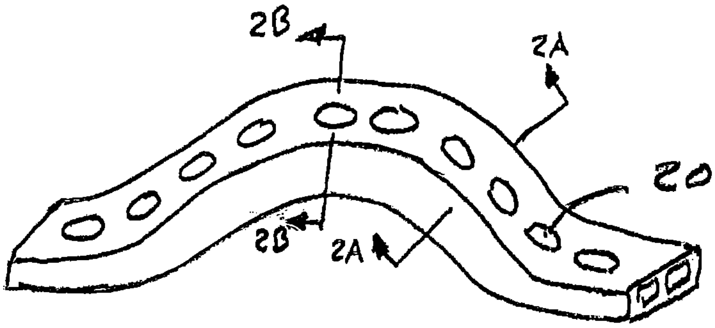


FIG. 2

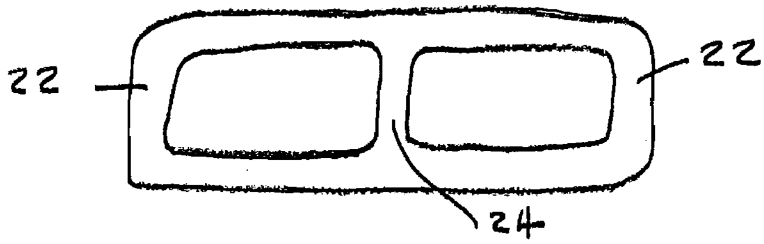


FIG. 2A

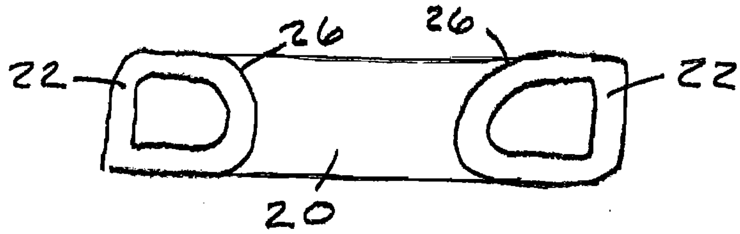


FIG. 2B

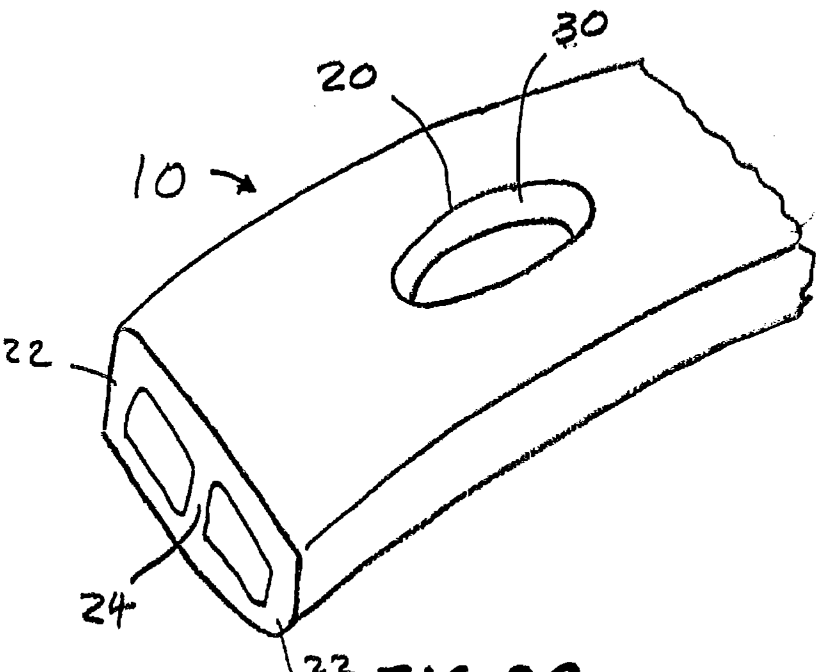


FIG. 2C

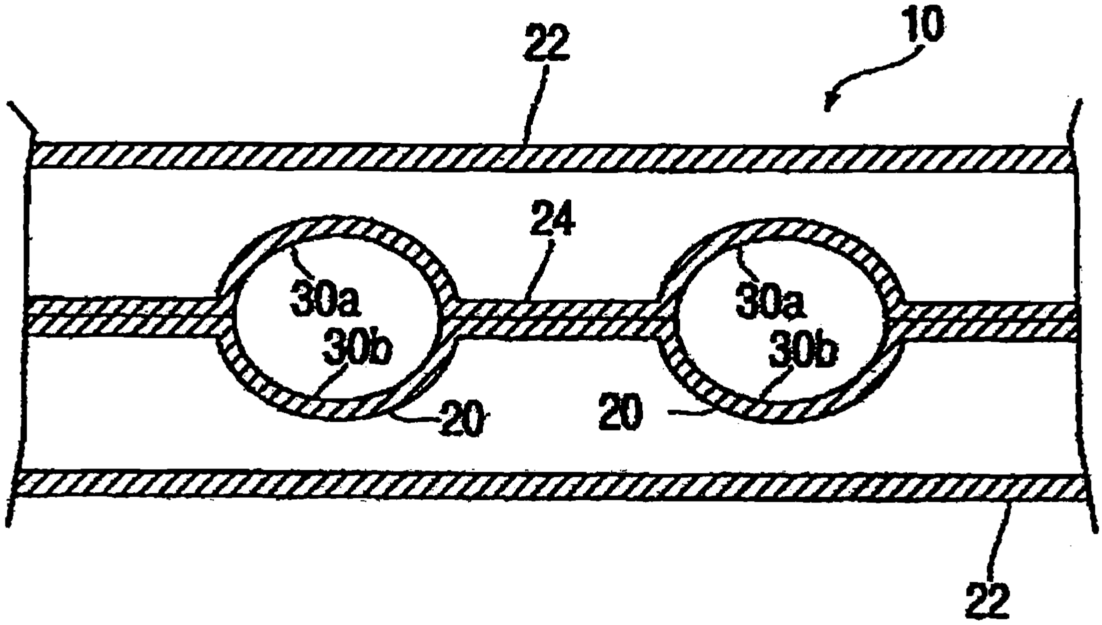


FIG.3

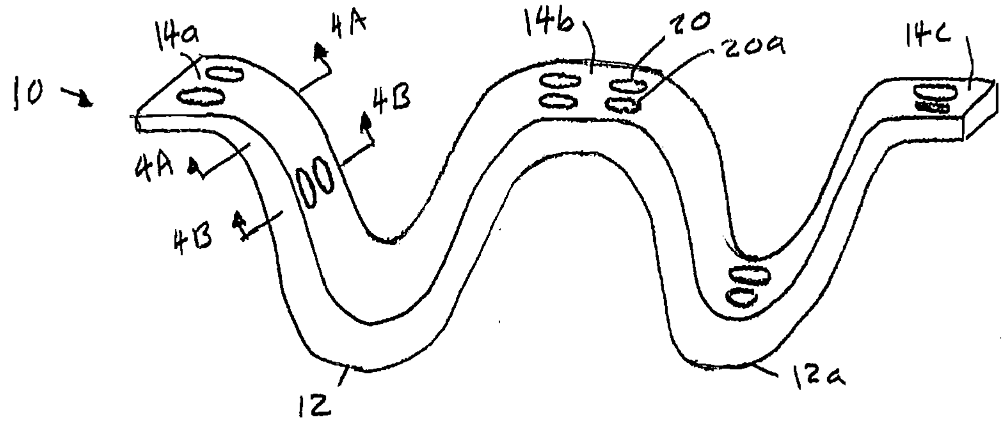


FIG.4

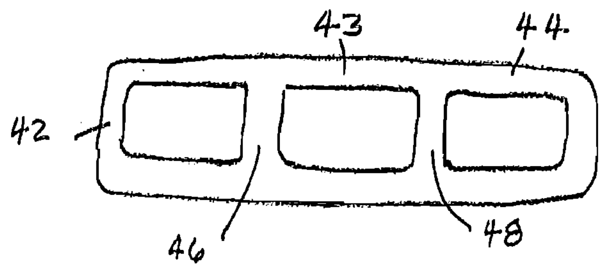


FIG.4A

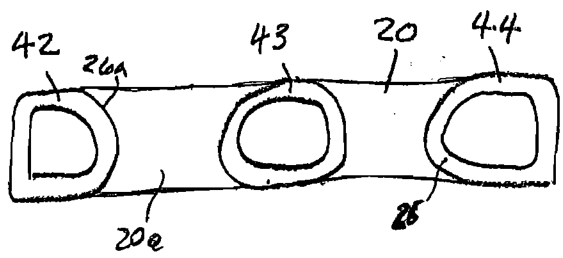
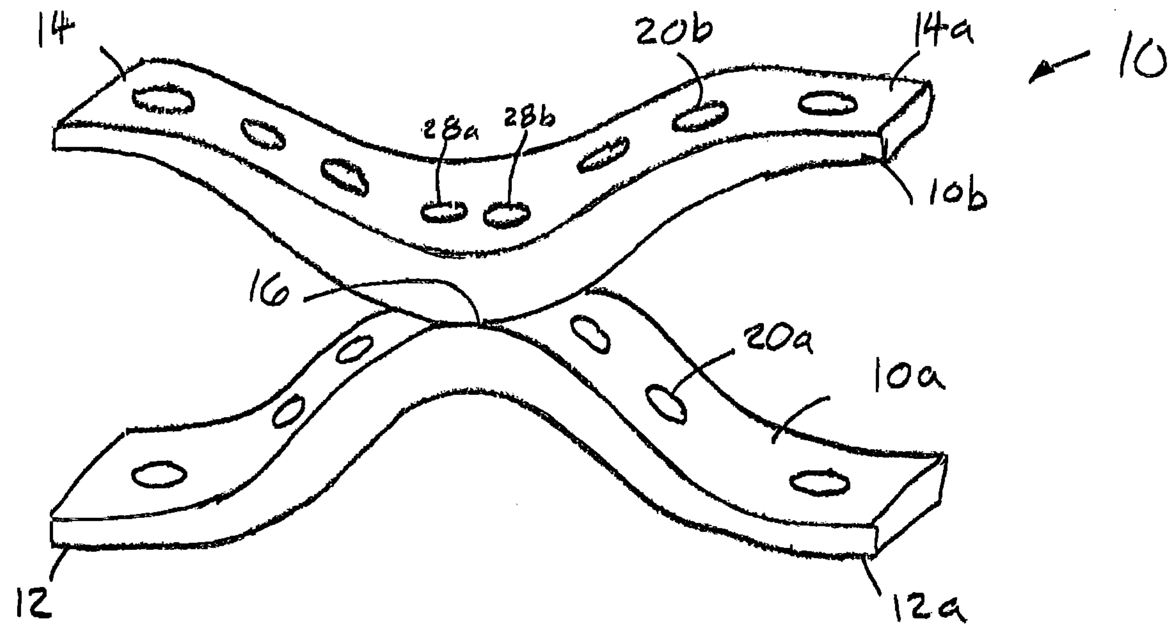


FIG.4B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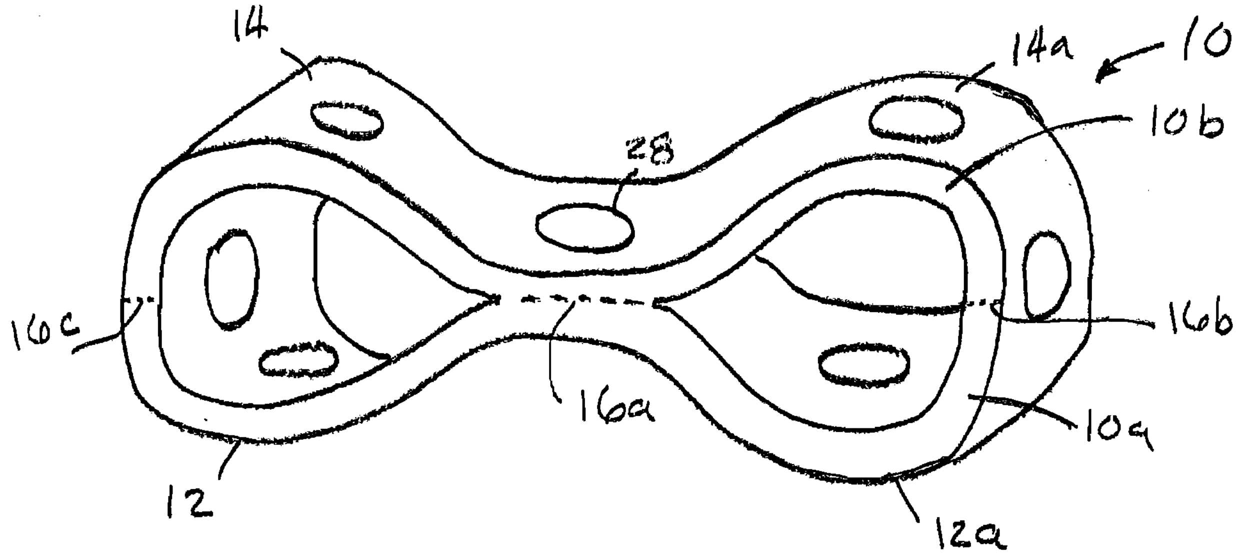
20b
14a
10
28a
28b
10b
16
20a
10a
12
12a

FIG.5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14a
10
10b
28
16c
16b
16a
10a
12
12a

FIG.6

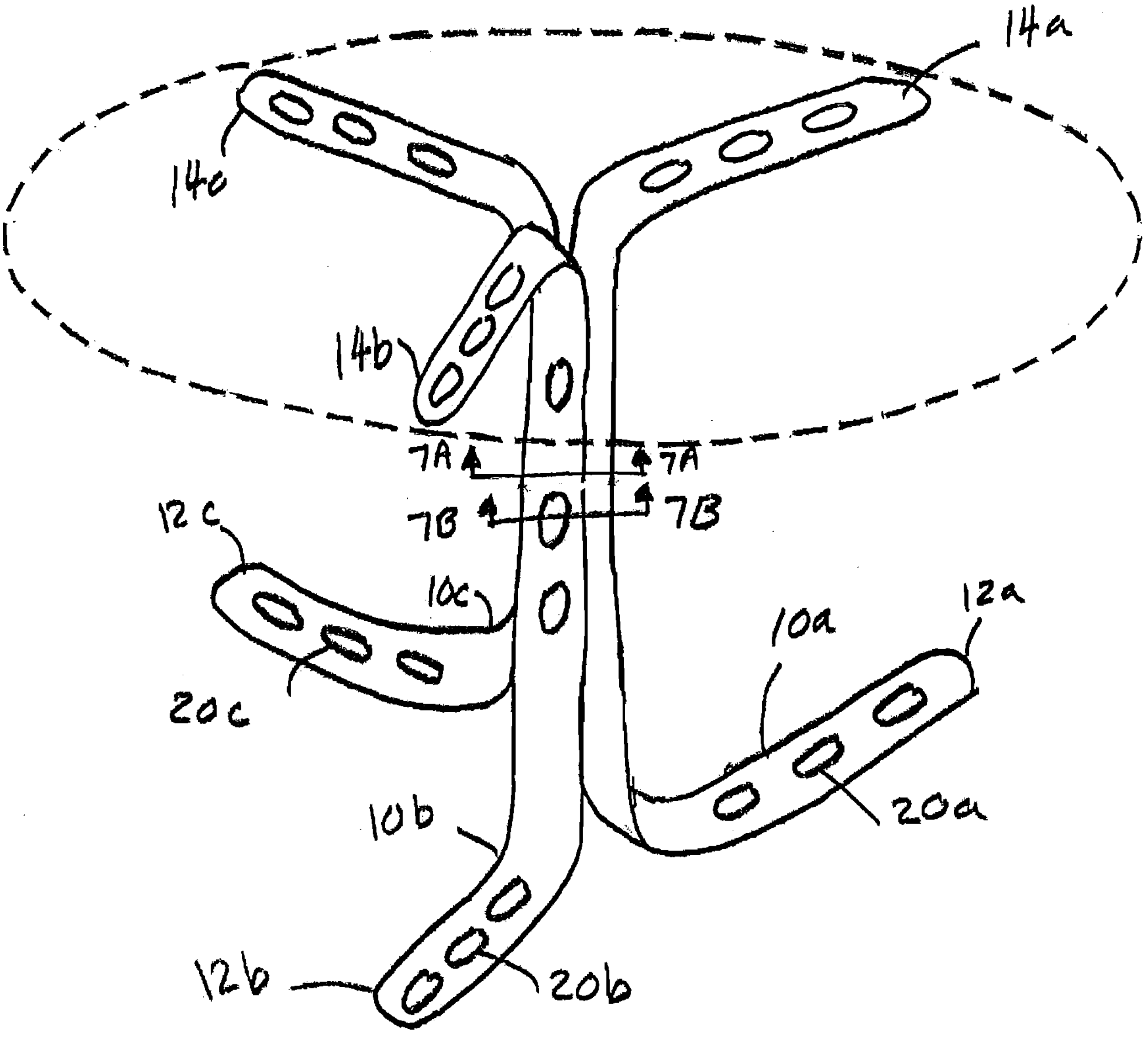


FIG. 7

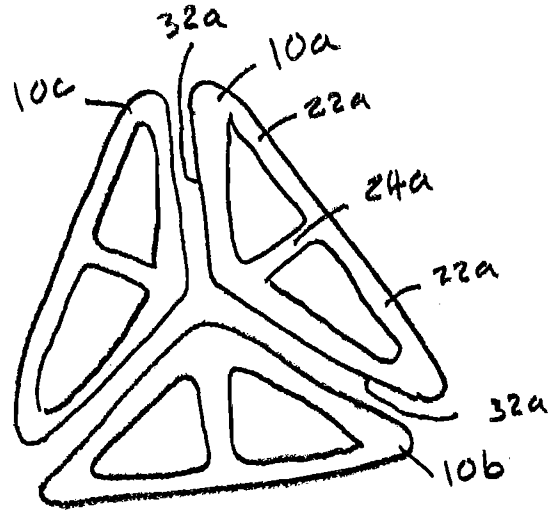


Fig. 7A

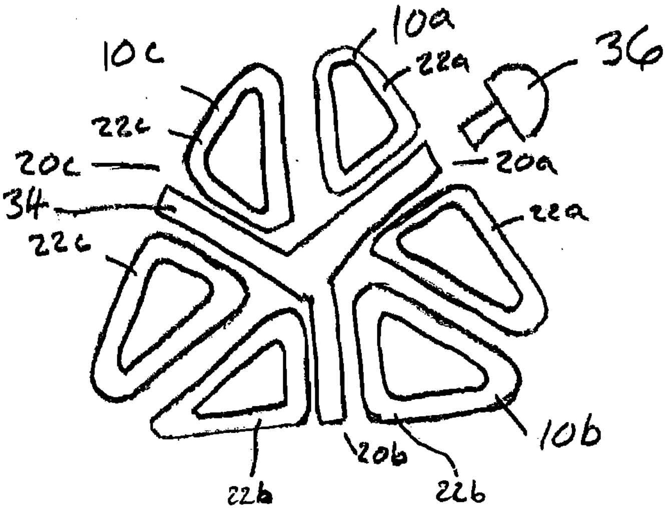


Fig. 7B

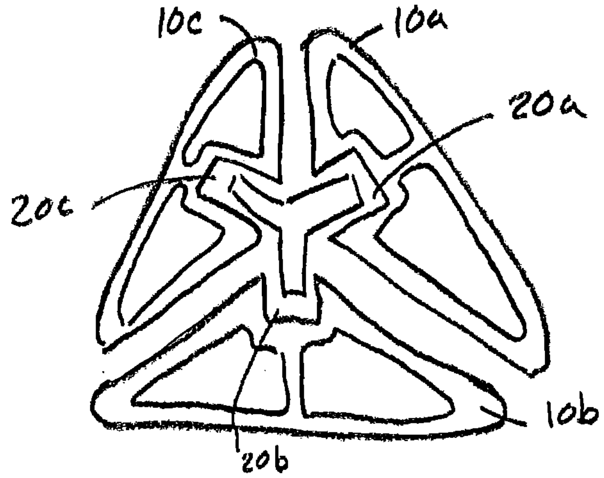


Fig. 7c

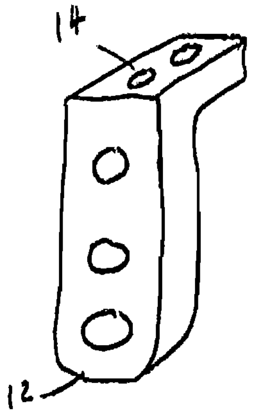


FIG.8A

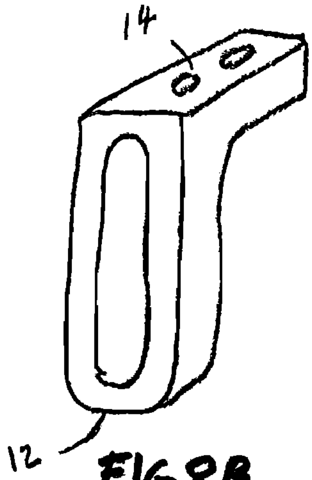


FIG.8B

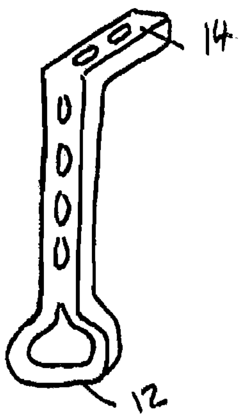


FIG 8C

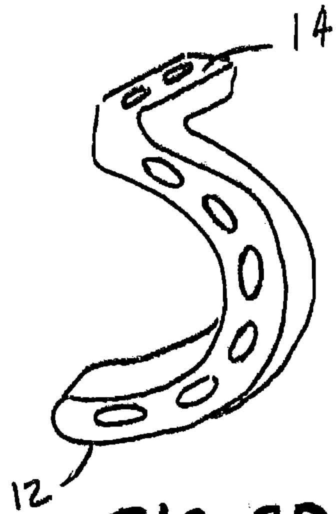


FIG. 8D

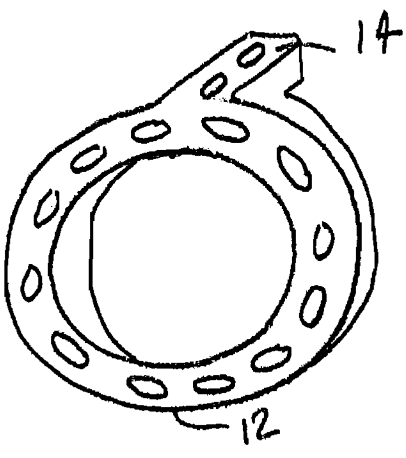


FIG. 8E

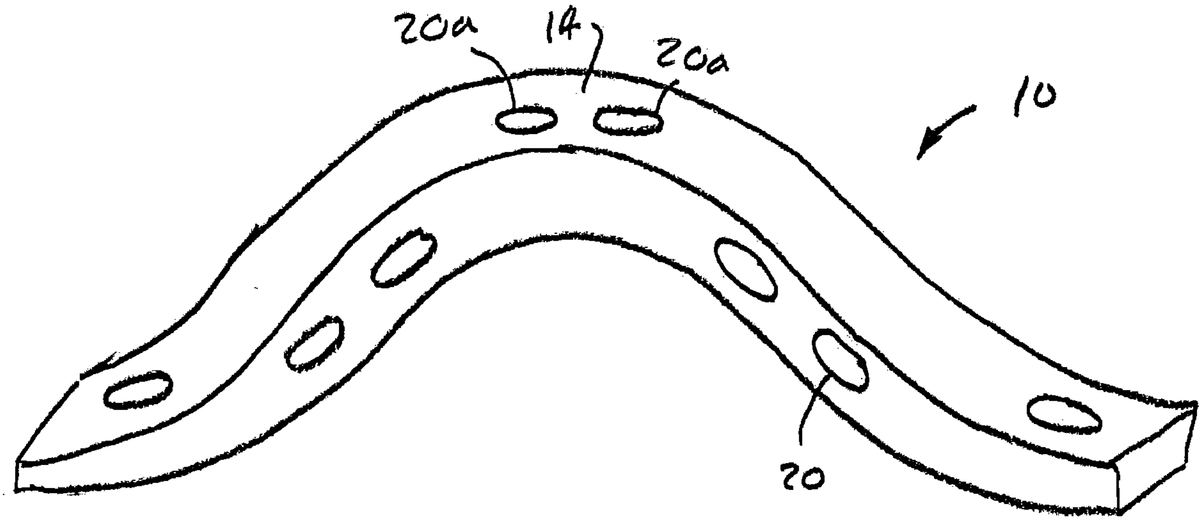


FIG. 9

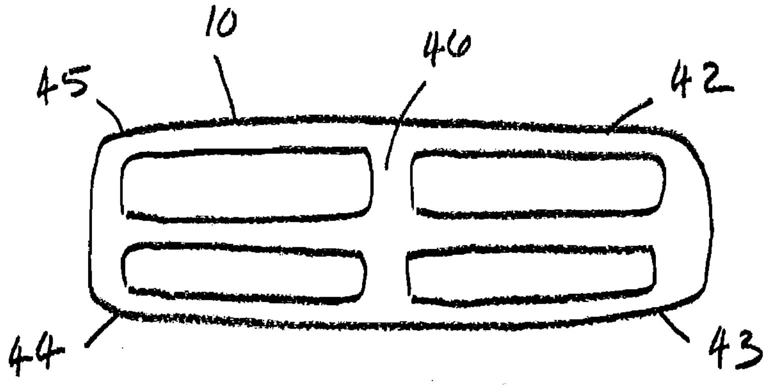


Fig. 9A

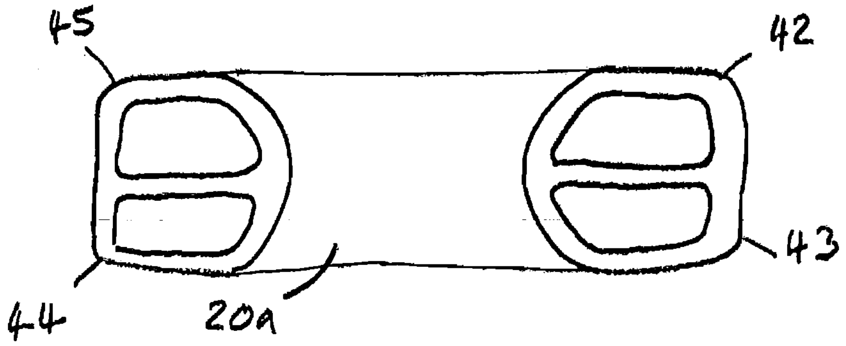


Fig. 9B

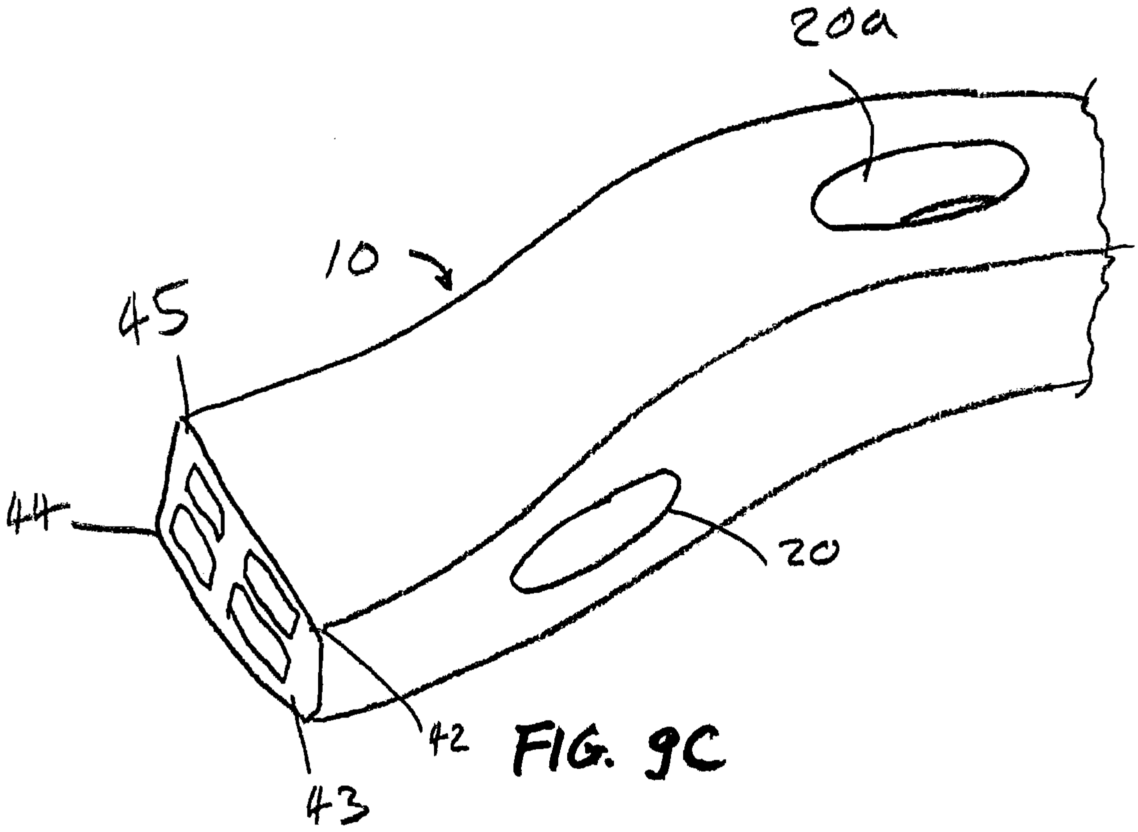


FIG. 9C

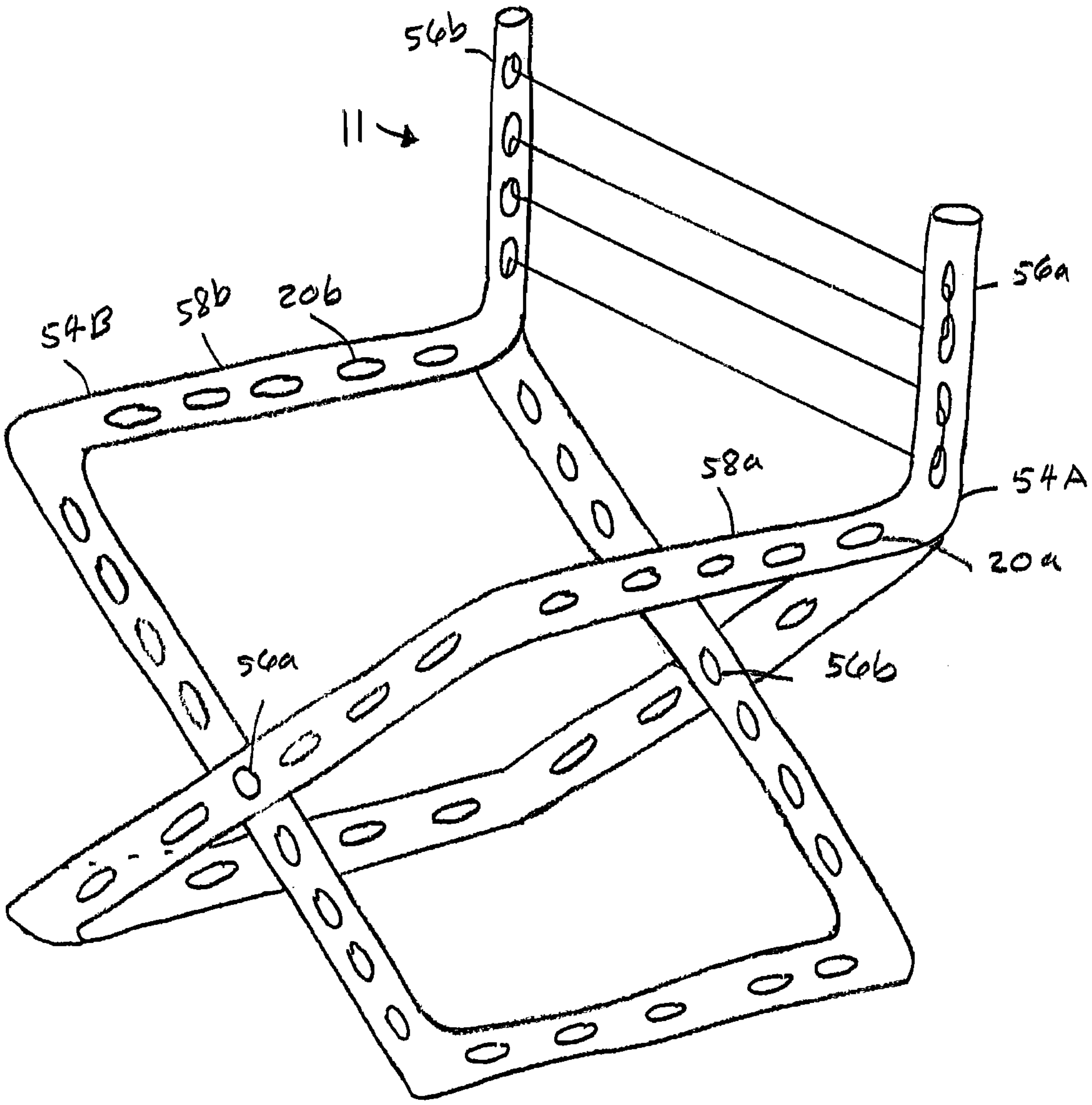


FIG. 10

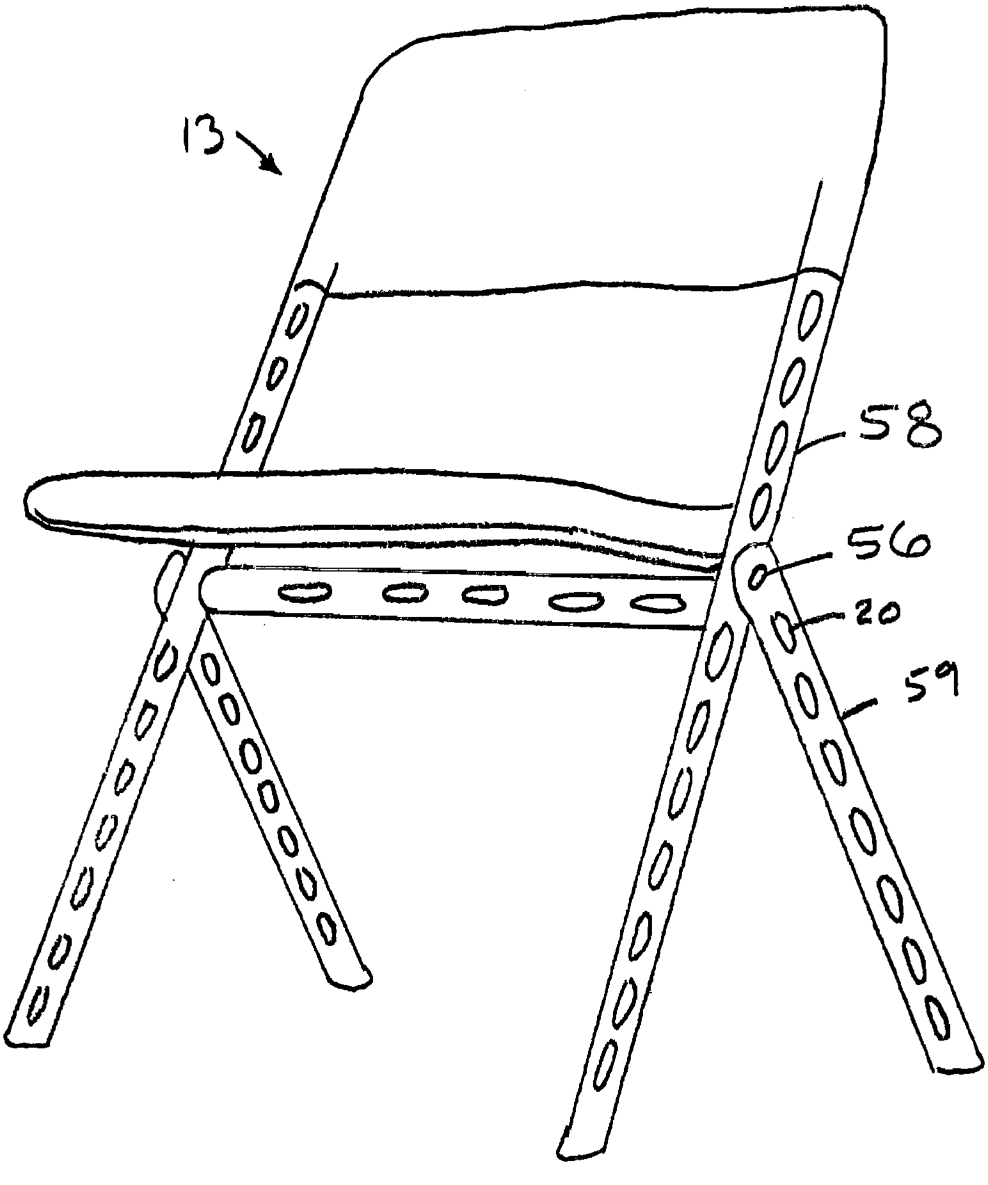


FIG. 11

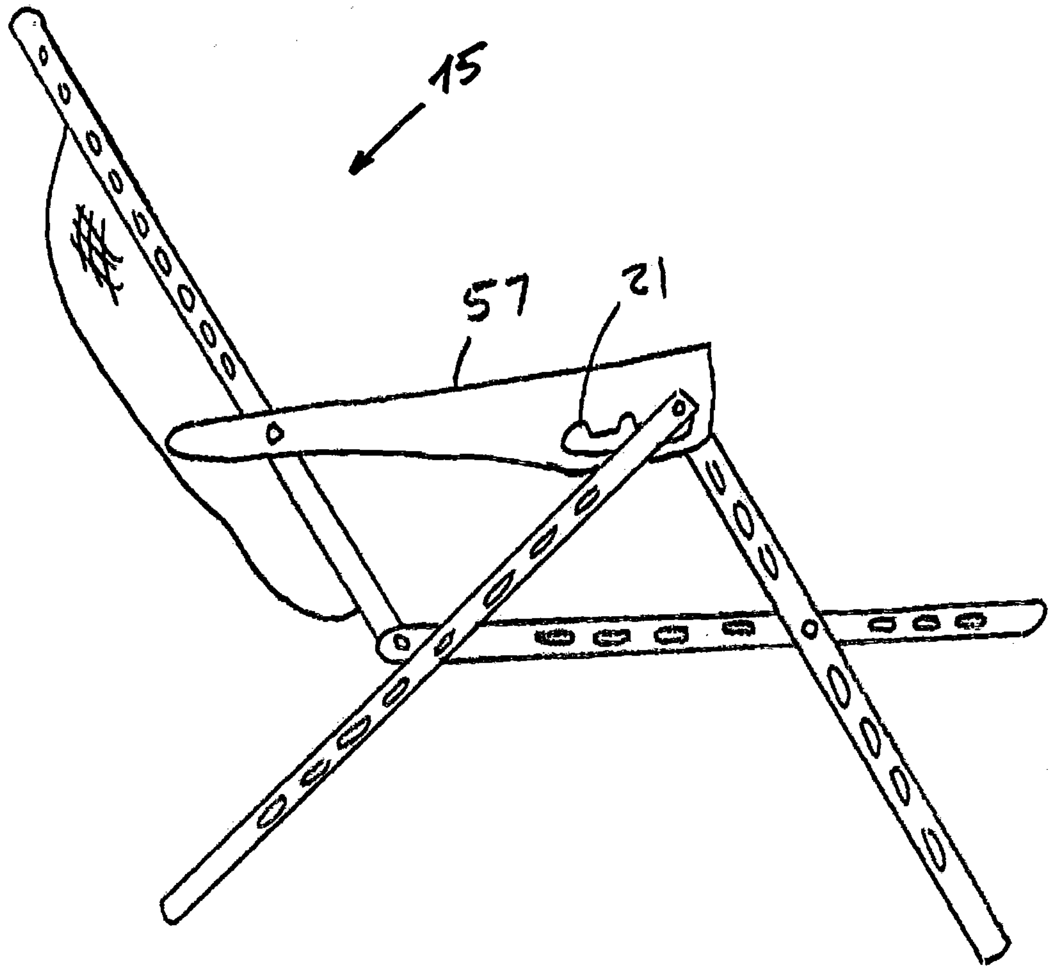


FIG. 12

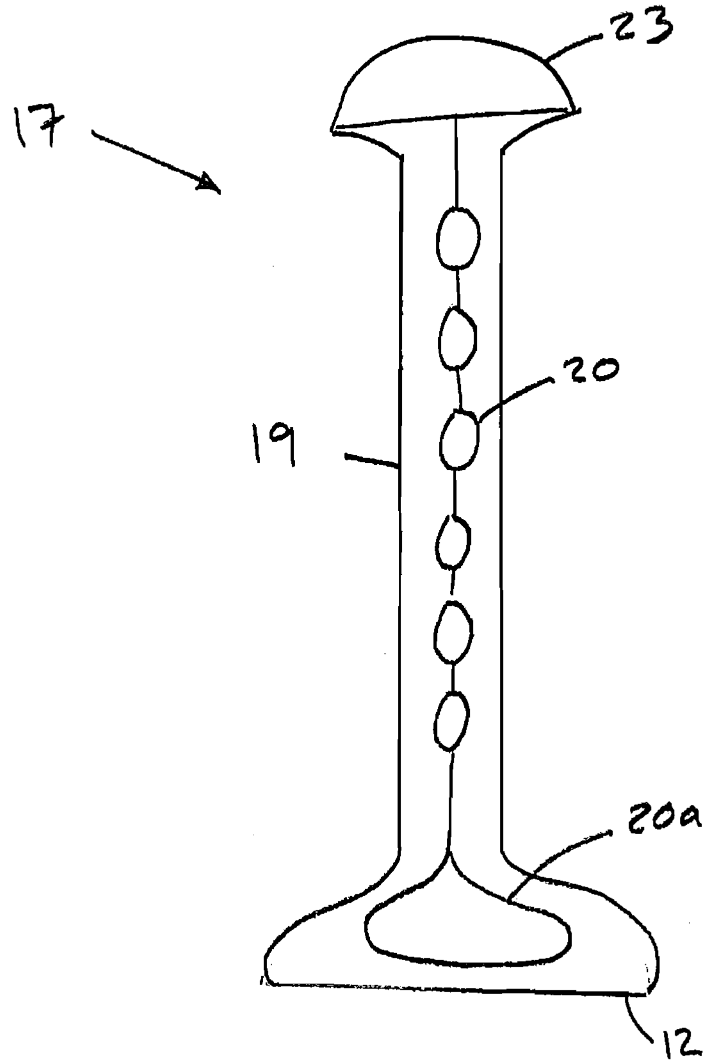


FIG. 13

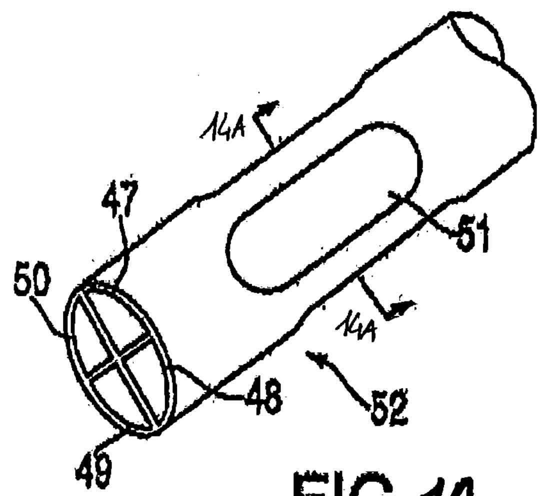


FIG. 14

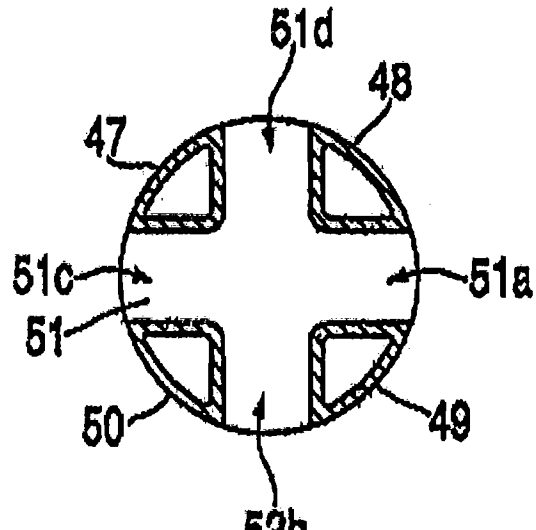


FIG. 14A

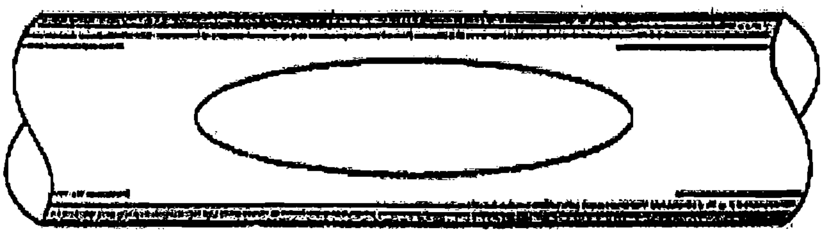


FIG. 15A

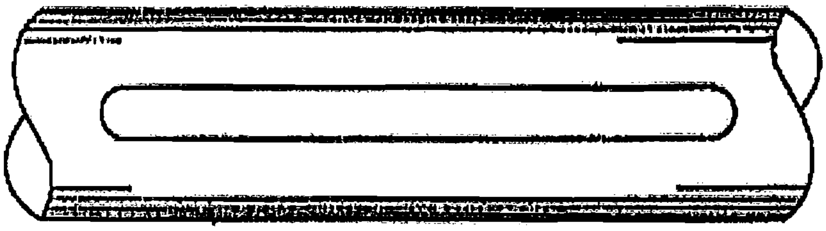


FIG. 15B

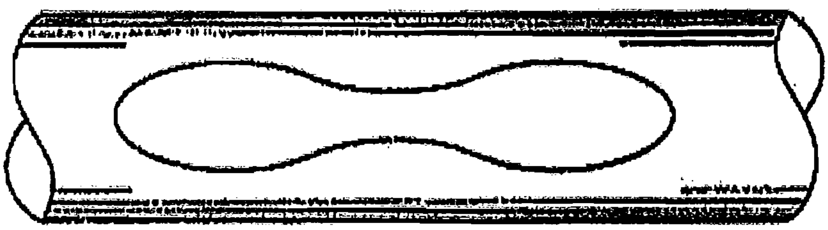


FIG. 15C

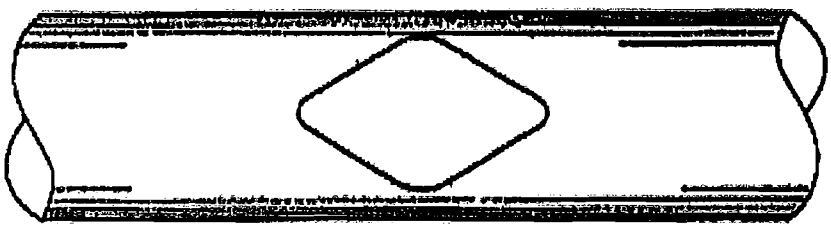


FIG. 15D

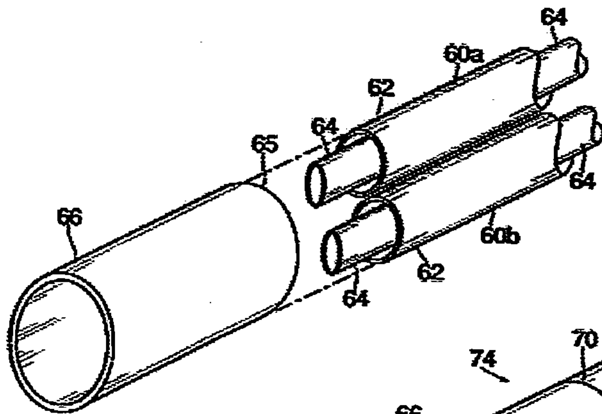
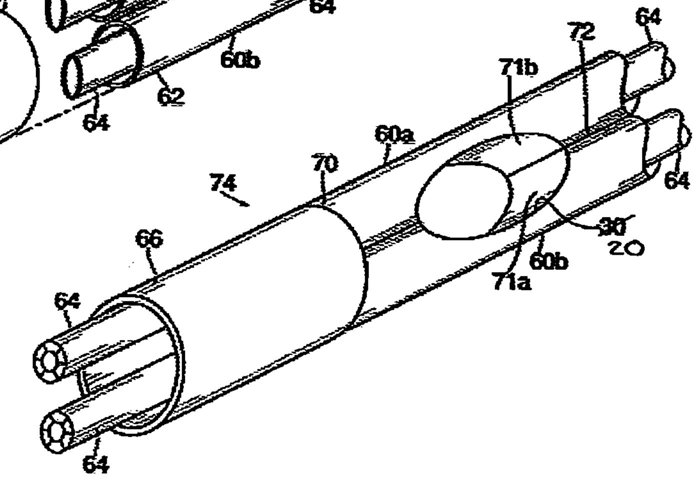

64
60a
62
64
65
64
66
60b
62
64

FIG. 16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72
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64
64

FIG. 17

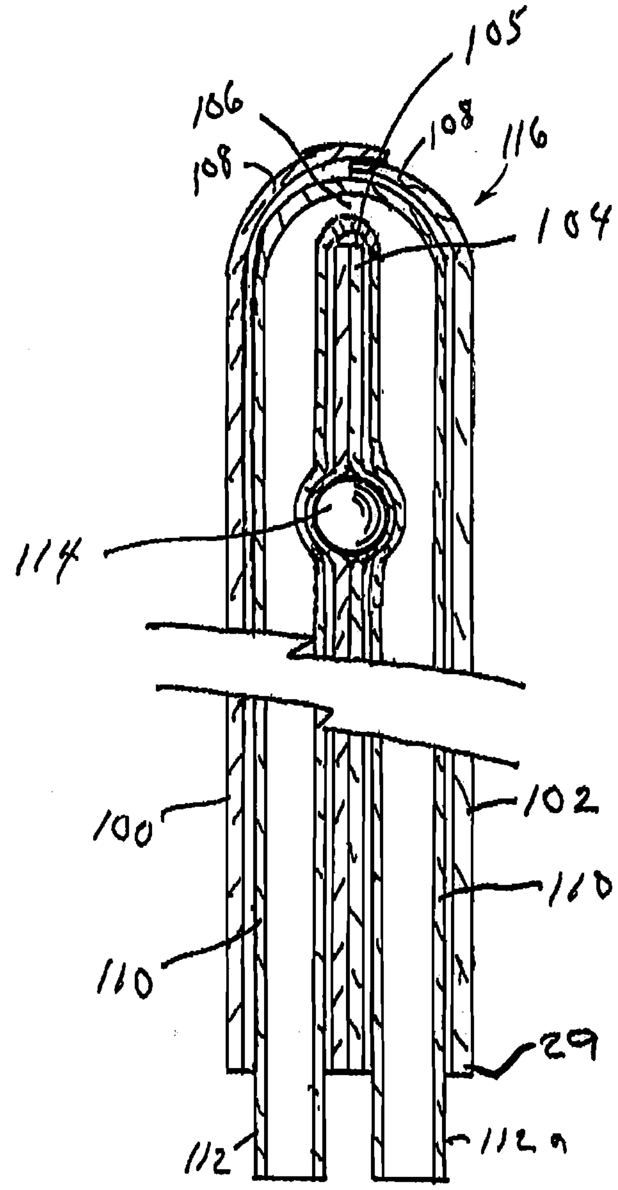

FIG. 18

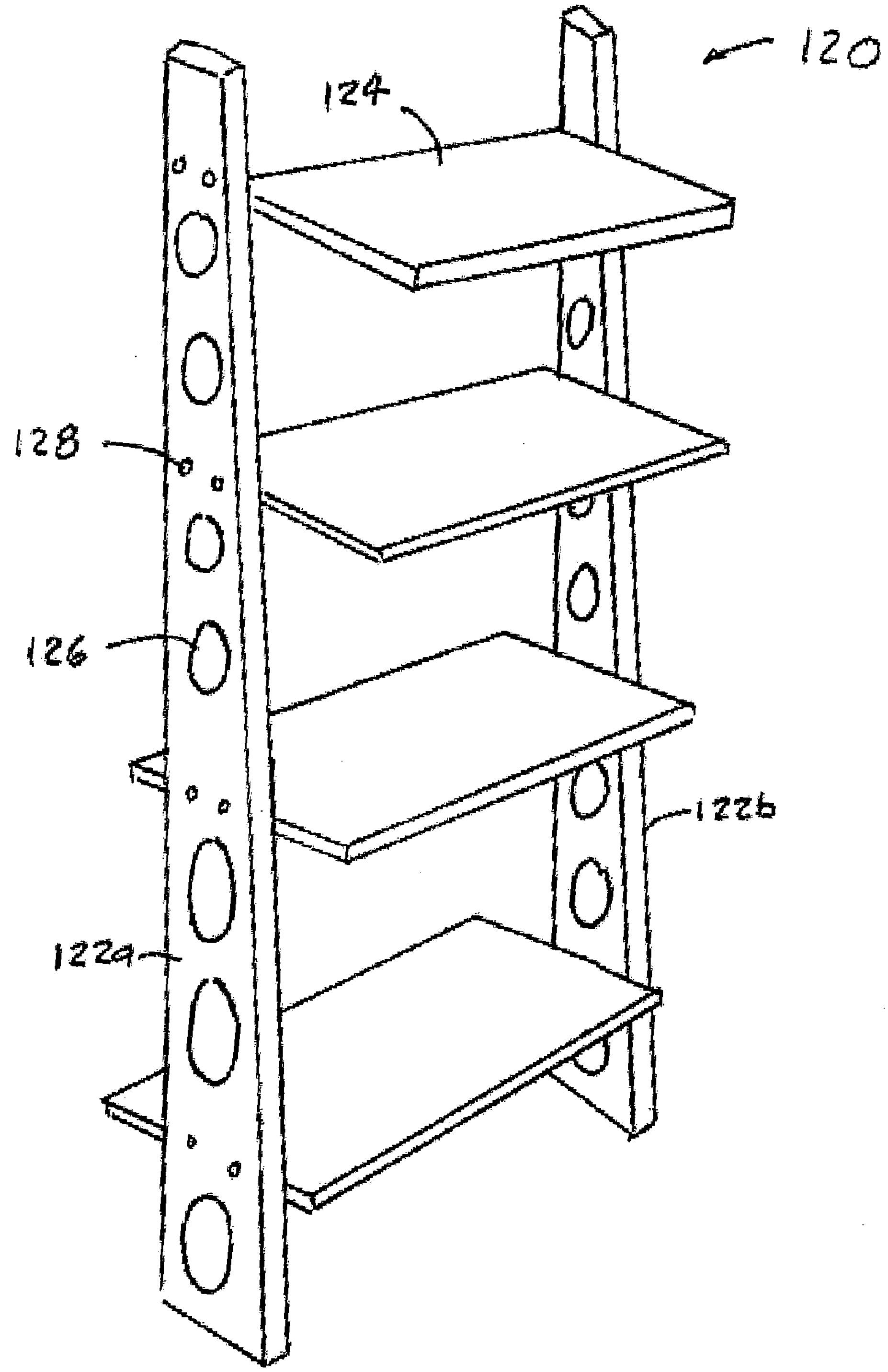

FIG 19

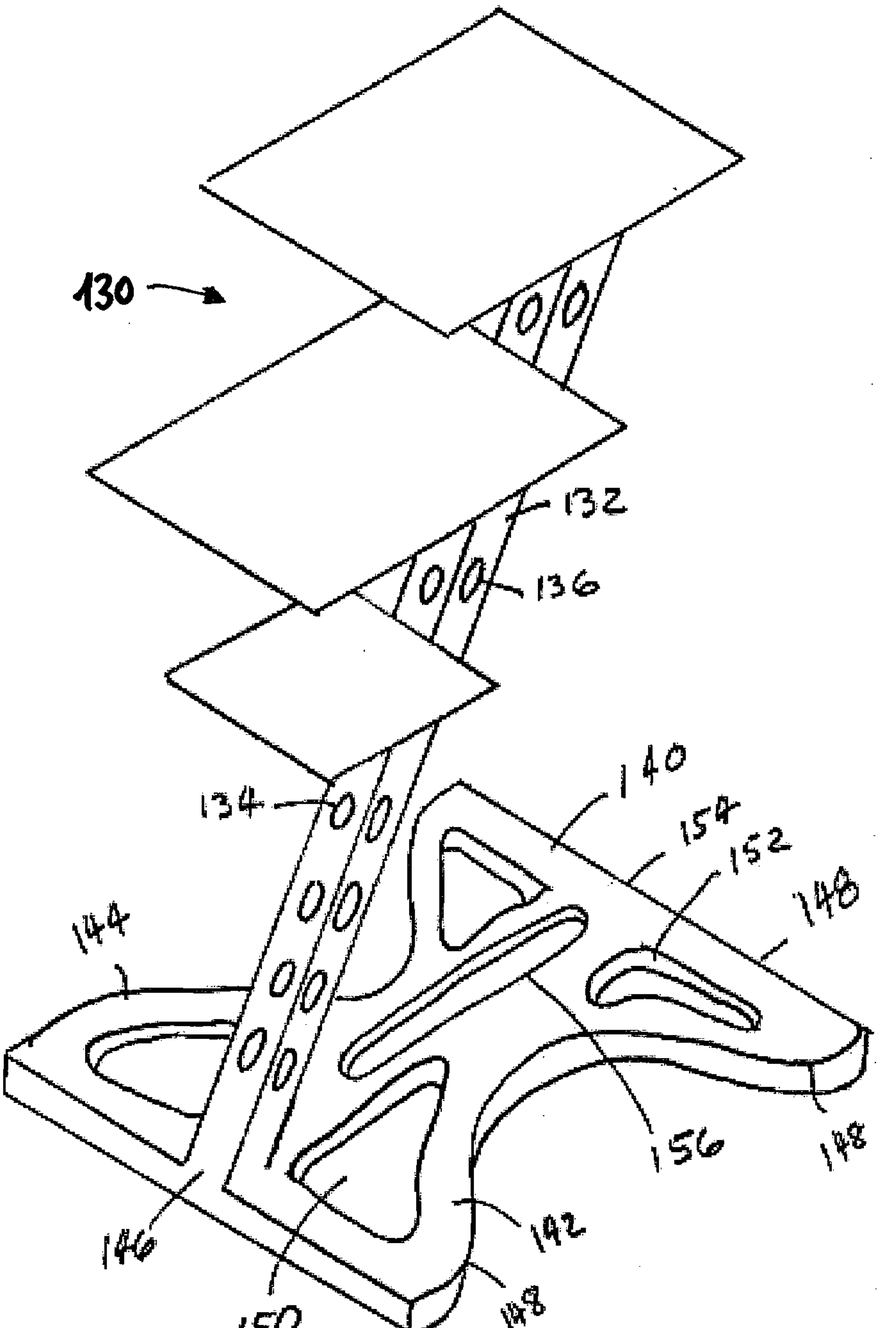

FIG. 20

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2007/052176

A. CLASSIFICATION OF SUBJECT MATTER
INV. A47C5/08 A47B96/14 F16B12/08 A47C5/12

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A47C A47B F16B A63B B29C B29K B60R F16S F21V F21Y F21W

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 00/09219 A (PRINCE SPORTS GROUP INC) 24 February 2000 (2000-02-24) page 11, lines 14-19; claim 1; figures 9,10,19	1,2,4-9
X	US 5 638 759 A (KLUGKIST) 17 June 1997 (1997-06-17) claim 17; figures 2,9,10	16
X	DE 34 08 175 A1 (MATJASIC) 12 September 1985 (1985-09-12) claims; figures	1,2,5-8
X	US 4 966 414 A (SCHWARTZ ET AL) 30 October 1990 (1990-10-30) abstract; figures	1,3,5-8, 10-15,18

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 February 2008	15/02/2008

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Kis, Pál

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2007/052176

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 079 053 A (CHANG) 7 January 1992 (1992-01-07) abstract; figures	1,3-8, 10-15,18
X	GB 2 337 453 A (DITTO SALES INC) 24 November 1999 (1999-11-24) page 12, paragraph 2; figures 4-12	1,17,19, 20
A	JP 2000 270932 A (ITOKI CREBIO CORP) 3 October 2000 (2000-10-03) figures	19,20
A	JP 2006 347073 A (TOYOTA IND CORP) 28 December 2006 (2006-12-28) abstract; figures	3
A	JP 2000 067637 A (OKAMURA MFG CO LTD) 3 March 2000 (2000-03-03) figures	20

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2007/052176

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			AU	5483099	A	06-03-2000
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