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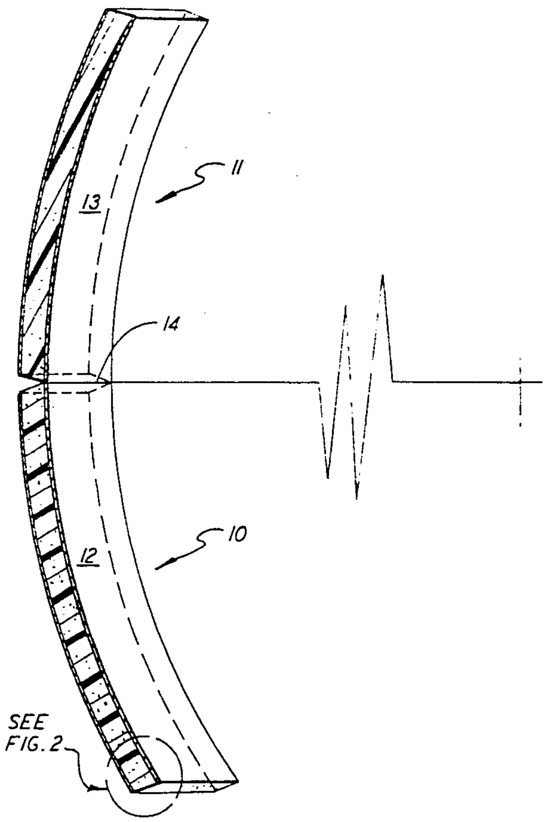
(57) Abstract

New structure for making a large screen or mirror, such as used in a vehicle simulator, whereby such large structure is divided into a plurality of, preferably, identical segments (10, 11). Each segment, then, is made on the same mold or pattern which ensures an accurate radius of curvature and that the edges of each segment will co-act with the adjacent segment in a laterally non-slipping relationship. By this structure, the curved surfaces co-act together to define a smooth larger surface. Each segment is formed of expanded polyurethane foam (17) with the two surfaces (12, 13 and 15, 16) treated in different ways, depending on the use to which the structure is to be put.



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SEGMENTED SCREEN CONSTRUCTION

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention, generally, relates to projected-image visual systems with screens and/or mirrors having large radii for exhibiting projected images and, more particularly, to a light-weight structure for a screen or mirror segment structure to cooperate with a plurality of similar segments in the construction of a larger projected-image structure.

In the construction of concave screens having large focal lengths, it is well known that it is important to avoid defects which can vary the focal point of the screen and become quite visible when an image is projected onto these screens. It is particularly important in large focal length mirrors.

The screens or mirrors for exhibiting projected images that have been used in the past, with curvatures of a large magnitude, have been difficult and quite expensive to produce. This is because of the unusually heavy weight involved with each segment not only due to the weight of each segment but due also to the support structure required to maintain the curvature faithfully.

Although such large projection structures have most every conceivable curved configuration, even to the provision of a complete sphere, varying the curvature of such structures has been neither convenient nor inexpensive. With present day emphasis on cost of construction, a screen or mirror constructed in accordance with the principles of the present invention will reduce the cost dramatically and will provide a structure that is useful, while providing a structure which admits of ready servicing to correct defects which develop from time to time.

Such large curved-surface structures for exhibiting projected images are found to be uniquely adapted for use in visual display systems for vehicle simulators and will be described in this connection. An important improvement in flight simulation and in similar display systems was achieved with the collimation of the displayed image, i.e., by making all image points appear to be at infinity. The problem of providing collimation is complicated by any requirement for a wide field of view, and optical systems are known which will provide collimated light for a wide field of view. However, such systems have not been capable of providing inexpensively collimated beams so wide that two or more trainees may view the scenes simultaneously.

2. Description of the Prior Art

In the prior art, numerous training and simulator apparatus have been constructed which embody a position from which a trainee or pilot can manipulate control and observe a response in a projected visual image. For example, the trainee or pilot is positioned in a mockup of a boat, submarine, airplane, tank or other vehicle, and when he manipulates controls, such as a wheel, stick or throttle, the observed visual scene responds in a manner which simulates corresponding movements of the training vehicle.

The prior art patents which are known to have relevant disclosures are as follows: 2,273,074, 3,607,584, 3,718,989, 3,998,522 and 4,124,277.

However, notwithstanding the extensive efforts that have been made in this field, there has not yet been shown a segment structure to co-act with a plurality of segment structures to form a larger structure with the degree of accuracy in its curvature that is required in the simulator field in order to develop the required realism in the projected scene. In addition, from the prior suggestions to divide a mirror surface into a "series of mirrors" or that a "screen is composed of a number of small screen surfaces", there is not one disclosure of how it can be done or how to do it inexpensively.

SUMMARY OF THE INVENTION

A principal object of the invention is to provide a new and improved structure for a segment which admits of co-acting with a plurality of segment structures to form a larger structure for exhibiting projected images with sufficient realism for use in a projected-image visual system of a simulator.

It is also an object of the invention to provide such a segment structure that is inexpensive to manufacture, yet maintains an unusually high degree of accuracy in the curvature of the assembled larger structure.

In a presently preferred form of the invention, a synthetic porous material, such as polyurethene foam, is cured to a predetermined density and having two surfaces spaced apart a predetermined distance, one surface having a curvature that is defined as accurately as feasible. The invention includes several different forms of means to attach and support a predetermined number of segment structures so that all of the accurately defined curved surfaces co-act together to form a smooth, continuous surface.

DESCRIPTION OF THE DRAWINGS

The foregoing, other and further objects, features and advantages will appear more fully from the detailed description of the presently preferred embodiments of the invention and from the appended claims, both viewed in conjunction with the accompanying drawings, where:

FIG. 1 is a perspective view, partly in cross section, of a segmented structure, constructed in accordance with the principles of the invention.

FIG. 2 is a detailed view of one end of FIG. 1.

FIG. 3 is a cross sectional view of a portion of two segments showing how they are attached and supported together.

FIG. 4 is a plan view taken along the line 4-4 in FIG. 3.

FIG. 5 is a view taken along the line 5-5 in FIG. 4.

FIG. 6 is a diagrammatic illustration of how two I-beams at 90° to each other, are fitted together.

FIG. 7 is a top view of segments assembled together in accordance with the present invention.

FIG. 8 is a view of the end of FIG. 7.

FIG. 9 is a view taken along the line 9-9 in FIG. 7.

FIG. 10 is a front view taken along the line 10-10 in FIG. 7 showing six matching segments assembled and attached together to form a curved section.

FIG. 11 is an illustration to a stand to assemble, align and test each section to ensure the smooth continuous curvature of a segment structure is maintained for an assembled section.

FIG. 12 is a vertical, perspective view showing part of a supporting structure for a plurality of segments.

FIG. 13 is a view in perspective, partly in cross section, of an entire sphere constructed of the segment structures, in accordance with the principles of the present invention.

FIG. 14 is a diagrammatic illustration of a manner of forming one segment structure, in accordance with the presently preferred form of the invention.

FIG. 15 is a diagrammatic illustration of a manner of forming another segment structure in accordance with the principles of the invention.

FIG. 16 is a diagrammatic illustration of the formation of still another segment structure in accordance with the principles of the invention.

FIG. 17 is a diagrammatic illustration of the formation of yet another segment structure in accordance with the present invention.

PRESENTLY PREFERRED EMBODIMENTS

While the description hereinafter relates to a structure which is uniquely adapted for wide-angle-display visual systems, particularly for simulator use, they may have other uses, as one skilled in the art will readily appreciate.

In accordance with the present invention, a curved mirror or screen structure is divided into any desired number of, preferably, equally sized segments. A reason for the present desire to have each segment of the same size is that it is contemplated that each segment is made from the same mold or on the same master, as will be explained in more detail presently, and the size of each segment is determined by choice as to the particular weight that can be handled and manipulated conveniently.

Each segment structure, made in accordance with the invention, is unusually strong and rigid in configuration, and having a low weight, it provides an exceptional degree of fidelity for the geometric curvature of the entire segment surface. The features of construction which contribute substantially to its low weight are the extreme thinness of the segment skin and the light weight of the segment body.

Although each segment is made of a tougher skin and, therefore, is more resistant to abuse, yet if the surface of a segment is damaged in any way, the entire segment may be removed and replaced easily, because of the particular construction of the segment and because of the particular means for holding and adjusting each of the segments relative to those adjacent to it.

Yet another advantage of a construction in accordance with the invention is that the unique structure of each segment effectively isolates the optical surface of a screen from the mounting surface. Since each segment structure is made from the same mold or pattern, it will match the adjacent segment perfectly, and thus, it will adapt readily to assembly into a larger configuration. On the other hand, each segment can be used as an entity if so desired.

In order to obtain maximum training value from vehicle simulators, the trend is to provide such simulators with a visual display system. Such a system can vary in complexity and sophistication from a fixed scene that is projected in the pilot's field of vision to computer-controlled image alteration systems with infinity image or CRT displays.

In the training of an aircraft pilot, costly flight training is avoided by providing a simulated cockpit of an aircraft wherein there is a simulation of many aspects of the environment within the cockpit of an actual aircraft. A portion of the training includes the utilization of a simulated visual scene from an aircraft.

The pilot uses the visual scene outside his cockpit most often during a take-off or a landing. Therefore, most simulators simulate the visual scene near an airport. In one type of simulator, a motion picture is made of the visual scene from an actual aircraft during a landing or take-off. The motion picture thereafter is projected through a complex optical system to provide a simulated visual scene in realistic perspective.

Due to the increased use of the visual system in simulators today, there is a real need for a field-of-view as large as possible, yet of a new, lightweight structure for use with a simulator. A structure in accordance with the present invention, uniquely fulfills this need. The unit weight of each segment of a mirror and/or screen that is constructed in accordance with the principles of the present invention approximates two to five pounds per square foot.

It is contemplated that only by the manufacture of each segment from the same mold, or from the same master, can the potential of uniformity and precision at a reasonable cost be realized. Any process of manufacture, that rests mainly on skilled labor to produce uniformity of geometry and finish, implies the risk of discontinuity in several aspects aside from probably prohibitive costs in producing a great number of segments. Moreover, the probability of mismatches when joining such variously made segments would be very high in spite of the close dimensional tolerances.

The present invention, in its broadest aspect, contemplates the manufacture of segments of a screen of larger dimensions by forming from the same mold individual segments of relatively large-area and substantially thin (when compared with its larger area), and of substantial strength, such as by the relatively new Reaction Injection Molding (RIM) technique. Such polyurethane structural foam has a high strength-to-weight ratio, when used with RIM production process, and produces a segment structure with an integral, solid skin and a micro-cellular core.

The polyurethane structural foam is the result of a balanced chemical reaction between a polyol and an isocyanate. In the reaction injection molding process, these liquid components are metered into a mixing chamber from which they are injected at atmospheric pressure into a closed mold. The mold is partially filled, depending upon the density of the finished product desired, and the mixture then expands to fill the entire mold space. The pressure developed during the foaming is relatively low, approximately 40 pounds per square inch.

Since polyurethane structural foam duplicates the mold surface, it is usual to have the mold surface as highly polished and smooth as possible. It is already light in color, and therefore, for most uses, further treatment for color is unnecessary. For uses where loads must be secured to the polyurethane structural foam segment, local reinforcement with metal inserts may be necessary.

These inserts can be foamed in place. For foamed-in-place inserts, the insert is fixed in place so that it does not move during the foaming phase. To improve adhesion between the segment and a metal insert, the metal surface is roughened and degreased.

For a simple, one-time connection, wood or self-tapping screws can be inserted directly into the polyurethane structural foam after it is cured. The screw pull strength is dependant upon such factors as screw size and pilot hole diameter. Screws should only be used in those segments with an overall density higher than 25 pounds per cubic foot.

The mold temperature must be controlled closely and precisely to obtain the results desired, i.e., the particular degree of density within the foamed material when it is cured. This density of the foamed material is the primary factor in determining its weight as well as its strength, and therefore, it is desired to have a low density in the center of the material, which density becomes increasingly higher (or more dense) as one proceeds toward the surface of the material. This temperature is controlled by maintaining its variations between two degrees C., making it essential to use only good heat conducting molding materials. Tempered water is used as the best medium for controlling this mold temperature.

It is important to note that the information concerning the polyurethane structure foam is furnished for the benefit of the artisan attempting to follow the teachings of the present invention, and, in and of itself, forms no part of the present invention. It is the structure of the particular segment that is the inventive feature here. Accordingly, the invention should in no way be limited to the particular plastic material used to form the basis of the segment, in that other, different and various materials may be used, as better within the purview of an artisan skilled in that art.

For example, in place of polyurethane foamed structures, reinforcing with carbon rather than glass fibers may be more effective for some uses, even though carbon fibers are much more costly. Another particular material is a percentage glass-reinforced polycarbonate, or a polyphenylene oxide structural foam may be used.

Of course, many other materials may be known to an artisan skilled in this art which might be appropriate for use in a particular segment structure, and still other and different materials might be available in the future. Accordingly, it is understood that the present invention is in no way limited to the particular material described in this presently preferred embodiment.

One alternative arrangement of materials with which a construction in accordance with the principles of the invention is uniquely adapted to be effective utilizes a segment formed of a suitable synthetic porous material with an appropriate metal, such as aluminum, nickel and the like, electro-formed on the optical surface in a very thin layer. There are companies today quite skilled in the electro-forming process.

Referring now to FIG. 1 of the drawings, the reference numeral 10 identifies one segment of a larger structure, and the reference numeral 11 identifies a second segment of the same structure, the segment 11 being identical with the segment 10, having been formed on the same mold or pattern. The optical surfaces 12 and 13 of the segments 10 and 11, respectively, are continuous and smooth, particularly at the line 14 where they join, and have a large radius of curvature. These surfaces 12 and 13 are appropriately formed to reflect an image which is projected thereon as in a normal simulation apparatus.

FIG. 2 of the drawings is an enlargement of one corner of the segment 10 in order to reveal its construction with more particularity. For example, it may be seen in FIG. 2 that the surface 12 is actually formed by a separate skin 15 which is identical to, in this particular embodiment of the invention structure, a second skin 16 spaced apart therefrom and sealed thereto by a plastic foam filler 17. The two skins 15 and 16 are relatively thin, preferably a typical example would be .031 inches max., as compared with a thickness of 2 inches between the inner surfaces of the skins 15 and 16. The plastic foam filler 17, which is foamed in place, bonds and, therefore, adheres readily to the inner surfaces of these two skins 15 and 16.

The two segments 10 and 11, as stated previously, are shown in FIG. 1 positioned approximately correctly relative to each other to form a smooth, continuous surface, without there being shown any means for holding them in this position. In FIG. 3 of the drawings, there is shown a way, presently preferred, of attaching these two segments together to support them in this position.

Referring now to FIG. 3, a type of insert 21 shown imbedded in the foam 22 adjacent the upper edge of the uppermost segment is shown with a flange 23 which may be any desired configuration, such as circular, square, octagonal, etc. Moreover, the flange 23 may be perforated with one or more rows of apertures 24 if desired, or it may be solid, it being a matter of the strength desired to be held by the insert 21.

The insert 21 also has a body 25 which may be any desired configuration, and the body 25 may have a series of raised surfaces 26, like deep threads, in order to give it more resistance to extraction from within the foam 22. The insert 21 has a centrally located aperture 27 in which a bolt 28 is threaded against a washer 29. Disposed between the head 30 of the bolt 28 and the washer 29 is a lock washer 31 in order to further secure the bolt 28 firmly in place. The body 32 of the bolt 28 fits within an enlarged clearance opening 33 which permits adjustment of position for the segments, as will be explained in more detail presently.

The lowermost segment structure, as viewed in FIG. 3, has a solid skin 18 on the back or reverse side thereof for the rigid, lightweight porous core of synthetic foam 20, and it has, also, a skin 19 on the opposite surface which may be of a different material from that of the solid skin 18, but the skin 19 must be solid and tough, as must be the skin 18. In this view of the inventive structure, the skin 19 is highly polished, more reflective, mirror-like finish, such as aluminum with a protective coating thereon. Alternatively, it can be a very thin glass plate, or it can be plastic, in order to achieve a highly reflective quality.

An insert 34 that is shown near the edge of the lowermost segment in FIG. 3 has a body 35 with a plurality of dull or rounded serrations 36 along its length to increase its resistance to extraction from the foam 20. An aperture 37, located centrally within the insert 34, opens externally through the skin 18 to receive a threaded end 38 of a bolt 39. The bolt 39 has a head 40 which squeezes and firmly grips a lock washer 41 against a plain washer 42.

The bolt 39 has a main body 43 which extends from the head 40 to the threaded end 38 and which fits within an enlarged clearance opening 44, the purpose of which will be explained in more detail presently. Both of the clearance openings 33 and 44 are located in a flange 45 of the I-beam 46, with a matching flange 47 spaced a predetermined distance from the flange 45.

A plurality of U-shaped spacer washers, indicated by the reference numerals 48 and 49, serve to space the flange 45 from the skins 18 and 18', which may vary from point to point because the skins 18 and 18' are curved into a predetermined shape, as viewed best in FIG. 1 of the drawings. Accordingly, since the I-beam 46 is contemplated as being only slightly curved and not necessarily curved to match the configurations of the segments, the flange 45 will vary in distance from the skin 18' at various points across its length.

It is important to note a space 50 located between the flange 23 of the insert 21 and the inside surface of the skin 19'. One reason for this space is to permit the foam 22 to enter and seal the insert adhesively to both the inside surface of the skin 19' and, thereby, fixedly position the insert 21. However, an even more important reason for this space 50 is to prevent any distortion in the surface of the thin skin 19', which would occur if it touched on the inside surface, because the skin 19' is so thin that any object touching on the inside surface would be visible through it and would cause optical aberrations on the face viewed.

Another important feature seen in this FIG. 3 is the space 51 between the adjacent edges of the skins 19 and 19', which is typical of the gap between adjacent skins all the way around each segment. The space 51 is small, in the order of .030 inch ± .003 inches, and is for the purpose of preventing any chipping as would occur if the skins 19 and 19' are glass and they touched.

To fixedly position adjacent segments with the spacing, as indicated by the space 51, a suitable resilient separator, preferably a silicone plastic, is injected into a space 52 and molded in place upon the completion of the assembly, as will be described in more detail presently. This will fixedly secure the two segments adjacent each other, preventing their touching with a solid impact sufficient to chip the edge of a surface.

As better seen in FIGs. 4 and 5, a dowel pin 53 fits snugly into a hole 54 drilled all the way through the flange 45 of each I-beam, the spacers 48 and into the body 25 of the insert 21. The manner of fixing these dowel pins, such as the pin 53, preferably two per segment, will be described in more detail presently. However, just briefly, once the segments have been adjusted carefully to fix the space 51 between them, as in accordance with the desired dimension given above, the bolt 28 and the bolt 39 are tightened. Then, while the segments are being thus held in place, a hole is drilled such as the hole 54, in FIG. 5, and the dowel pin 53 is driven into place, thus fixedly securing the dimension 51. A similar pin 55 is shown for the insert 34, in FIG. 4.

The I-beam 46 extends continuously past the two sides 56 and 57, respectively, is best shown in FIG. 4 of the drawings. The fillet weld 58 is shown on each side of the side 56 and also on each side of the side 57 to join these two to the I-beam 46. In FIG. 5, the fillet weld 59 is shown to join the side 56 also to the horizontal flange 45 of the continuous I-beam 46.

In FIG. 6 of the drawings, there is shown how two I-beams are joined together perpendicularly. The bottom flange 60 of the I-beam 62 is cut off along a line 63, and in like manner, the top flange 64 is cut off along a line 65, leaving a projecting extension 66, which is that portion of the body 62 that extends past a line drawn between the line 63 and 65. As best seen in FIG. 6 of the drawings, an extension 66 is formed by that part of the body 62 which remains after the upper and lower flanges, 64 and 60, respectively, are cut off back to the respective lines 65 and 63. The edge 67 will touch against the surface 68 of the I-beam 46 just when the line 63 touches the end 69 and the line 65 touches the end 70. Thereafter, firm joints may be made by suitable welding, or any other suitable attaching means.

Referring now to FIGS. 7, 8 and 9 of the drawings, it is shown how a plurality of segments are joined together to form a "section" having a desired number of segments. FIG. 7 shows more particularly a top view of a section having three segments 71, 72 and 73, respectively. However, also visible in FIG. 7, is a portion of three additional segments 74, 75 and 76, joined also to the segments 71, 72 and 73 along a line indicated by the reference numeral 51, identified more particularly in FIG. 3 of the drawings. This same reference numeral 51 is used here to indicate that the spacing, in the order of .030

inches, is common between all segments, generally. In addition, the same reference numeral 51 is used to indicate the spacing between adjacent segments 71 and 72; and between adjacent segments 72 and 73.

While I-beams are utilized in these respective Figures for the purposes of this illustration, there are available alternative forms of construction to affix adjacent segments to each other rigidly and to provide the necessary overall support. Such an alternative is shown in FIG. 8 of the drawings as being an alternative to that end referred to and identified in FIG. 7.

In FIG. 8, two channels 77 and 78 are bolted together as illustrated by the straight lines 79 and 80, respectively. With the channels 77 and 78 firmly affixed to each other, the resemblance to an I-beam is present.

However, having the so-called I-beam in this form of structure, i.e., the two channels 77 and 78, admits of another means to space the two segments with respect to each other in order to accurately obtain the spacing 51. By way of example, the channels 77 and 78 may be affixed at the borders of the respective segment structures, and then, when the two segments are positioned next to each other and when the spacing 51 is established, a washer or other suitable spacer may be placed within the gap 81, before the channels 77 and 78 are bolted together at 79 or 80.

FIG. 9 is a side view of this section, but taken along the line 9-9 in FIG. 7. It illustrates the effectiveness of the I-beam superstructure for supporting the individual segment structures 73 and 76 in relation to each other in order to firmly affix the space 51. In this side view of the section, the space 82 is clearly visible between the lowermost flange 83 of the bottom-to-top I-beam 84.

It is contemplated, although not essential, that the vertical I-beam 84 is the continuous one, whereas the side-to-side I-beams are arranged to abutt in a manner as shown in FIG. 6. In this FIG. 9, the lowermost I-beam is identified by the reference numeral 85, whereas the uppermost I-beam is identified by the reference numeral 86 and the intermediate I-beam is 87. Also as shown in FIG. 9 are four spaces identified from top to bottom as 88, 89, 90 and 91.

Whereas the view in FIG. 9 includes approximately 40 degrees, the top view shown in FIG. 7 includes approximately 60 degrees.

FIG. 10 is a full frontal view of the assembled section as shown in FIG. 7 of the drawings, taken along a line 10-10 in FIG. 7. In this view, each segment is identified by reference numbers 71, 72, 73, 74, 75 and 76. It is contemplated that the vertically positioned I-beams, identified by reference numerals 92, 93, 94 and 95, in FIG. 10, are continuous, as viewed in this Figure, as contrasted with the horizontally arranged I-beams 96, 97 and 98, from top to bottom, which are intermediate of the vertical I-beams and are attached together as illustrated in FIG. 6.

Also shown in FIG. 10, for the segment 75, there are indicated four crosslines and identified by the reference numeral 99 to illustrate that in each of these positions, a cast-in-place insert is positioned during formation of the segment structure and used to facilitate carrying by temporarily attaching a suitable handle (not shown). It is contemplated that each segment structure, manufactured in accordance with the invention, that is of sufficient size to make handling otherwise awkward, such cast-in-place inserts may be so included.

Since each of the segment structures are constructed and formed from the same identical mold, they are identical in size and in arcuate shape. A predetermined number of such segments are assembled together to form a shape somewhat larger (such as that shown in FIG. 10) and is called a "section", for the purposes of this description. A "section" is assembled of a desired number of the "segments", and any convenient method may be used in such assembly.

As shown in FIG. 11 of the drawings, a convenient way of assembling these segments is on a large table 100, having an upper surface 101 in order to support the structure being assembled. By a series of vertically positioned members 102 with suitable braces 103, the table 100 is supported in an elevated position relative to a floor surface 104.

In this illustration, there are three segment structures visible on the table 100, they being segments 105, 106 and 107, in order to form a section 108. By a suitable gauge (not shown), the space 51 is set by adjusting the position of adjacent segments. Then, a suitable resilient separator (such as a fluid silicone mixture) is injected and molded in place, as described in connection with FIG. 3. Since each of these segments are supported vertically on the table 100, once the silicone mixture is set, the gauge may be removed because there are no forces acting upon each segment structure to alter the spacing.

Various I-beams, or other segment support structure, are arranged within the space identified by the reference numeral 109 and supported appropriately on the upper surface 101 of the table 100. Then, a plurality of individual segments (three being visible in this view, 105, 106 and 107) are attached to the I-beams, as explained in connection with FIG. 3, supra.

As is well known, an important factor in the cost of any material ordered from a vendor is dependent directly upon the degree of tolerance specified when ordering the material. Therefore, while the I-beams are ordered to a desired curvature, the tolerance may be in the order of ± 1/2 inch, and the deviations from the desired curvature are compensated for by spacers, indicated by the reference numerals 48 and 49 in FIG. 3 and the spacers 48 and 49 being U-shaped permits them to be slipped into place about the respective bolt without removing the bolt.

By any suitable structure, a hook indicated by the reference numeral 110 is located and fixedly positioned a distance from the surface of the section 108 equal to the radius of its curvature. A suitable radius gauge is formed by having a non-extensible member 111 to accurately position a plumb 112, having a plastic or other soft tip, an accurate distance above the surface of curvature for the section 108. Then, by moving the plumb 112 about the surface in any desired direction, any deviation in the curvature of the section 108 will become apparent immediately.

A structure identified generally by the numeral 113 serves to provide the non-extensible member 11 with the desired length. It is important that the hook 110 be fixed positively, as well as accurately, and to accomplish this, the structure 113 has surfaces 114 and 115 which are flared apart upwardly until they reach a surface 116, such as a ceiling or, as seen in this view, as formed by a horizontally arranged beam 117. The beam 117 is braced by diagonally arranged braces 118 and 119 attached between the beam 117 and the downwardly flared apart support legs 120 and 121, positioned on pedestals 122 and 123, respectively.

In FIG. 12 of the drawings, there is shown, by way of illustration only, one structure (or superstructure) 124 for supporting a plurality of sections embodying more than one segment each. The particular number of segments that are joined at the factory prior to shipping is dictated by such considerations as weight, convenience and ease of handling the section. If the surface of the segments is that of highly reflective material, such as polished metal or even a glass mirror surface, then the weight might be expected to be substantially more than if only a screen surface is involved.

For the heavier weighing segments, perhaps only four segments might be joined to form a section, such as segments 125, 126, 129 and 130, or alternatively, 125, 126, 127 and 128. The segments 131 and 132 might be joined together at the factory as a two-segment section, or alternatively, these two segments 131 and 132 might be combined at the factory with segments 129 and 130 or with segments 127 and 128, it largely being a matter of choice, dictated by convenience.

The particular supporting superstructure, illustrated by way of example only in FIG. 12, is depicted in sufficient detail that a description thereof is not believed to be necessary, because the particular superstructure is not an aspect of the present invention, but rather, goes to illustrate another use for the invention.

In FIG. 13 of the drawings, the particular invention is shown in an environment in which it is believed to be a particular benefit in the simulator art. Here, the invention is used to form a complete sphere with a screen-type of surface, indicated by the reference numeral 133. A plurality of identical segment structures 134 are joined in a manner as has been described already in order to form a sphere, indicated generally by the reference numeral 135.

The particular superstructure to support the individual sections, each composed of a plurality of segments 134, is not shown because it can be removed once such a sphere 135 is completed. Of course, if the simulator is not a fixed-base type, but rather is a motion-base type, the supportive superstructure may be retained in place. With the support structure removed, however, each segment structure supports the adjacent segments, making a superstructure unnecessary.

A small opening 136 is left in this structure to provide access to a simulator apparatus 137 located within this sphere 135 in such a manner as the eyepoint 138 will be at the geometric center of the sphere for maximum realism of an image projected upon the screen 133. The opening at the very top of the sphere 135 is small and is filled by a single segment made to fit that opening.

To illustrate a presently preferred method of making each segment structure with either a screen or a mirror surface, in accordance with the present invention, reference is made to FIG. 14 of the drawings. In this view, a fixed mold is indicated by the reference numeral 139 and has a plurality of openings 140 for the circulation of either heating or cooling medium, such as tempered water, to contol the temperature of the upper surface 141 precisely. The surface 141 is the critical part of this mold 139, because it is of the same radius as the finished screen or mirror. By using the same surface to form each segment, clearly the curvature of the final product will be the desired curvature.

The total area of a desired display surface is divided into an equal number of segments of equal dimensions, preferably rectangular, but, however, they may be square, which is a special form of a rectangle. Then, knowing the rectangular dimensions of each segment, an angle 142 is formed of a suitable material and is joined at its ends to form a generally rectangular border to match the desired shape of each segment structure.

Then, the joined form of angle 142 is laid upon the mold surface 141 to define the border, as described, and in FIG. 14, it is contemplated that the border defining angle 142 will become part of the segment structure. However, this need not be the case in every instance. For example, the means to define a suitable border can be attached to either the mold 139 or, preferably, to an upper platen 143. It can be at an appropriate angle to form a V-shaped trough with the border of an adjacent segment structure, as shown in FIG. 3 by the reference numeral 52.

The upper platen 143, being movable vertically, is adjusted to just touch the rectangular configuration formed by the angle 142. This defines a cavity 144 between the lower surface 141 and a surface 145 on the movable, upper platen 143.

The temperature of the surface 145 is controlled, like the temperature of the surface 141, by a plurality of holes 146 in order to circulate either a heating or a cooling medium from a suitable source 147.

With the space 144 accurately defined as described above, predetermined quantities of a polyol and an isocyanate are metered into the space 144, which can serve now as a mixing chamber, partially filling the space 144, depending upon the density of the finished product desired, the mixture reacts and expands to fill the entire space. During the curing process, the temperature of the mixture is controlled closely and precisely to obtain the desired results. The foam material is injected from a suitable supply 148 through any convenient access opening 149 into the space 144.

A segment constructed in the manner just described immediately above is the presently preferred form, i.e., where the foam itself forms the surface to be used as a screen. The polyurethane structural foam segment formed in this manner may have a density sufficiently dense along its concave surface formed against the mold surface 141 to permit it to be highly polished and, preferably, coated with a highly reflective material by any of the present-day known processes, such as electro-forming an ultra-thin but highly reflective coating of aluminum, nickel or the like.

In addition, the surface of the segment structure that is formed against the surface 145 also is the denser foam surface and is entirely suitable, in many instances, to attach it in place with ordinary wood screws. For example, a support for the segment structure may be provided by inserting directly into this denser foam part of the segment structure a suitable self-tapping screw.

The above description suggests a modification which is illustrated diagrammatically in FIG. 15 of the drawings. In this view, the same mold 139 may be used with its upper convex surface 141 and a plurality of holes or tubular openings 140 to receive the heating and cooling medium.

A positioning stop 150 is located adjacent one edge of the mold 139 to position accurately each part to be formed on the surface 141. In this view, a lower skin 151 is laid directly on the mold surface 141 with one edge against the positioning stop 150, and then, an identical upper skin 152 with suitable end angles 153 and 154 attached is positioned over the skin 151 and against the positioning stop 150, forming a generally rectangular space 155.

The stop 150 has a surface 156 against which the angle 154 is positioned to give the angle 154 the correct position relative to the lower skin 151 for the finished segment. By way of illustration, the angle 154 as well as the angle 153 and the other ends (not visible) may be positioned with a desired tilt to form a somewhat V-shaped opening between adjacent segments for filling with the desired resilient material, as the space 52 shown and described in connection with FIG. 3 of the drawings.

In FIG. 15, two inserts 157 and 158 with respective flanges 159 and 160 are shown held in position by short screws 161 and 162 against the upper skin 152 in order to define a space 163 and 164 between each respective flange 159 and 160 of the inserts 157 and 158 and the lower skin 151. It has been found that the spaces 163 and 164 are required in order to prevent a distortion being visible through the lower skin 151. Therefore, the spaces 163 and 164 are just sufficient for a layer of the foamed material to flow between the flanges 159 and 160 and the lower skin 151, thereby making the flanges 159 and 160, respectively, invisible as viewed through the lower skin 151.

A suitable synthetic porous material is injected, as illustrated diagrammatically by the reference numeral 165, into the space 155 at about the uppermost point in order to prevent air being trapped as the synthetic porous material expands during the curing process. The material, for example, polyurethane structural foam, is cured in place in the chamber 155 and is sufficiently strong to make the entire segment structure unusually strong and rigid.

Therefore, after the polyurethane is cured, the temporary screws 161 and 162, as well as any others that might be holding foamed-in-place inserts in their proper position, are removed to permit either the temporary attachment of a handle for manipulating the segment structure or for the attachment of an I-beam, as illustrated in FIG. 3 of the drawings. By attaching to the upper skin 152 the two inserts 157 and 158 as well as the angles 153 and 154, all of this activity is benchwork, where it can be done much faster and with a much higher degree of accuracy than at the manufacturing site.

As clearly visible in FIG. 15, each of the two angles 153 and 154 is not illustrated as being fixedly attached to the lower skin 151. In practice, the lower skin 151 is placed upon the mold surface 141, and since the lower skin 151 is relatively thin and flexible, it will immediately assume the configuration of the surface 141.

Thereafter, the assembled unit of the upper skin 152 with all of the inserts (such as the inserts 157 and 158) and the surrounding angles (such as the angles 153 and 154) is placed over the lower skin 151 and is positioned against the stop surface 156. After the polyurethane structural foam is cured within the space 155, the synthetic porous material forms a rigid attachment adhesively fixing the lower skin 151 to the upper skin 152, as well as within the spaces 163 and 164 and within the channels of the angles 153 and 154, making further attachment unnecessary in order to lift the lower skin 151 with the upper skin 152.

Referring now to FIG. 16 of the drawings wherein it is shown a further embodiment of a segment constructed in accordance with the principles of the invention. Here a very thin mirror skin 166 is laid over the surface 141 of the mold 139 and is positioned against the stop 150.

An upper skin 167, then, with all of its attachments, such as the angles 168 and 169 and the inserts 170 and 171, is positioned against the stop surface 156 over the lower skin 166, as illustrated in FIG. 16 of the drawings. As explained above, the angles 168 and 169 are not attached to the mirror skin 166 because they would be visible through the skin.

Each angle member 168 and 169 is sharpened at one end to a fine line edge as illustrated by the reference numeral 172 in FIG. 16 in order to minimize contact area with the surface of the skin 166. Because of this characteristic of a surface against the lower mirror skin 166, the two inserts 170 and 171 are maintained out of contact with the mirror skin 166, as illustrated by the spaces 173 and 174 and as explained in detail above.

The inserts 170 and 171 are fixedly attached to the upper skin 167 by means of a longer threaded member with a nut 175 and 176, respectively, intermediate of this threaded member, to leave extending from the upper skin 167 a substantially longer threaded end 177 and 178, respectively.

By this means, the foamed-in-place inserts 170 and 171 are fixedly attached to the upper skin 167 and need not be touched further because the extended threaded ends 177 and 178 are used to insert through a larger hole in the flange of a suitable I-beam for attaching adjacent segment edges. Of course, by attaching the segment structures in this manner to an I-beam, the threaded extended ends 177 and 178 need only have a suitable spacer washer inserted and then a nut threaded over each end to make them operative. As illustrated by the reference numeral 179, a suitable synthetic porous material is injected within the cavity 180.

Yet another embodiment of a segment, constructed in accordance with the principles of the present invention, is illustrated by the diagrammatic view in FIG. 17. A thin glass sheet 166 is laid on the curved surface 141 of a mold 139 with the border angles 142 carefully positioned thereover so that the edges will match the edges of the glass skin 166, as illustrated by the reference numeral 181, forming a line contact with the skin 166.

Then an upper platen 182, which is movable vertically, is lowered to touch the edges of the border angles 142 thereby defining a space 183. From a suitable source 184, a polyrethane structural foam is injected into the space 183, so that as it is cured, it will expand to touch the upper surface 185.

From a suitable source 186 of heating and cooling, a suitable fluid is circulated through the openings 187 in order to control the curing of the polyurethane that has been injected into the space 183. Since no foamed-in-place inserts are illustrated in this view, the foamed polyurethane may be cured to a degree that makes it more dense than usual by controlling its temperature, and the segment structure is attached to a suitable support and to each other by wood screws, as described previously.

In view of the above detailed description of the presently preferred form of the invention and in view of the detailed description of various modifications thereto, other and still further modificatons, variations, advantages and uses will occur to one skilled in this art. Accordingly, the description and modifications presently presented hereinabove are to be considered as illustrative only, the true spirit and scope of the invention being that defined by the claims appended hereto.

Claims

1. In a projected-image visual system for a simulator, a segment structure for co-acting with a plurality of segment structures to form a larger structure for exhibiting projected images, said segment structure (10, 11) comprising:

a synthetic porous material (17) cured to a predetermined density and having two surfaces (15, 16) spaced apart a predetermined distance, at least one surface (15) of said two surfaces (15, 16) having an accurately defined curvature, and

means (21) to support said segment structure with accurately defined spacing (14) between adjacent segment structures,

so that all of said one surfaces (15) co-act together to define a smooth, substantially continuous surface for exhibiting said projected images.

2. In a projected-image visual system as claimed in Claim 1, characterized in that said two surfaces (15, 16) include sheets of the same material.

3. In a projected-image visual system as claimed in Claim 1, characterized in that said one surface (15) is different from the other of the said two surfaces (15, 16) in a highly polished, more reflective, mirror-like quality, to enhance realism in its reflection of said projected images.

4. In a projected-image visual system as claimed in Claim 1, characterized in that said one surface (15) is different from the other of said two surfaces (15, 16) in a diffuse light reflective quality to enhance its function as a screen on which projected images are exhibited.

5. In a projected-image visual system as claimed in Claim 1, 2, 3 or 4, characterized in that a predetermined number of insert means (21, 34) are embedded within said cured synthetic porous material (17) to enable a plurality of segment structures to be attached together rigidly.

6. In a projected-image visual system as claimed in Claim 1, characterized in that border means (142) is positioned around the periphery of each individual segment structure and is formed in a manner to fit with the border means of adjacent segment structures in a laterally non-slipping relationship.

7. In a projected-image visual system as claimed in Claim 5, characterized in that each of said insert means (34) includes surface means (23, 36) to increase its resistance to extraction.

8. In a projected-image visual system as claimed in Claim 7, characterized in that said surface means (23) to increase the resistance to extraction of said insert means (34) from said cured synthetic porous material (17) is in the form of an annular flange of a predetermined size and shape.

9. In a projected-image visual system as claimed in Claim 7, characterized in that said surface means (36) is in the form of a plurality of serrations arranged along the length of the body (35) to increase its resistance to extraction.

AMENDED CLAIMS
(received by the International Bureau on 6 March 1981 (06.03.81))

1. (Amended) In a projected-image visual system for a simulator, a segment structure for co-acting with a plurality of segment structures to form a larger structure for exhibiting projected images, said segment structure (10, 11) comprising:

a synthetic porous material (17) cured to a predetermined density and having two surfaces (15, 16) spaced apart a predetermined distance, at least one surface (15) of said two surfaces (15, 16) having an accurately defined curvature, and

means (21) to support a plurality of said segment structures with accurately defined spacing (14) between adjacent segment structures so that all of said one surfaces (15) co-act together to define a smooth, substantially continuous surface for exhibiting said projected images.

2. In a projected-image visual system as claimed in Claim 1, characterized in that said two surfaces (15, 16) include sheets of the same material.

3. In a projected-image visual system as claimed in Claim 1, characterized in that said one surface (15) is different from the other of the said two surfaces (15, 16) in a highly polished, more reflective, mirror-like quality, to enhance realism in its reflection of said projected images.

4. In a projected-image visual system as claimed in Claim 1, characterized in that said one surface (15) is different from the other of said two surfaces (15, 16) in a diffuse light reflective quality to enhance its function as a screen on which projected images are exhibited.

5. In a projected-image visual system as claimed in Claim 1, 2, 3 or 4, characterized in that a predetermined number of insert means (21, 34) are embedded within said cured synthetic porous material (17) to enable a plurality of segment structures to be attached together rigidly.

6. In a projected-image visual system as claimed in Claim 1, characterized in that border means (142) is positioned around the periphery of each individual segment structure and is formed in a manner to fit with the border means of adjacent segment structures in a laterally non-slipping relationship.

7. In a projected-image visual system as claimed in Claim 5, characterized in that each of said insert means (34) includes surface means (23, 36) to increase its resistance to extraction.

8. In a projected-image visual system as claimed in Claim 7, characterized in that said surface means (23) to increase the resistance to extraction of said insert means (34) from said cured synthetic porous material (17) is in the form of an annular flange of a predetermined size and shape.

9. In a projected-image visual system as claimed in Claim 7, characterized in that said surface means (36) is in the form of a plurality of serrations arranged along the length of the body (35) to increase its resistance to extraction.

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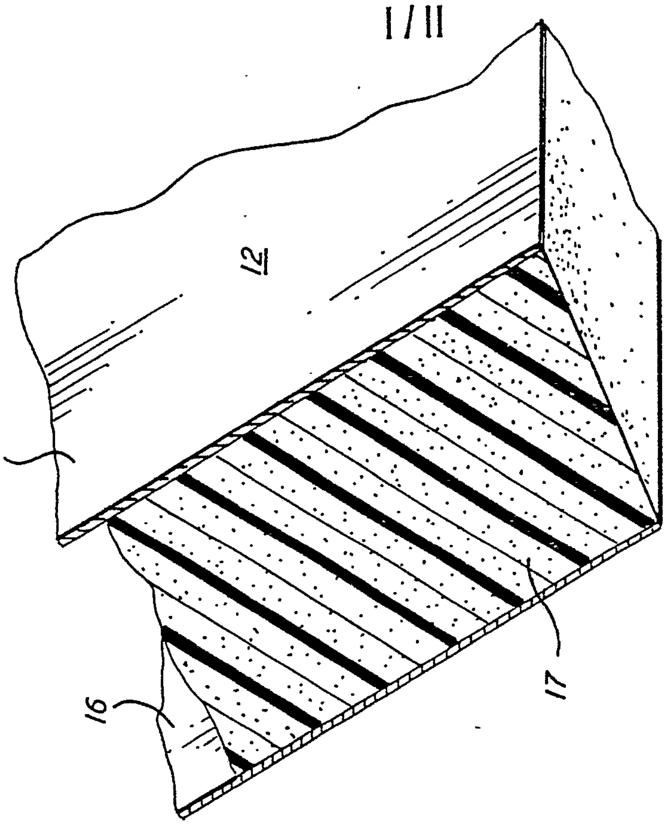

FIG. 2

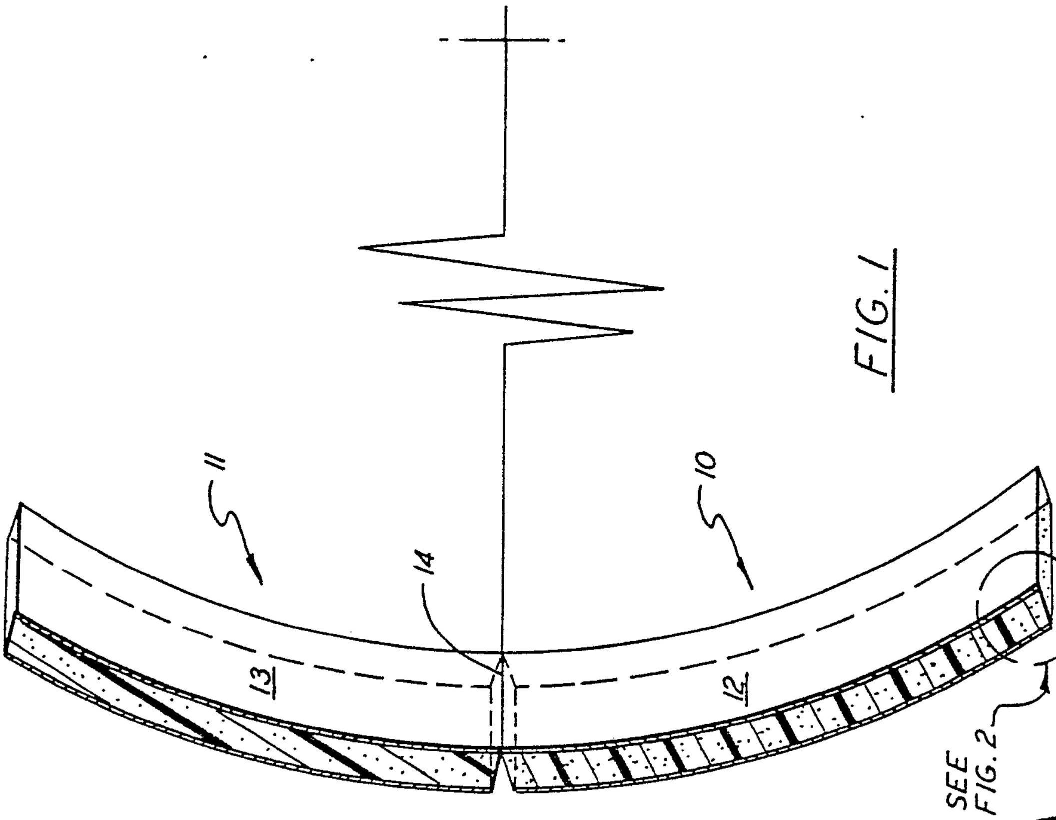

FIG. 1

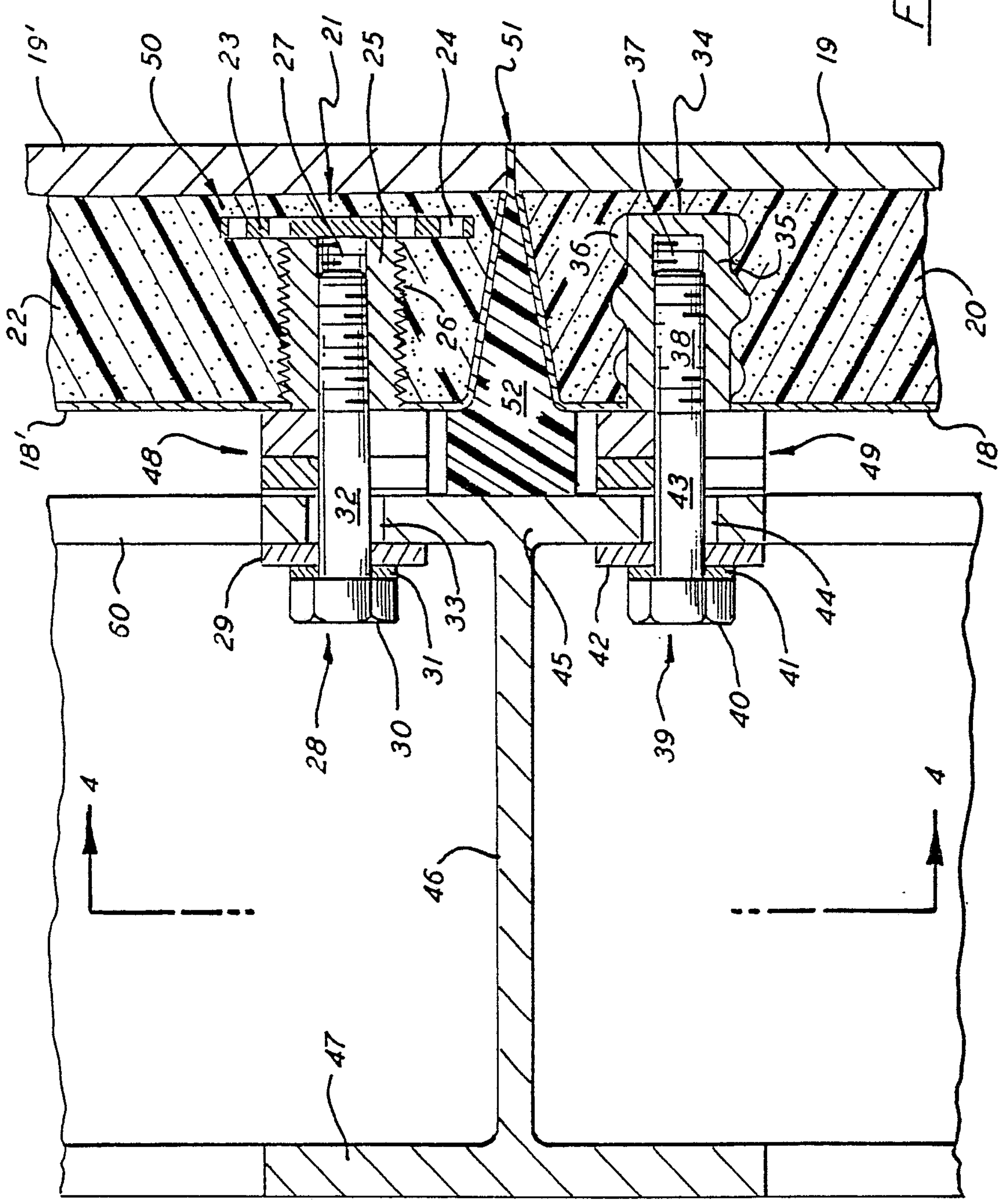

FIG. 3

3/11

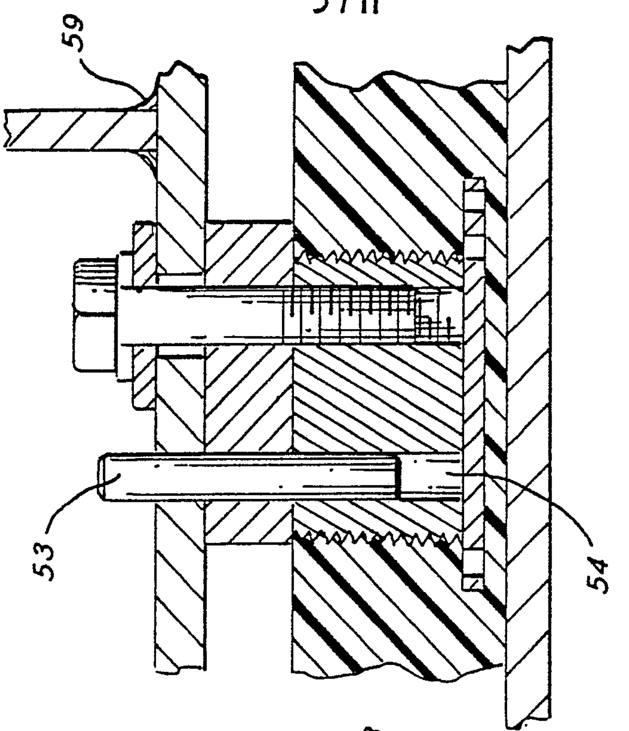

FIG. 5

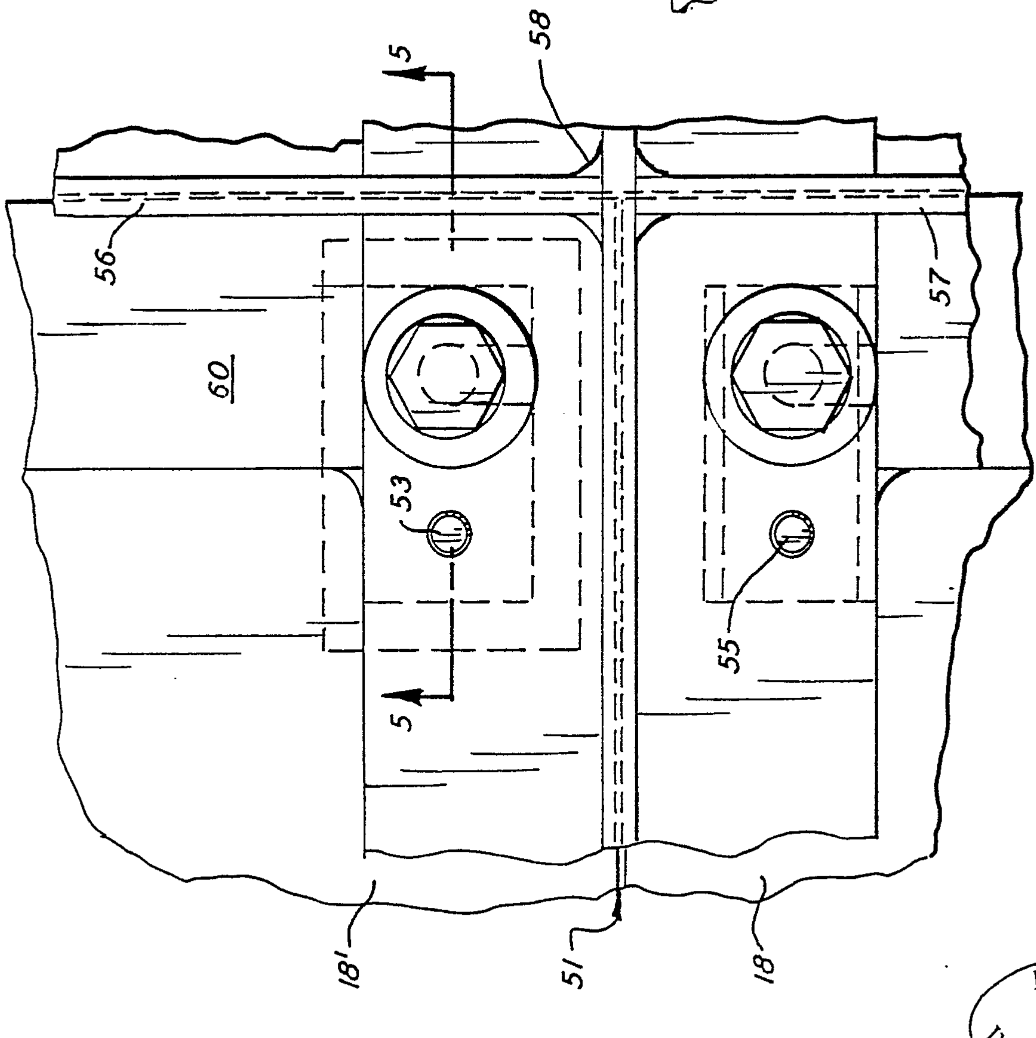

FIG. 4

4/11

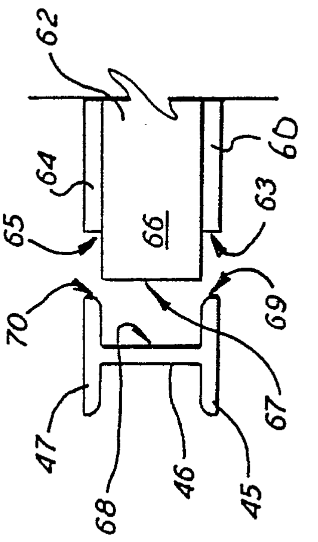

FIG. 6

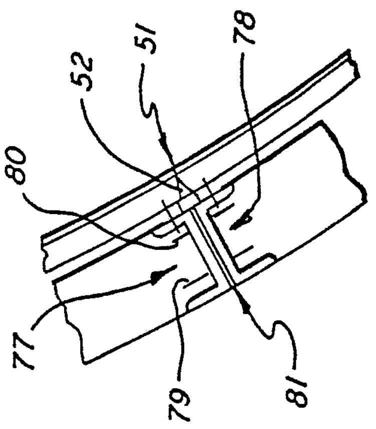

FIG. 8

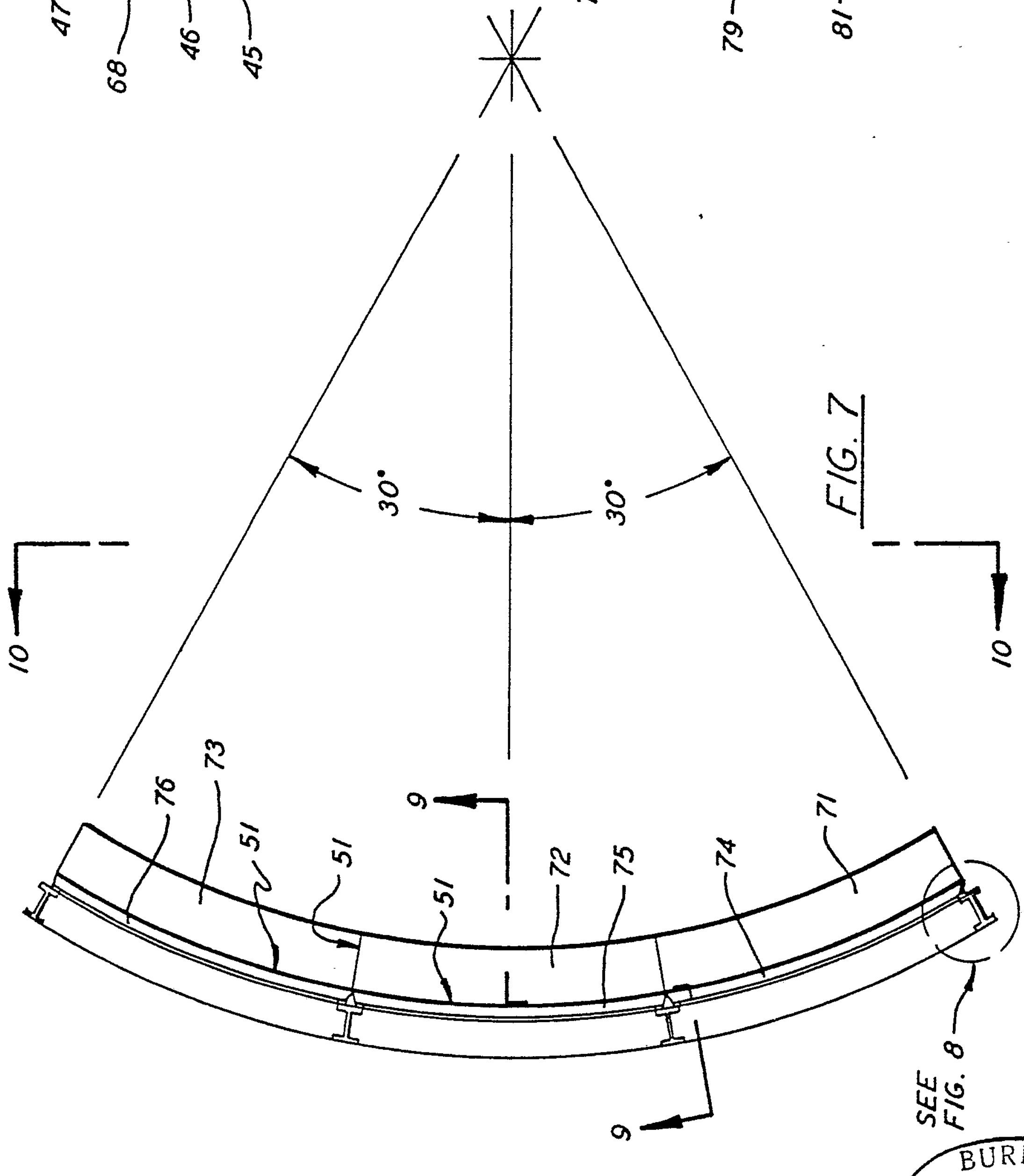

FIG. 7

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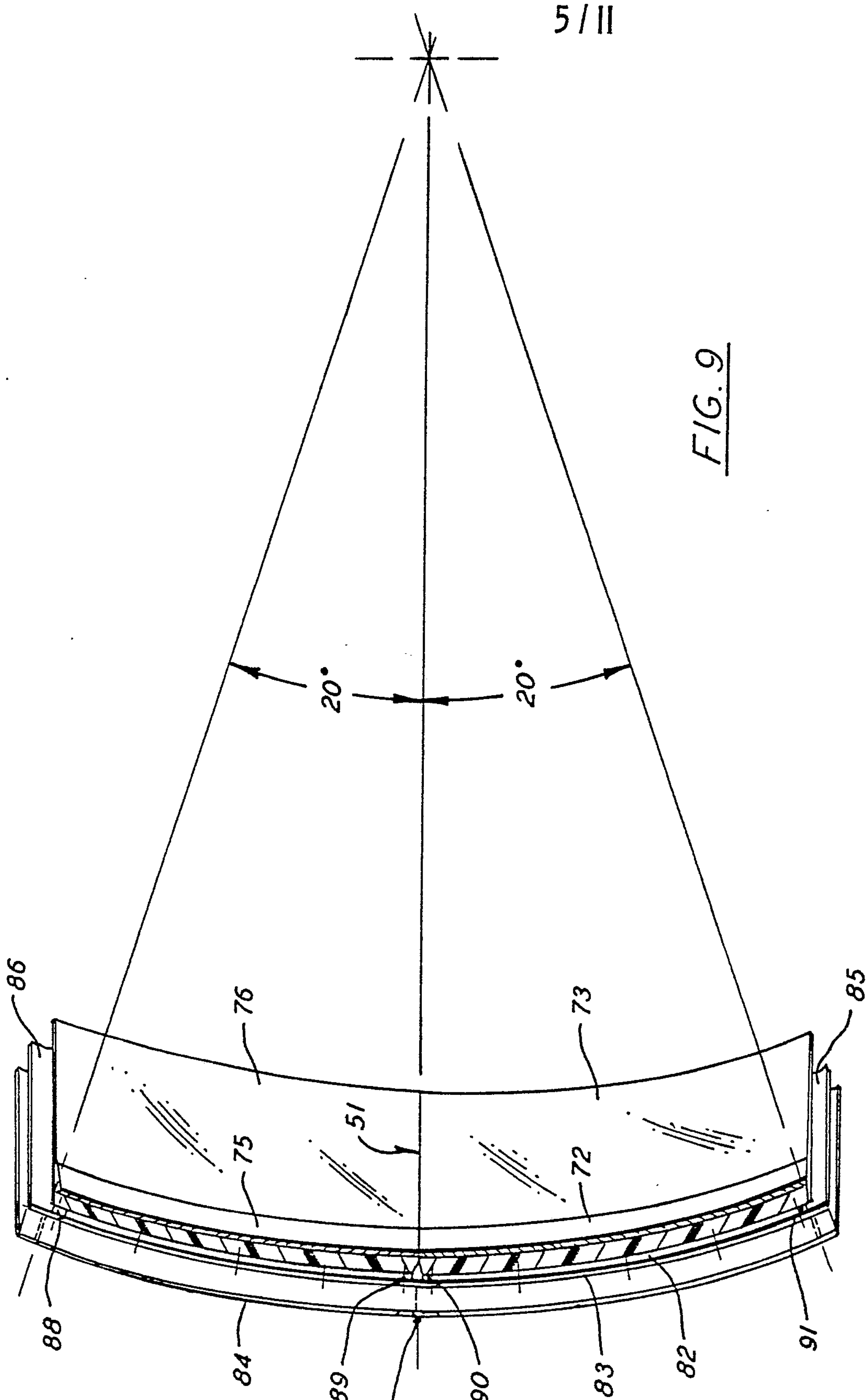

FIG. 9

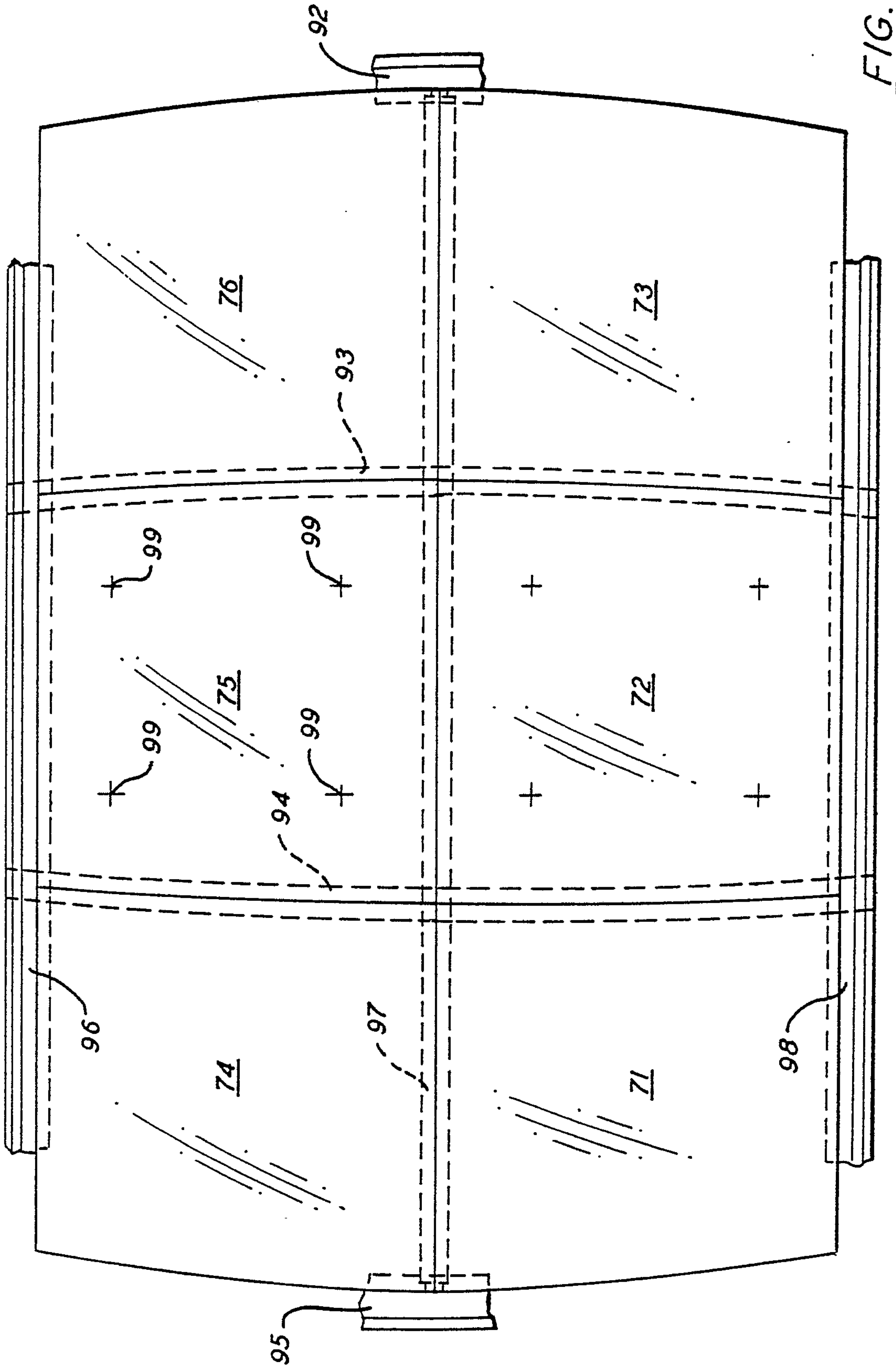

FIG. 10

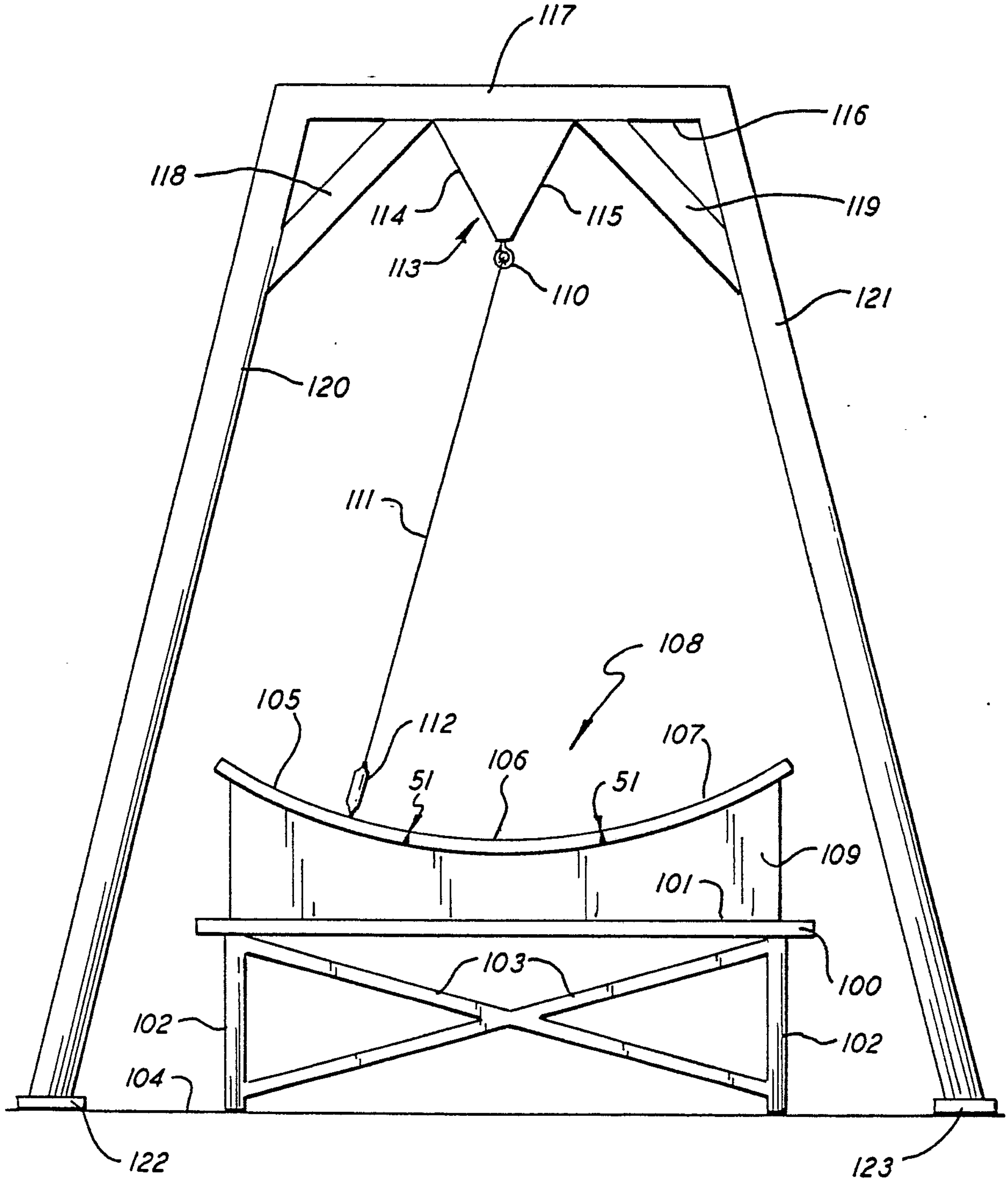
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FIG. 11

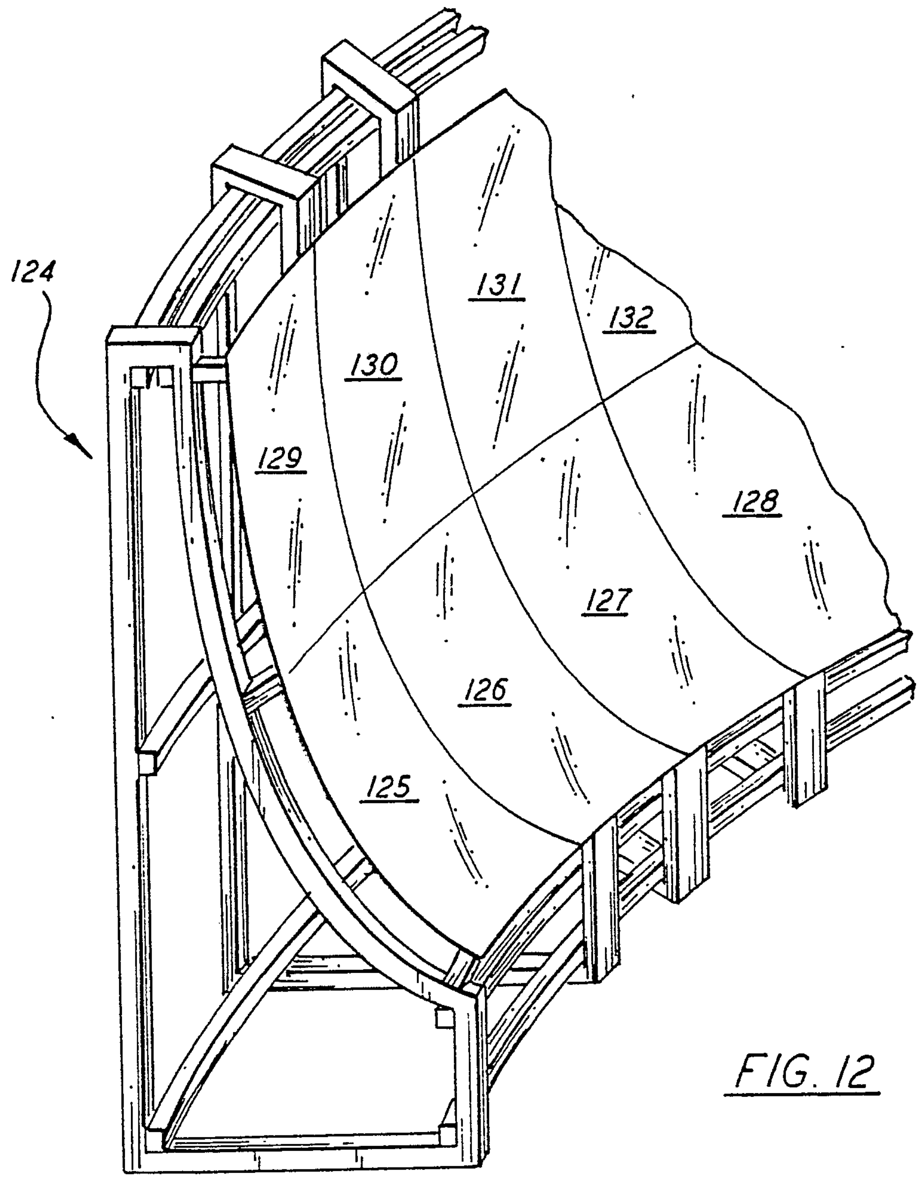


FIG. 12

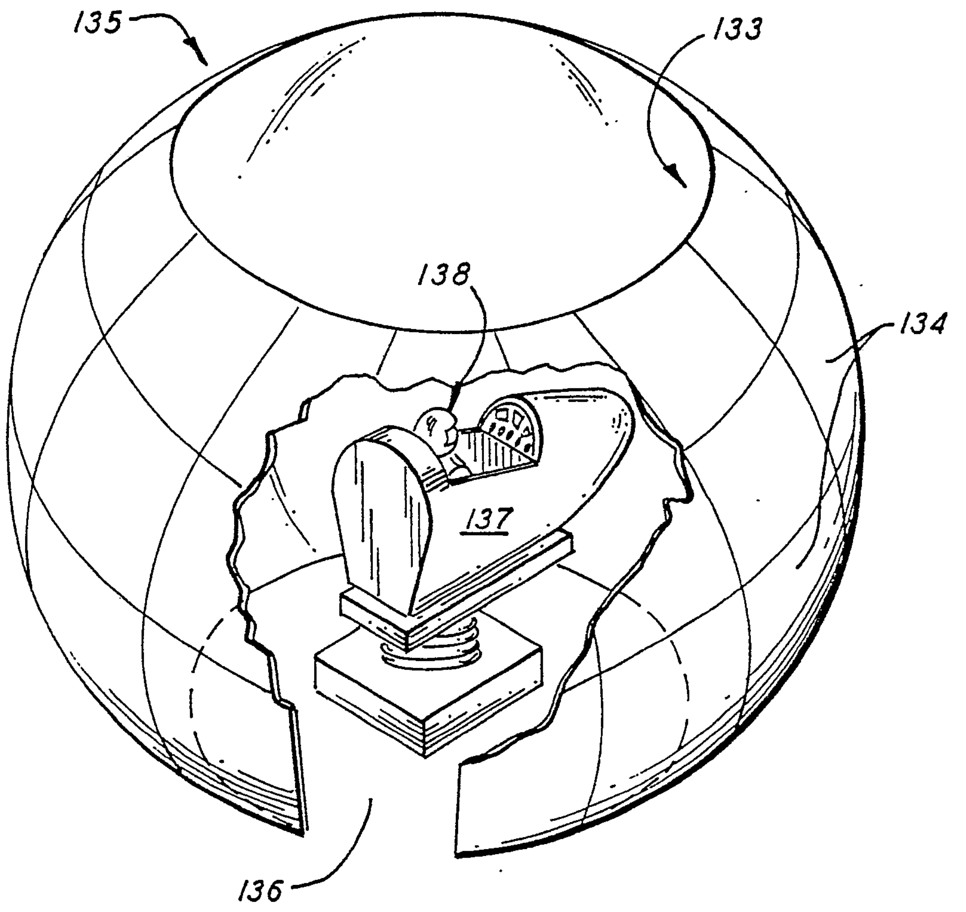


FIG. 13

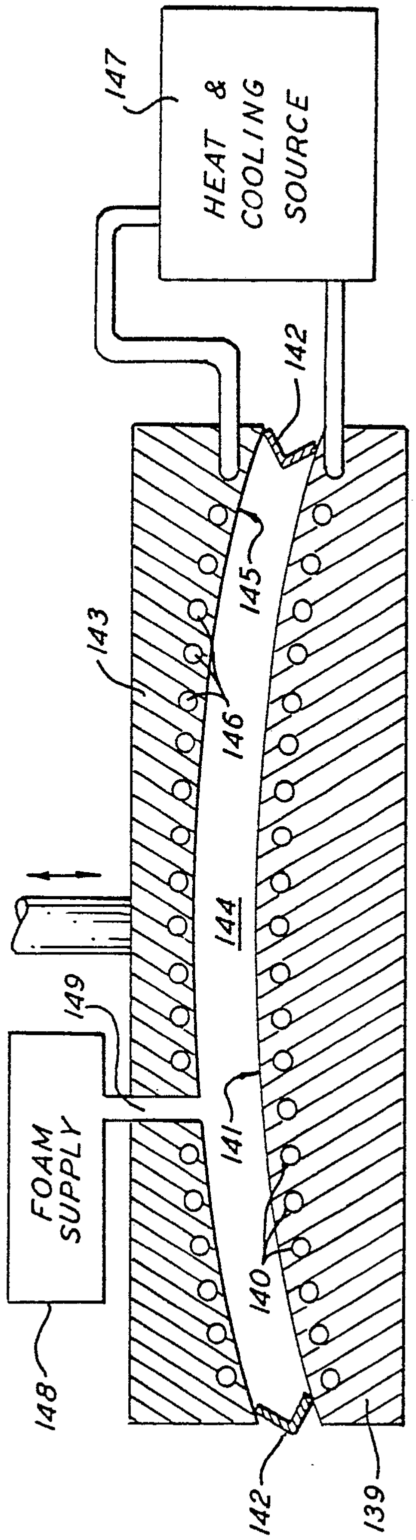
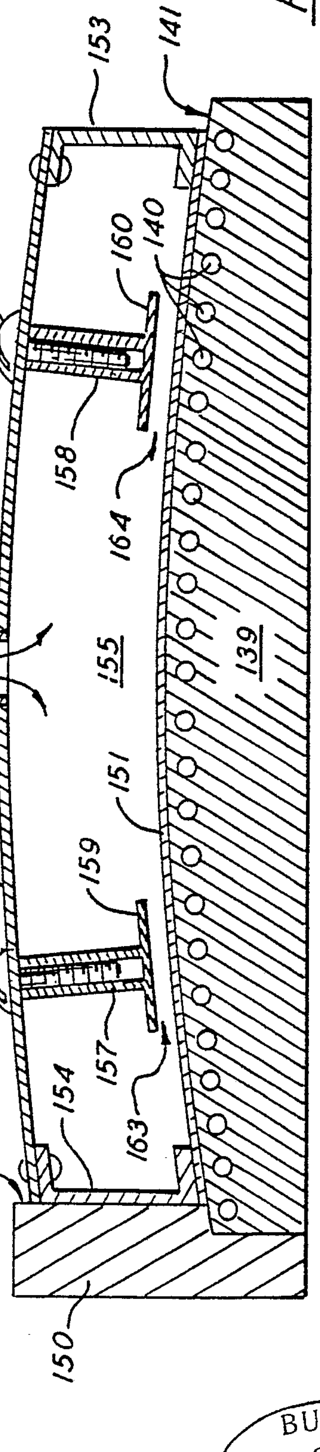

HEAT & COOLING SOURCE
FOAM SUPPLY
147
142
143
145
146
144
149
141
140
148
142
139

FIG. 14


153
141
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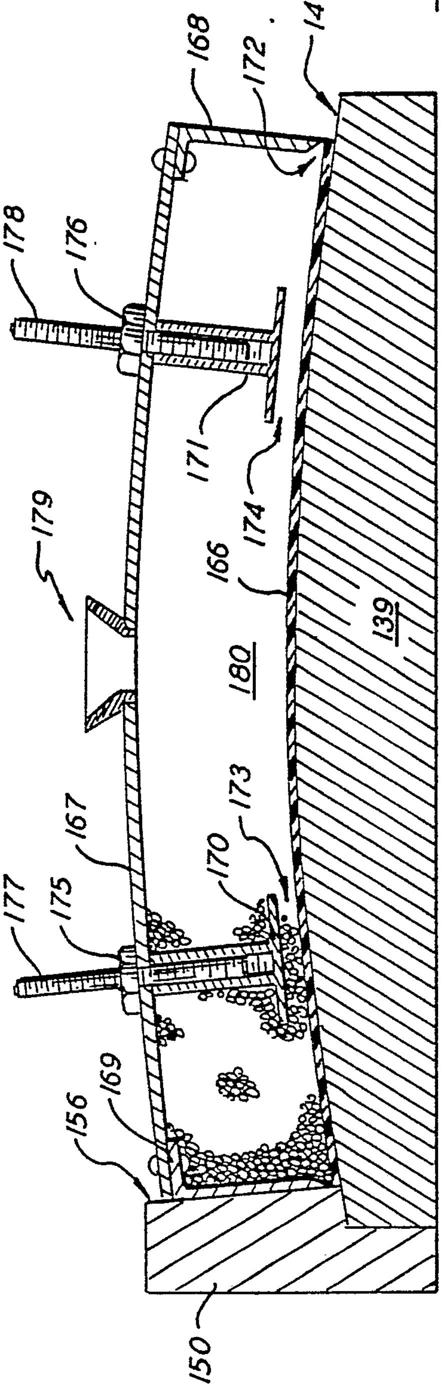
150

FIG. 15


168
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175
169
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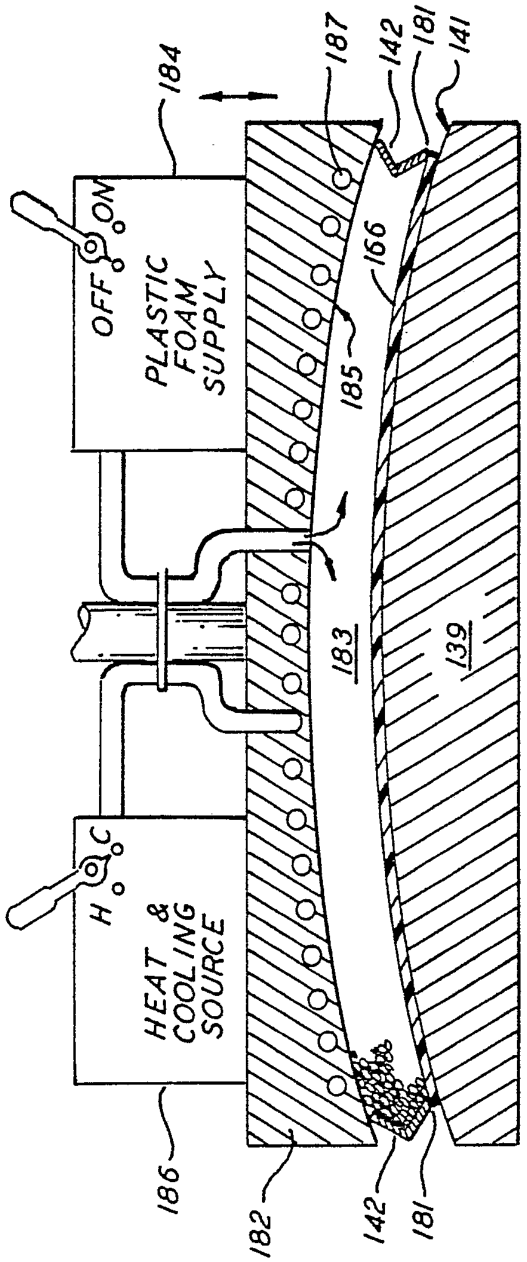
150

FIG. 16


184
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OFF
ON
PLASTIC
FOAM
SUPPLY
166
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183
139
H
C
HEAT &
COOLING
SOURCE
186
182
142
181

FIG. 17

INTERNATIONAL SEARCH REPORT

International Application No PCT/US80/01335

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl.[3] G09B 9/08 G03B 21/56 G02B 5/10

U.S. Cl. 434/44 350/125,129,293

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
U.S.	434/40,44,38 350/125,129,292,293,296,310, 264/46.5 343/916

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
A	US,A, 1,248,456, Published 04, December 1917 CLARK	1-9
A	US,A, 3,030,259, Published 17 April 1962 LONG	1-9
A	US,A, 3,904,289, Published 09 September 1975 YAGER	1-9
A	US,A, 3,916,418, Published 28 October 1975 ERDMANN ET AL	1-9
A	US,A, 3,607,584, Published 21 September 1971 BECHT	1-9
A	US,A, 3,377,595, Published 09 April 1968 CARR ET AL	6-9
A	US,A, 4,040,717, Published 09 August 1977 CINQUE ET AL	3,4
A	US,A, 3,346,221, Published 10 October 1967 FARMER	8
A	US,A, 3,372,396, Published 05 March 1968 BRACCINI	6

* Special categories of cited documents: [15]

"A" document defining the general state of the art

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

"L" document cited for special reason other than those referred to in the other categories

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

"P" document published prior to the international filing date but on or after the priority date claimed

"T" later document published on or 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

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
09 February 1981	12 FEB 1981
International Searching Authority [1]	**Signature of Authorized Officer** [20]
ISA/U.S.	Richard Pinkham RICHARD J. PINKHAM