URDome

GENERAL INSTRUCTION MANUAL

A Simple & Integrated System

To Build Enclosed Geodesic Domes

ABSTRACT

This is a complete and integrated system for building enclosed geodesic domes and space frames. It addresses enclosing, creating entryways and venting, interior partitioning, anchoring, and external shading.

It is a very simple system using a minimum of parts and simple tools.
It enables the individual to create their own bubble.

In general terms, this is a method of creating and attaching membrane panels of thin film, fabric or laminate to a stable tubular framework, keeping the membrane tight over a wide range of air temperature and effectively sealing the edges to provide a weather tight enclosure.

TABLE OF CONTENTS

ABOUT

This is the General Instruction Manual for the URDome Geodesic Dome system.
It describes the procedures and processes for fabricating and assembling tubular geodesic dome structures and attaching membrane panels to enclose them. See URDome Instructional Videos on-line to further illustrate the materials and methods involved.

This manual is meant to accompany detailed QUICK START manuals for specific dome models.

BACKGROUND

Geodesic Domes and Space Frames offer distinct advantages in structural and construction efficiency over conventional construction methods. Frameworks for these structures can be simply and readily fabricated from tubes, pipes or rods that are flattened on the ends and drilled, then bolted together. This has been a common method for hobbyist, do-it-yourselfers and professionals to build Geodesic Domes since the 1970's. To convert this type of structure to usable interior space, some type of cladding, sheeting, film or fabric cover is applied to the framework. Commonly, a one piece balloon shaped membrane is either draped over or suspended from inside of the structure. This requires relatively complex development geometries, fabrication methods and a large area for layout.

The URDome method of attaching a membrane to a tubular framework enables the effective enclosure of such frameworks and is conceivably applicable to most any stable tubular structure, generally independent of its overall geometry or hub design.

Tubular geodesic domes and space frames, using this method of membrane attachment along with a simple bolt-together framework, provide a shelter of high efficiency at minimal cost. They are easily fabricated from common materials and assembled with simple tools. A single person can erect a relatively large structure over the course of several days. This method approaches the level of structural performance discussed in R. Buckminster Fuller's Building Construction patent 2,682,235.

This technique of attaching flexible thin films, fabrics and/or laminates to tubular frameworks, retains the membrane on the structure, while keeping the material taut over a wide range of operating temperatures. Keeping the membrane taut or tensed is important because a tight membrane does not fatigue to failure as readily as a loosely flapping membrane and thus lasts longer. A tight membrane is also quieter in gusty winds and reduces aerodynamic drag on the structure. This method of membrane attachment provides generally uniform tension throughout the membrane over all of the structure.

This method seals the panel edges and hubs, keeping wind, precipitation, debris, etc. out, providing an effective weather seal. It can also retain interior contents, for instance, humidity in a greenhouse or toxic gases in a hazmat containment application.

This method of membrane attachment permits the use of a wide variety of membrane materials for a wide variety of purposes, including, but not limited to, fabrics (natural or manmade materials), polymer films (clear, translucent or opaque, multicolored, printed and/or polarized), metal foils and laminates. These laminates could possibly include materials with electronically tunable opacity and reflectance (e.g. LCD) and thin film electronic video display and lighting (for information, entertainment, control, virtual reality, electronic camouflage, etc., e.g. LED), thin film audio (speaker) panels and photovoltaic (solar collector) panels, when the associated technologies are available. A wide variety of different membrane materials can be used on the same structure at the same time in different locations at the user’s discretion. The user can also easily make and install custom panels and/or replacement panels from available materials. This can be especially useful in emergency situations and third world countries.

This system allows projections from the parent structure to have the same continuously tensed surface. Such projections can include walk-thru entries, vents, cupolas, balconies and towers.

Membrane panels can be maintained or replaced at any time, from the inside of the structure using ladders, scaffolding or platforms, without having to climb on the outside of the structure. Failure of any one of the panels, by itself, does not directly affect the integrity of the remaining panels. This method also allows for re-tensioning of panels on the fly with a built-in tension adjustment.

The manufacturing involved in this method requires minimal equipment, machinery and space. The structure’s own struts can be used as the templates for the membrane panels. This makes for a simple, integrated construction system ensuring a good and reliable panel-to-structure fit.

The STRUCTURES

We start with the tubular structure to which the membrane is going to be attached, typically a Geodesic Dome, as shown in Fig. 1, or a Space Frame, Fig. 2, or other unspecified stable tubular structure.

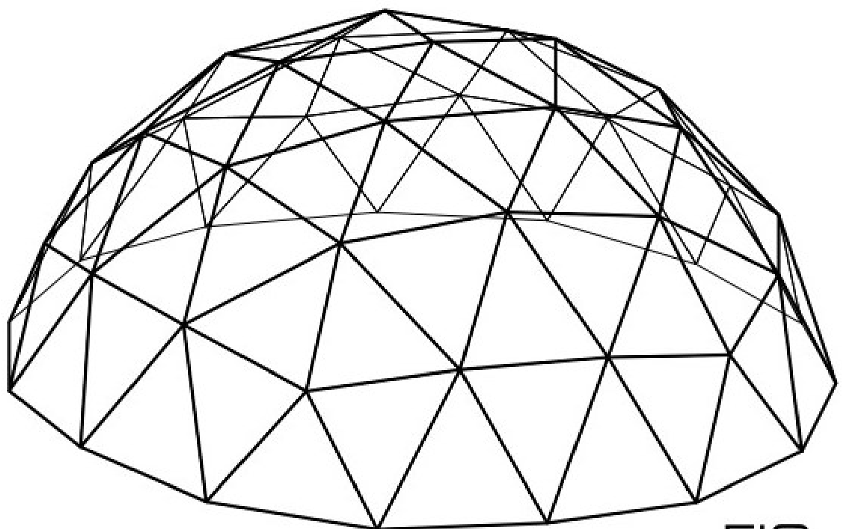


FIG. 1

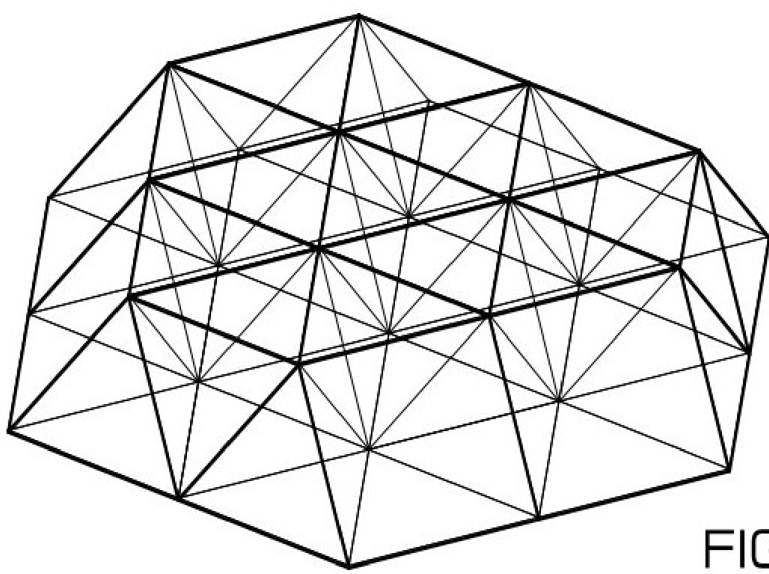


FIG. 2

The STRUTS

The structure consists of struts (1), Fig. 3, which are round pipes, tubes or rods that are flattened and drilled at the ends, to form the tongues (2). The struts (1) are marked with a color or otherwise coded band (42) indicating strut length, to assist in structural assembly and glazing.

These struts (1) are bolted (4) together creating the hubs (3) of the structure as per Fig. 4. This type of hub (3) is very simple, angularly self-adjusting and does not require complex machining to create.
Generally, these struts flex at the tongues (2), bending naturally to the angles required by the geometry of the structure. This requires the strut/tongue material to be somewhat malleable or springy.

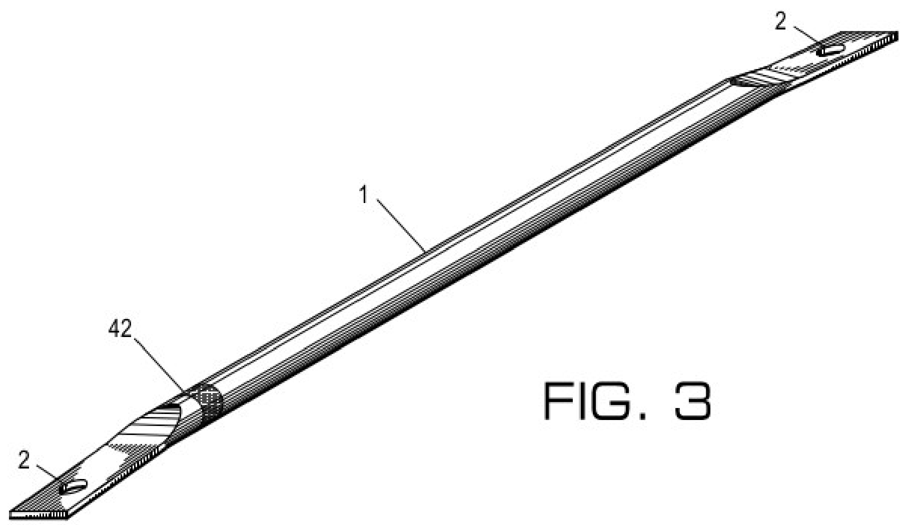


FIG. 3

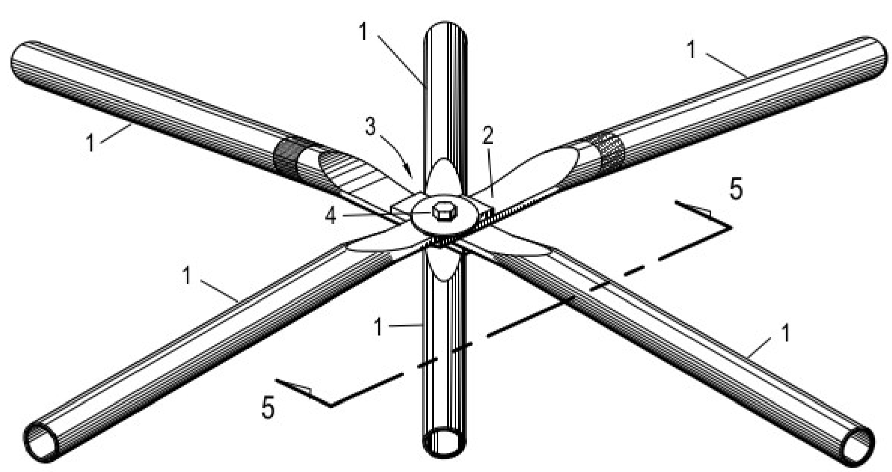


FIG. 4

LOW PROFILE HUB

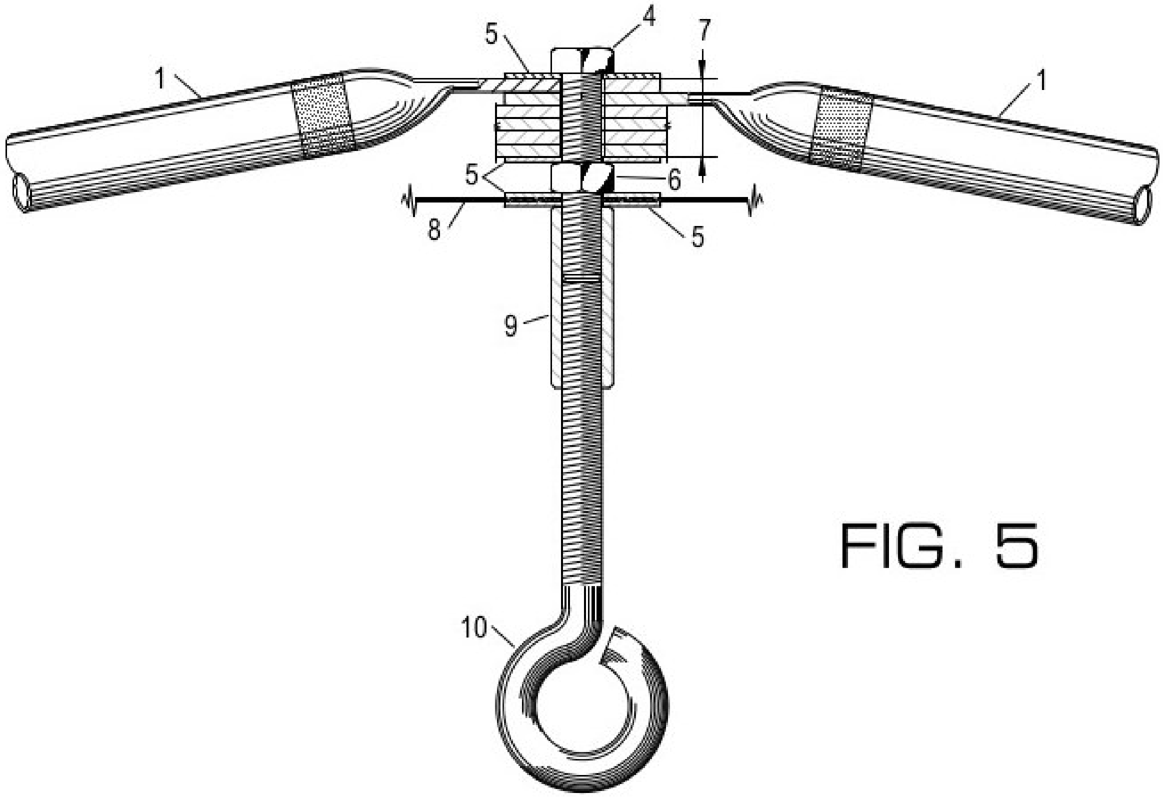


FIG. 5

A section through a Low Profile Hub, Fig. 5, shows a bolt (4), two washers (5) and nut (6) holding a stack (7) of struts (1) together, to form a hub of the structure. The bolt (4) also passes through a hole in the membrane hub cap (8) used to seal the membrane. This hole is clamped shut between two washers (5) by the nut (6) and a coupling (9). This coupling (9) in turn holds an eyebolt (10) that can be used to suspend items (e.g. shades, tarps, platforms, equipment) from the inside of the structure. The coupling (9) can also support equipment directly.

There have been many different hubs designed for Geodesic Domes and Space Frames. This method of membrane attachment is generally independent of the type of hub used, as long as the struts are tubular.

PANEL CREATION

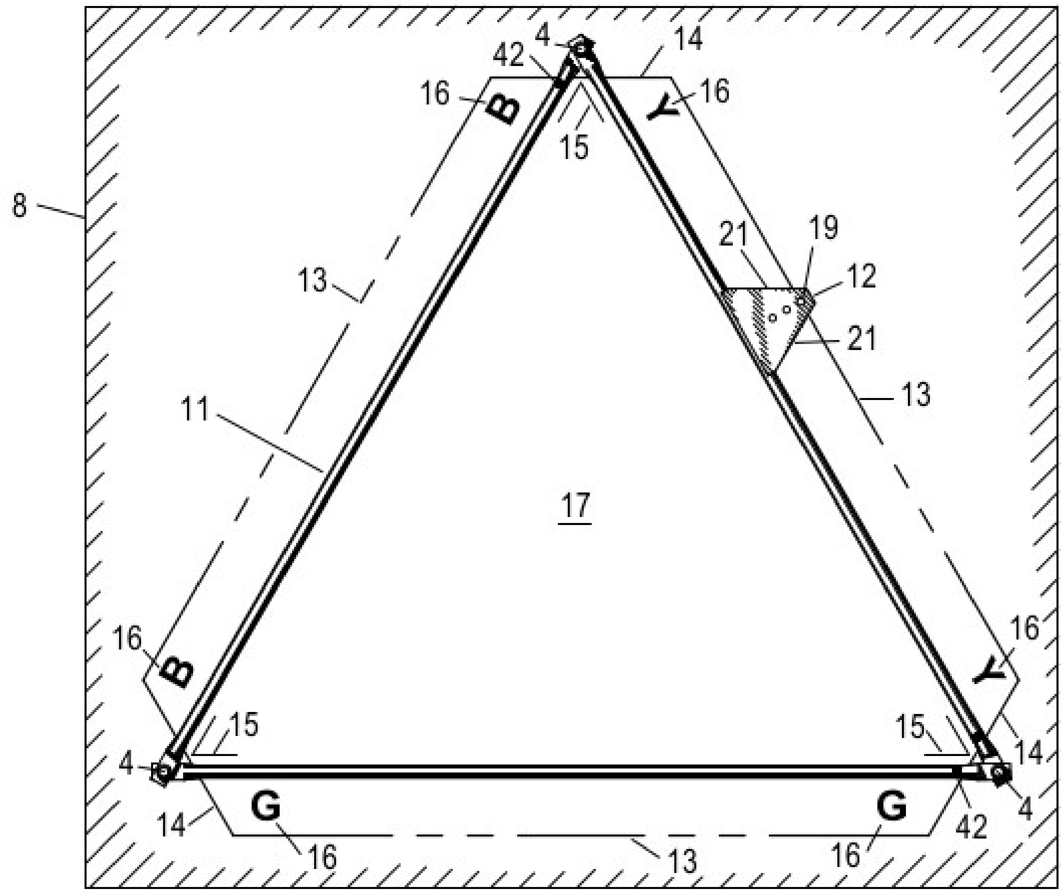


FIG. 6

Fig. 6   To create a Membrane Panel (17), rolls or sheets of membrane material (8) are hung or laid flat against a surface. A template (11) is placed over the membrane material (8). A Scribe (12), with a marker or cutter inserted into hole (19), rides along the outside of the template (11) , on each side from end to end, between the bolts (4), tracing the outer edges (13) of the panel (17). Panel cutbacks (14) are marked by placing the Scribe (12) on the Template (11) close to the bolts (4) and using the Scribe's sloped edges (21), strike the panel's cutback edges (14) on each side of each bolt (4). The panel's cutback edges (14) comes close to, but do not overlap, the bolts (4). The Panel Index lines (15) are marked by tracing the inside corners of the Template (11) near the bolts (4). The Strut Designations (16), corresponding to Color Bands (42) on the struts of the Template (11), are written on or otherwise applied to the Panel (17). A strut designation can be as simple as a swatch of the color thus transcending language boundaries. The Panel (17) is cut out of Sheet (8), along lines (13) and (14).

The TEMPLATE

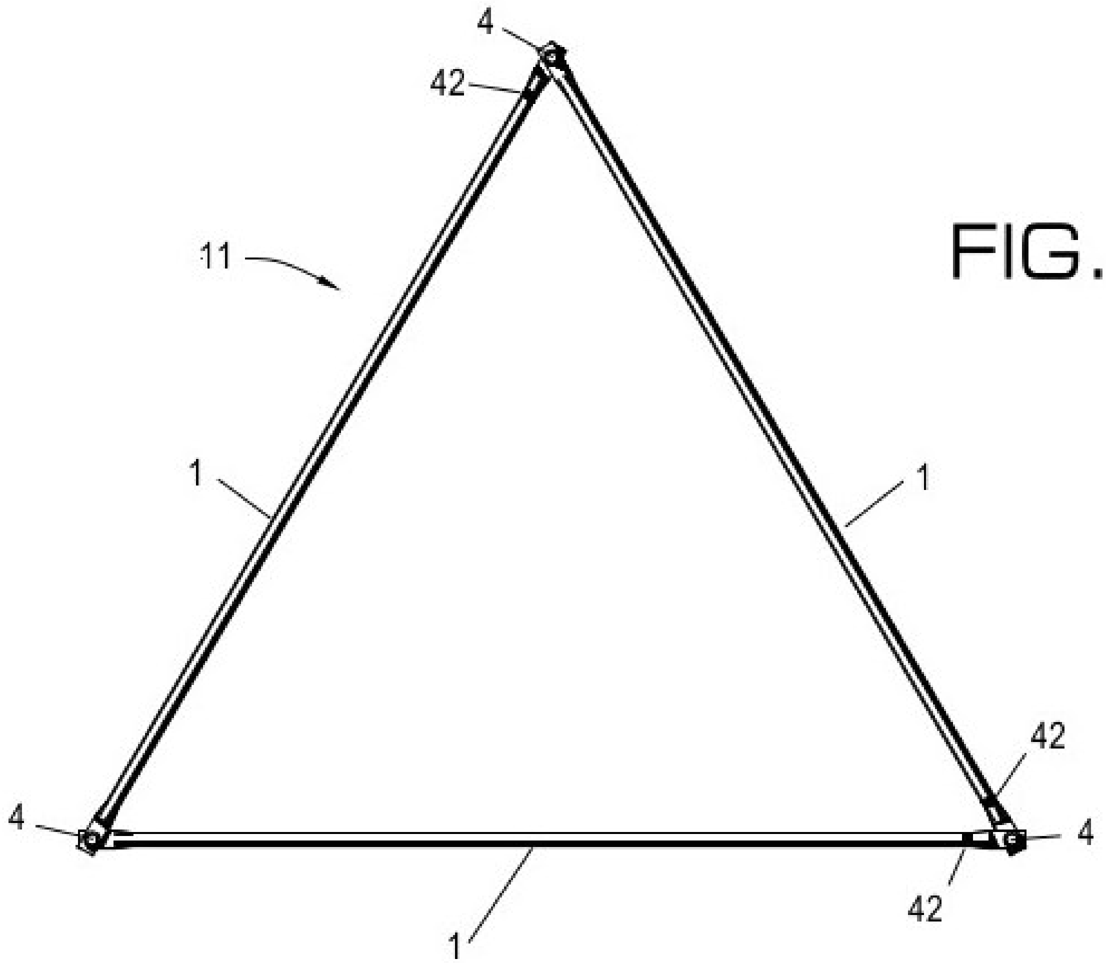


FIG. 7

Fig. 7 The templates are generally strut (1) triangles connected by bolts (4). Templates (11) can be other shapes for special purposes, e.g. rectangular or trapezoidal for entry ways. There is one template required for each unique facet of a structure, indicated by the color code bands (42). Since there is a repeating pattern of similar triangular facets in a Geodesic Dome or a Space Frame, relatively few templates (11) are required for a structure compared to the total number of facets of the structure. Templates (11) can be created from struts borrowed from the structure. This is what is meant by an integrated system. The structure itself can be the pattern for the membrane panels. The only additional special part required to layout the panels is the Scribe (12). Optimally, designated stand-alone Templates (11) are kept for replacement panel creation or for mass production.

The SCRIBE

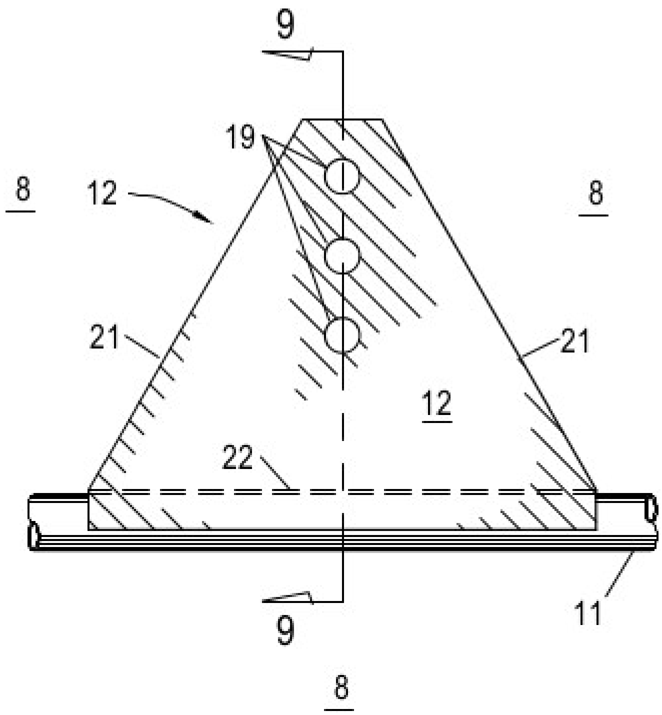


FIG. 8

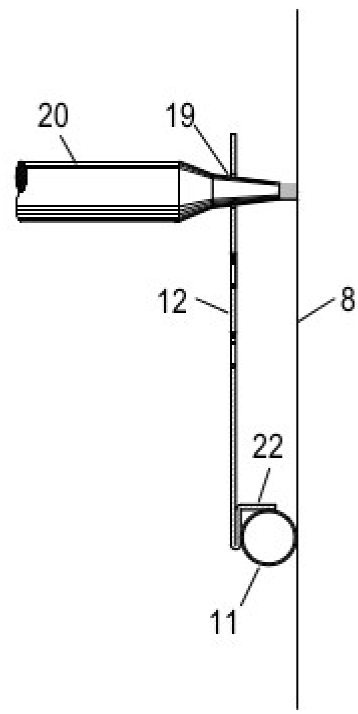


FIG. 9

The front view of the Scribe (12) used to trace the template (11) is shown in Fig. 8. It has at least one hole (19) into which a marking or cutting device is inserted to mark or cut the long outer edges of the panels. Multiple holes (19) for different amounts of overlap are optional. The sloped scribe edges (21) are used to mark the panel cutbacks.

As shown in Fig 9, the Scribe (12) is made of thin gauge sheet metal that holds its shape, while being easily cut, formed and drilled. The ledge (22) is created by folding the sheet metal. The Scribe (12) can be fabricated from sheet metal, plastic or other suitably rigid thin material. It rides along the outside of the template (11) on its ledge (22), while a pen (20) inserted in hole (19) marks the panel's long edges on the membrane raw material (8).

PANEL FEATURES

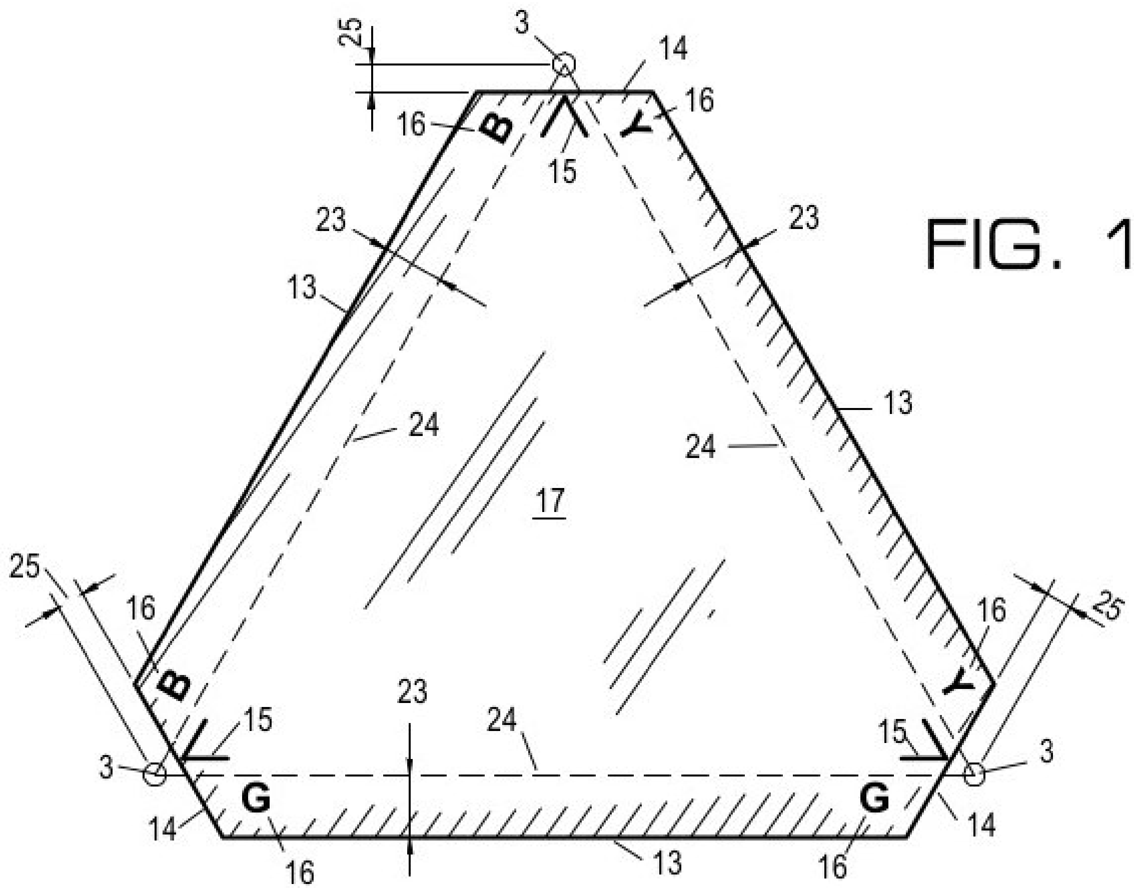


FIG. 10

Fig. 10 The resulting Membrane Panel (17), provides for a substantial panel flap (23) outside of the strut line (24) and stops a short distance 25 from overlapping the hubs (3). The strut designations (16), corresponding to the color codes on the template struts, are marked on (applied to) each end of each panel flap (23). The strut designations (16) and the panel Index lines (15) are the only markings on a finished panel (17) required for installation. One benefit of this method is that the resulting panels (17) will exactly match the structure to which it is being applied. While modern industrial processes can easily be applied to creating these panels (17), the ability of the individual user to readily create their own panels is an asset, especially in third world environments, in emergency situations, for do-it-yourselfers, artists and for advertising.

The results you get with this method depend on the type of panel material used. The membrane material should be of such tensile strength that it will not significantly stretch under the tensile loads created by the clips used to attach it to the structure. Smooth materials with few flaws, produce a consistently tight and smooth surface. Some wrinkled materials have a tendency to smooth out over time with this method, under the constant application of tension, along with repeated heating and cooling cycles. UV resistance is a major consideration in panel material selection for outdoor use, generally determining the lifespan of the panels. Thermal expansion is a factor as well, generally the lower the coefficient of expansion, the more consistent the smoothness throughout the operating temperature range.

MOUNTING of PANELS

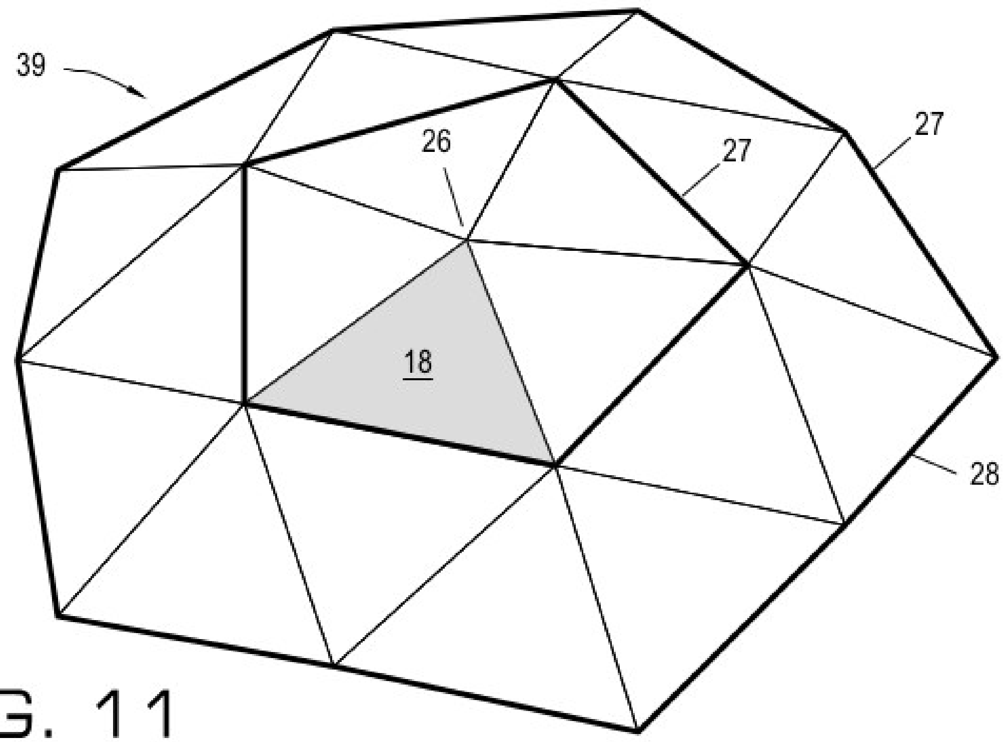


FIG. 11

Fig. 11 shows a geodesic dome (39) in the beginning stages of assembly, with two levels of struts and one panel installed. The tubular geodesic dome (39) is readily assembled from the top (26) down, raising on its outer edge (28). Panels (18) are attached to the dome (39) as it erected, with time being given for glazing between the assembly of subsequent dome levels (27). It is advised to have one complete level assembled between the layer being glazed and the ground or floor, until the last level is complete. The bolts on the layer (27) being glazed should be thoroughly tightened before glazing. Generally, all the membrane panels for a given level (27) are installed one after the other, after which the dome (39) is raised another level (27).

ANCHORING the DOME

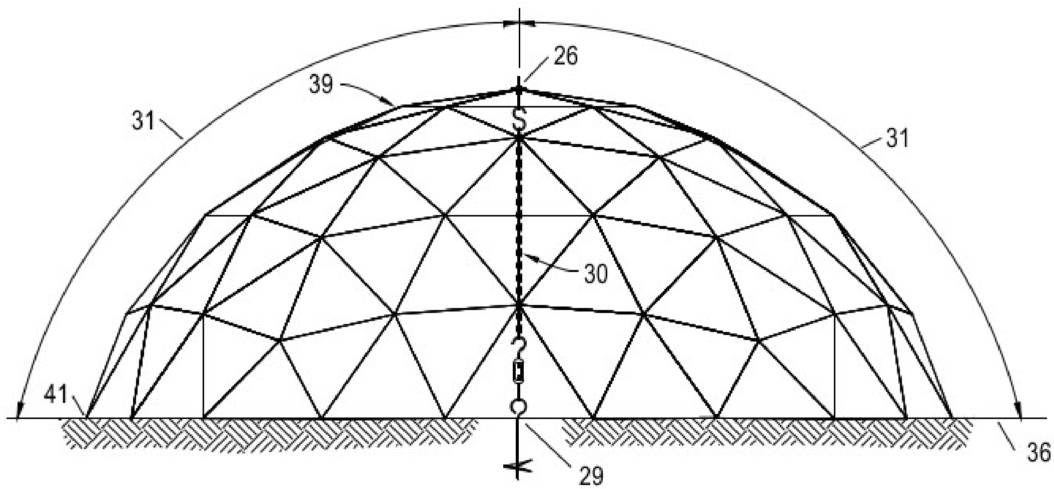


FIG. 12

Fig. 12 It is important that the dome (39) is anchored during erection and after completion, so that the glazed dome will not be blown away, should strong winds arise. This is an important issue due to the high surface area to weight ratio of this type of structure. The Zenith Anchor (30) is the only anchor required to effectively anchor a dome (39) that is ½ sphere or less. The Zenith Anchor (30) attaches the dome zenith (26) directly to the dome base center point 29. This provides a geodesic line of attachment that resists any movement away from the anchor point (29), being that the zenith (26) is locked into place in the horizontal plane (X & Y) by the geodesic arc 31, 360 degrees around the dome (39) and the geodesic line from zenith (26) to the base point (29) locks the vertical direction (Z). The Zenith Anchor (30) allows for rotation about the Z axis. This rotation can be utilized in the overall function of the dome (39) (e.g. in use as an astronomical observatory). Rotation can be locked into place with the addition of at least one anchor point (41), anywhere around the base of the dome. The Zenith Anchor (30) can also work in non-horizontal conditions: on slopes, vertical walls and upside down.

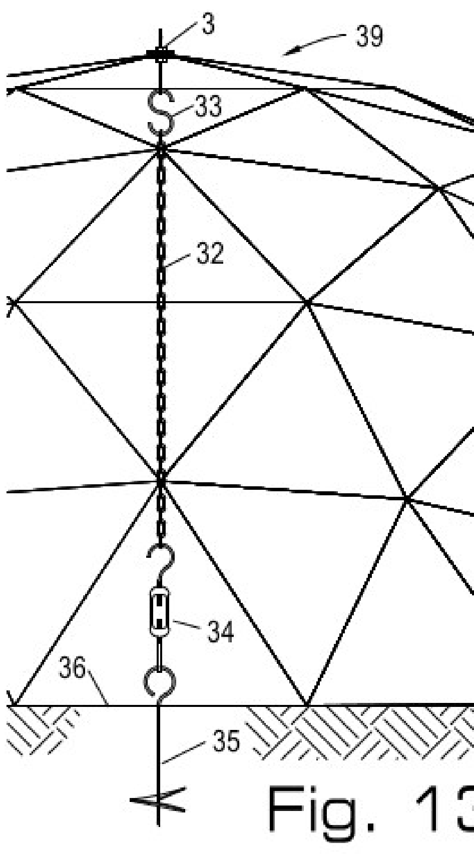


Fig. 13

The Zenith Anchor is a very simple, yet effective method of anchoring a geodesic dome. As shown in Fig. 13, starting from the Zenith Hub (3), an 'S' shape (33) connects a chain (32) that runs to a turnbuckle (34) attached to an auger anchor (35). This makes make a sturdy and adjustable Zenith Anchor running geodesically into native soil/earth (36) at the dome base center point. The auger anchor (35) can be replaced by lugs on a steel deck, an eye bolt imbedded in wood or concrete, or by weights, to name a few possibilities. The turnbuckle (34) tightens to lock the structure in place or releases tension for removal or relocation.

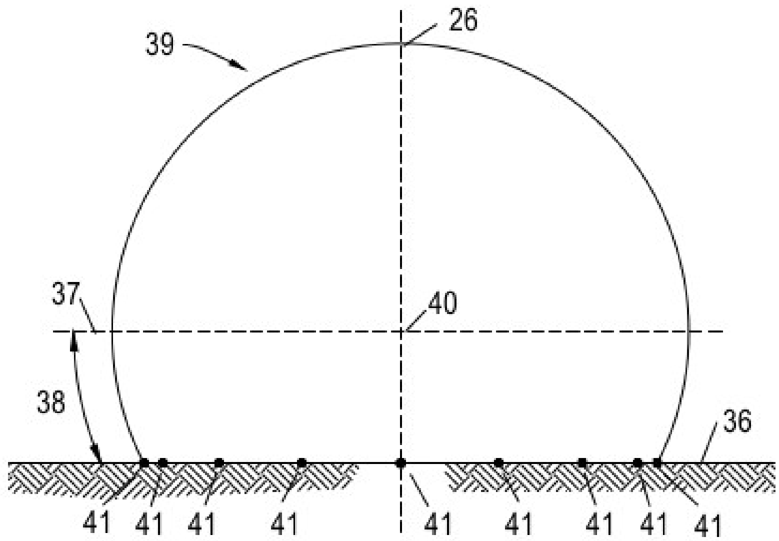


FIG. 14

Fig. 14 A Zenith Anchor is not applicable to or recommended for a dome (39) with a profile greater than ½ sphere, as hereon designated by line (37). This is because the inward curvature (38) of the dome (39) and the elevated center of the sphere (40) lead to instability with a tendency of the dome to buckle below midline (37) during assembly. A dome (39) greater than ½ sphere (37) must have extra support for stability during assembly, such as lifting with a crane, multiple jacks around its perimeter or an internal column with tie downs. Anchors (41) need to be placed at hubs all around its base upon completion, for the structure (39) to be stable and self-supporting.

ATTACHING PANELS

To initiate Glazing, referring to Fig. 11, get a Membrane Panel whose strut designations match the strut pattern of facet (18).

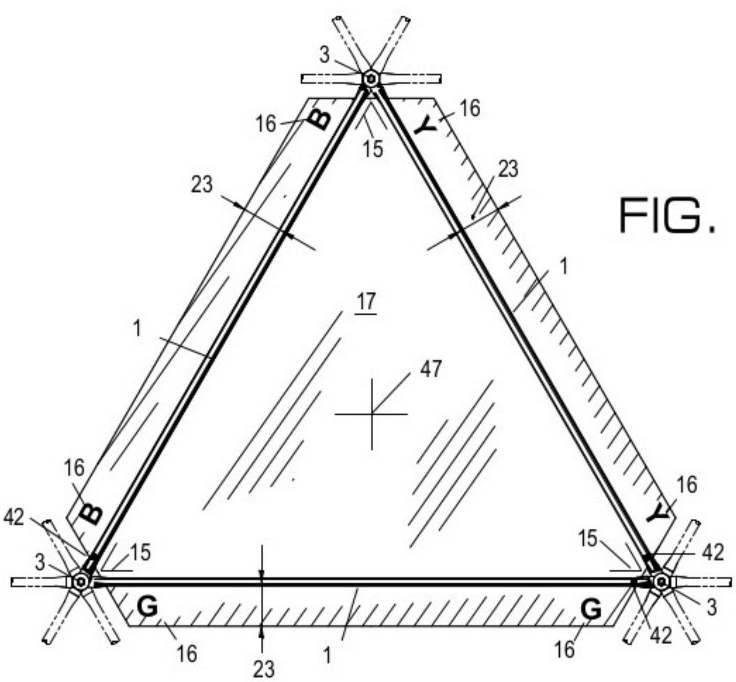


FIG. 15

Fig. 15 Viewed from inside the structure, the panel (17) is laid over the struts (1), matching the panel strut designations (16) with the appropriate struts (1), as indicated by color code Bands (42) and aligning the panel Index lines (15) with the hubs (3). The panel should be installed with the markings facing toward the inside of the structure, so they are visible from the inside to be useful in mounting and are hidden after installation.

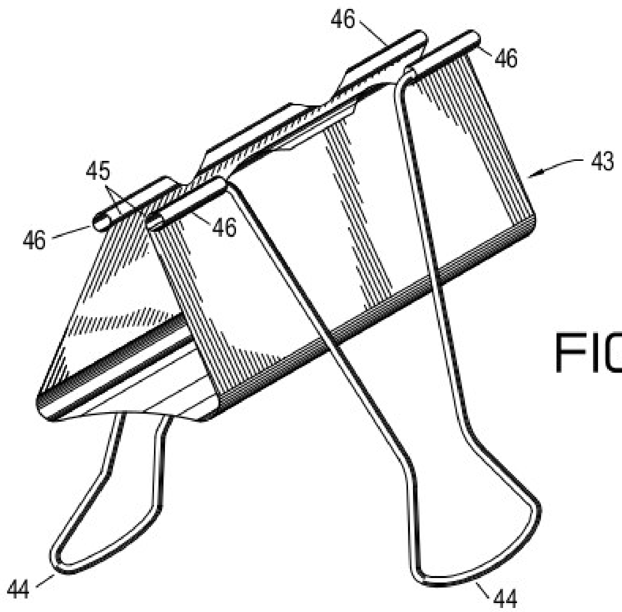


FIG. 16

Fig. 16 Panel clips (43) are used to retain and apply tension to the membrane panels. The panel clips (43) are equal or similar to what are currently manufactured and commonly called binder clips. They are springy and exert considerable force, yet are easily opened by an average human hand. The clips (43) are opened by handles (44) that are removable. The handle ends are inserted into tubular lips (46). These lips (46) provide rounded corners (45) at the point of contact with the membrane panel and allow a rod of the appropriate size to be inserted and held in place by friction fit.

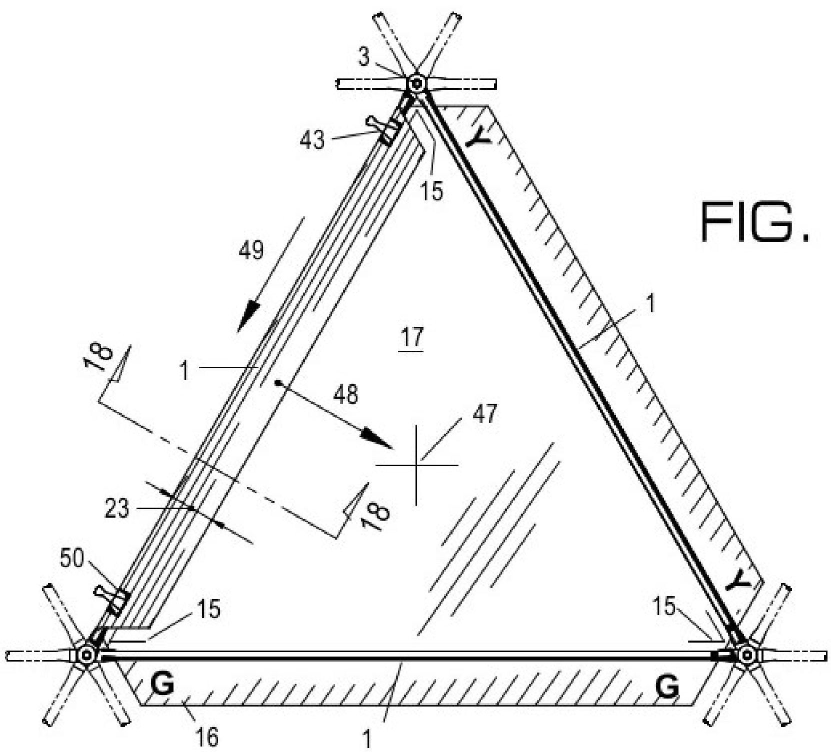


FIG. 17

Fig. 17 To start mounting the panel, fold one of the panel flaps (23) around its strut (1), pointing inward (48) toward the center (47) of the panel (17). Attach a panel clip (43) at one end, in the manner shown in section in Fig. 18. Carefully maintain the panel (17) to strut (1) alignment, using the panel Index lines (15) as the guide. Smooth the panel (17) along the strut (1) in direction (49), so that it lays flat and smooth on the strut (1), then place a second clip (50) at the opposite end of the strut (1).

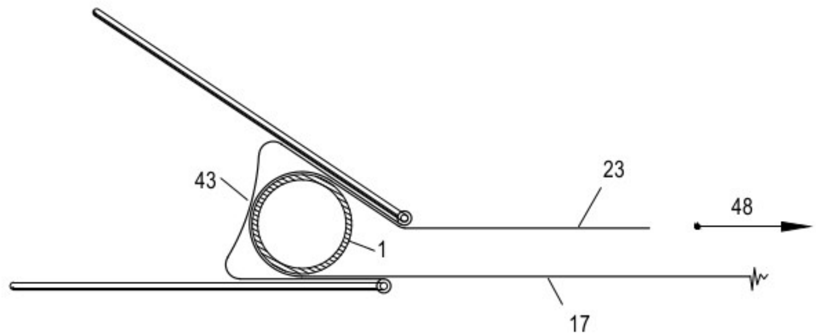


FIG. 18

Fig. 18 shows the way that a panel (17) is attached to struts (1) along an outer edge. The overlapping flap (23) is folded over the strut in direction (48) and the clip (43) is attached in a way that leaves the panel (17) tangent to the strut (1).

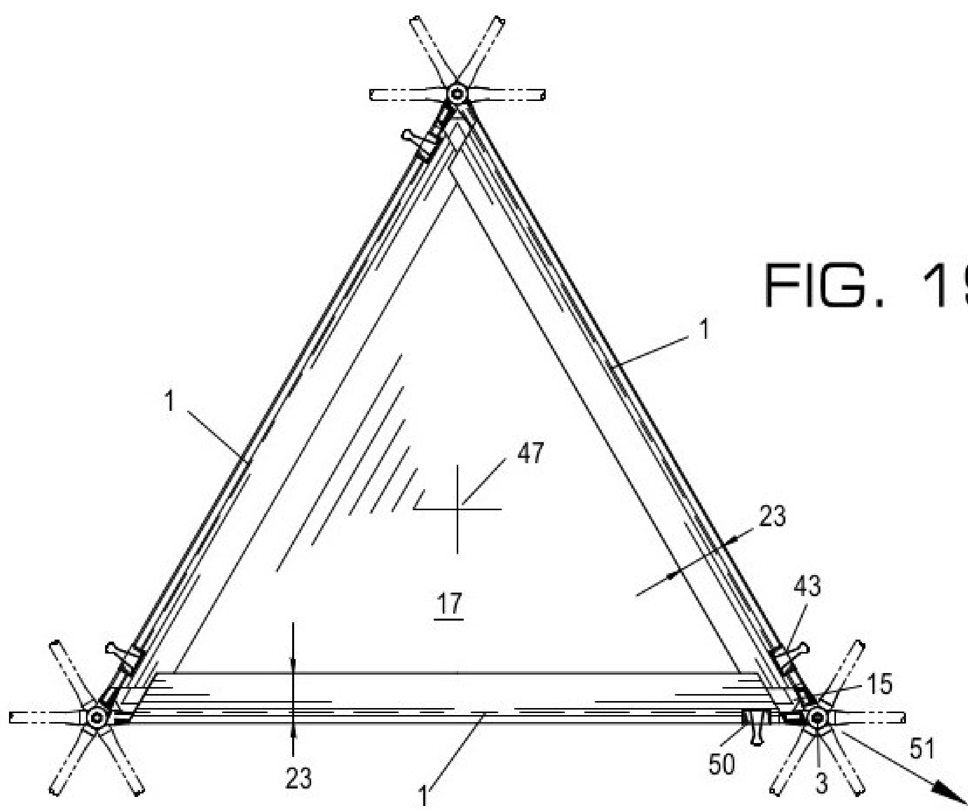


FIG. 19

Fig. 19 Take the panel index (15) opposite the edge just secured and align it with the Hub (3). While pulling the panel (17) tightly in direction (51), fold one of the loose panel flaps (23) around its strut (1) and place a clip (43) at this end, in the manner of Fig. 18. Fold the other loose panel flap (23) over its strut (1) and place a second clip (50) on it.

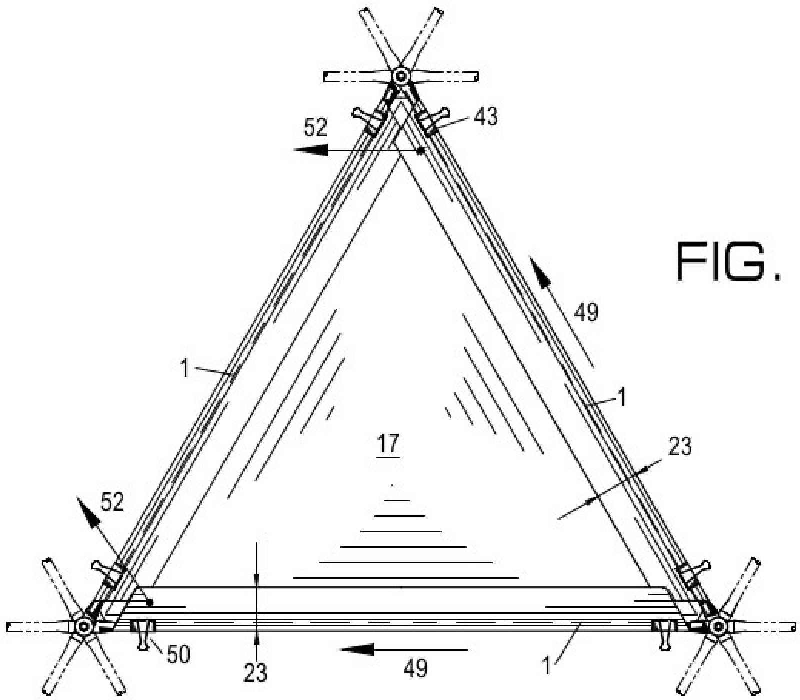


FIG. 20

Fig. 20 Along one side, smooth the panel in direction (49) and flatten the panel (17) on the strut (1). Pull the loose end of the panel flap (23) in the direction (52) and place a clip (43) close to this end, in the manner of Fig. 18. Place a second clip (50) the same way for the other loose panel flap (23).

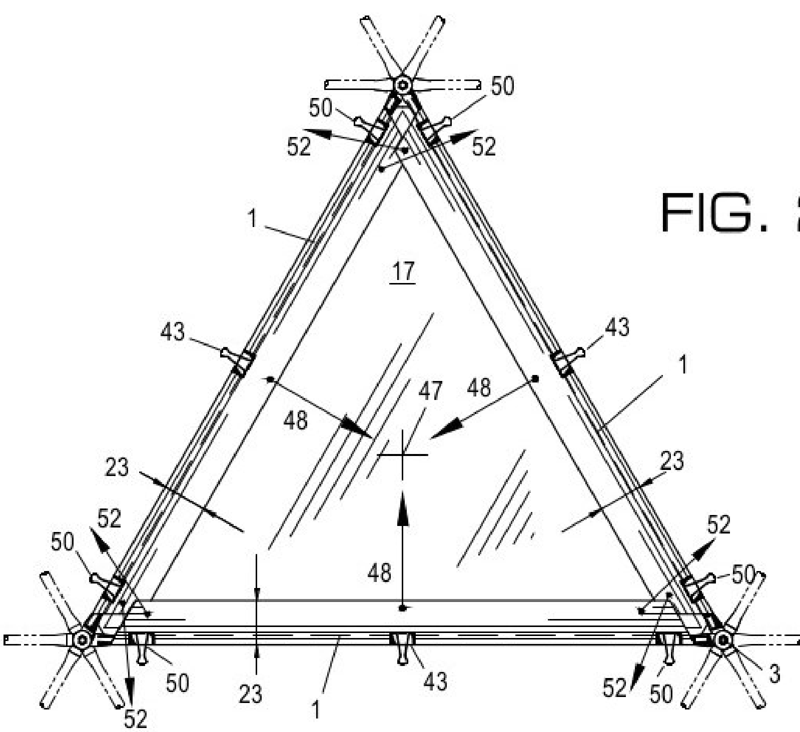


FIG. 21

Fig. 21 Grab the center edge of one of the panel flaps (23) and pull (48) tightly toward the middle (47) of the panel (17). Place a clip (43) on the strut (1) perpendicular to where you are pulling and in the orientation shown in Fig. 18. Repeat this procedure on all 3 sides.

If subsequently, warps occur over the panel (17) surface, go to the end of the panel flap (23) end nearest the warp and remove the clip (50). Pull the panel flap (23) in direction (52), carefully smooth the panel (17) along the strut (1) and re-attach the clip (50). Do this for as many areas as required, until warps have been minimized and the panel (17) is smooth and tight (as the material permits).

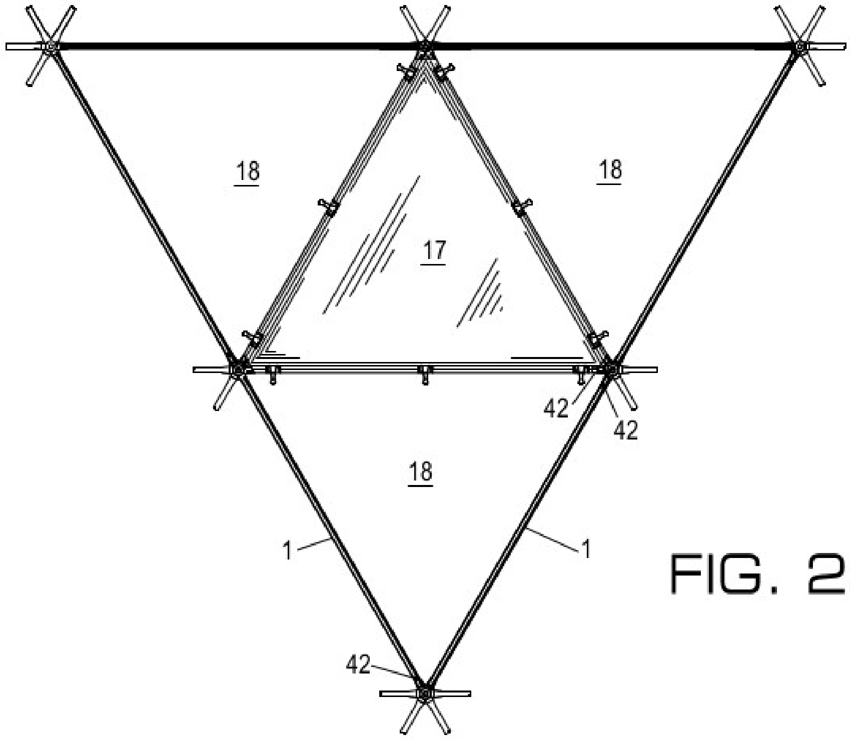


FIG. 22

Fig. 22 is the outside view of the panel (17) just mounted. Select one of the structure facets (18) adjacent to the first panel (17) for the location of the next panel. Note the strut pattern as indicated by the color coded Bands (42) on the struts (1). Get a membrane panel that matches that strut pattern.

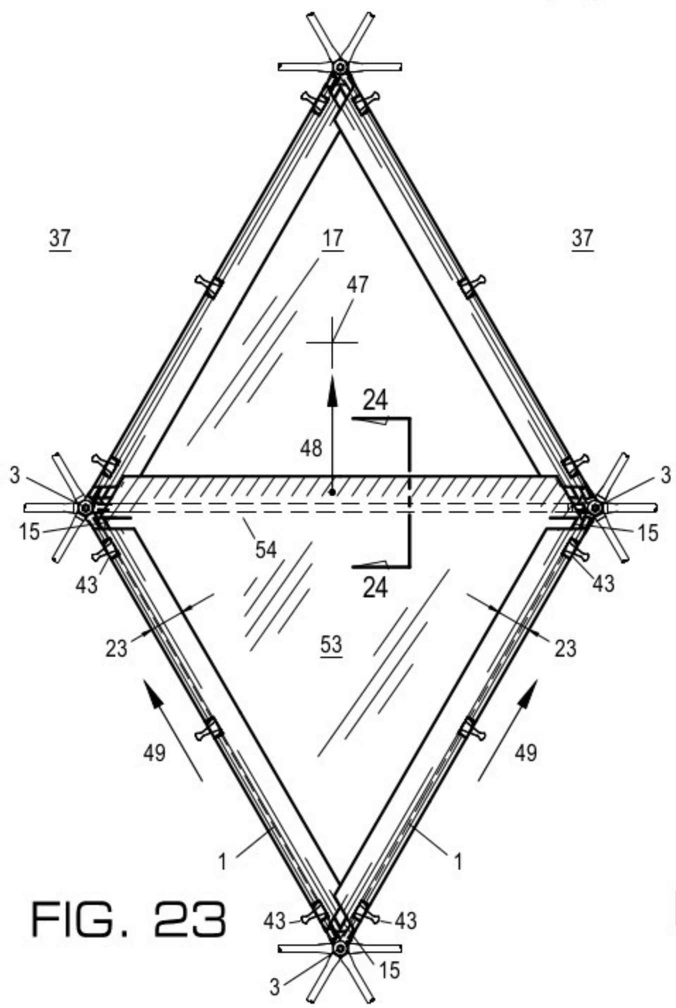


FIG. 23

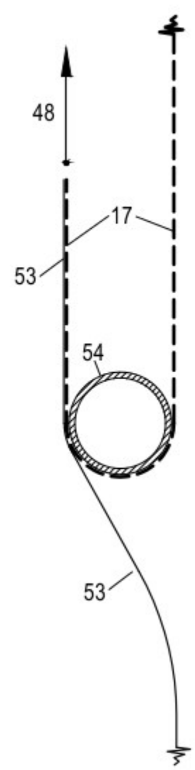


FIG. 24

Remove the clips previously set on strut (54). Wrap panel (17) around the strut (54), pointing inward (48), as shown in section Fig. 24. Bring the second panel (53) beneath the strut (54) and overlap the first panel (17). Pull the center edge of panels (17) & (53) together tightly in direction (48) toward the center (47) of panel (17).

Viewed from inside in Fig. 23, align the second panel (53) with its struts (1) and hubs (3), using the panel strut designations and panel index lines (15). Overlap and clip (43) each of the panel flaps (23) that are on bare struts (1) , making sure that panel (53) lays smooth and flat along the struts (1) in direction (49), as was done with the first panel (17).

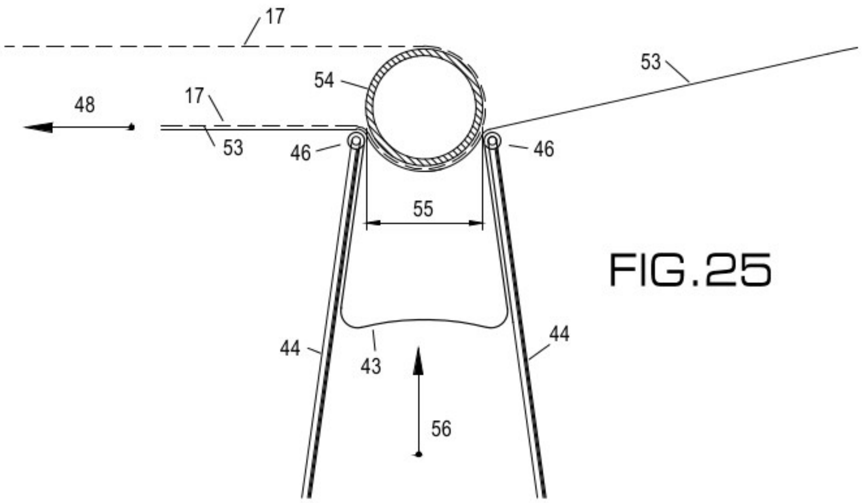


FIG.25

Fig. 25 Open the clip (43) to about the diameter (55) of the strut (44). Place a clip (43), over the middle of the strut (54), against the panels (17) & (53). Push (56) the clip (43) toward the strut (54), while maintaining tension (48) in the panels (17) & (53).

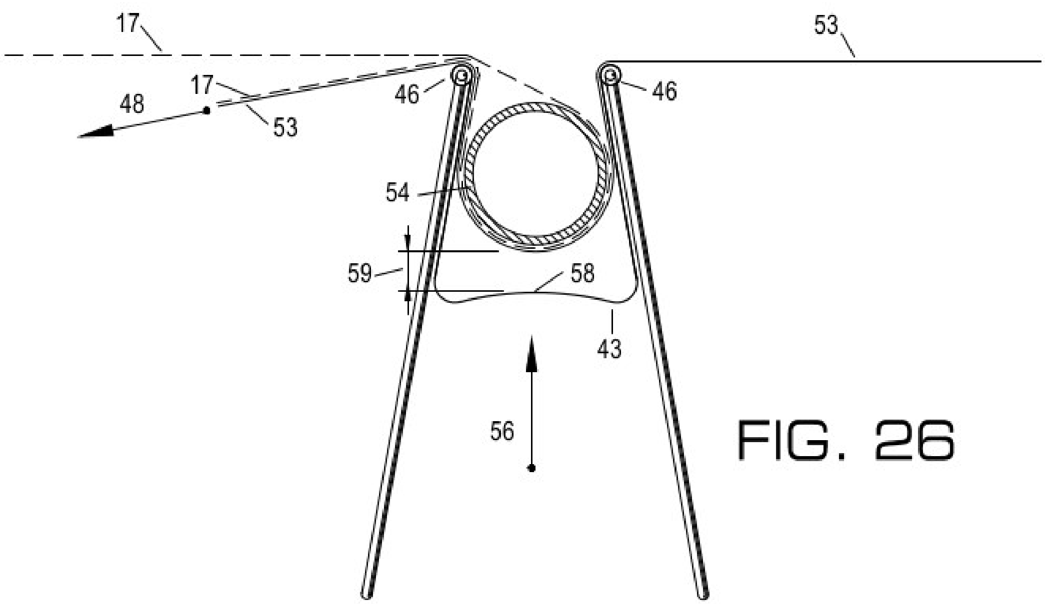


FIG. 26

Fig. 26 Continuing to Push (56) the clip (43) toward the strut (54), gradually reduce tension (48) on the panels (17) & (53), allowing the clip (43) to move to the point where the strut (54) sits between the clip lips (46) and the clip back (58) , in other words "inside" the clip (43) , but not so much as to allow the clip back (58) to touch the strut (54). Release the panels (17) & (53) and clip (43). When a clip (43) is properly set by this method, it can be pushed (56) toward the strut (54) and it will not move. Keeping the strut (54) within these parameters, ensures that there is tension being applied to the panels (17) & (53), as they resist the force exerted by the clip (43). If the distance (59) between the clip back (58) and the strut (54) is reduced to zero, there will be no tension applied to the panels (17) & (53) by the clip (43), because the lips (46) have reached their limits of travel and cannot exert force on the panels (17) & (53) beyond this point. A distance (59) of zero is a prime visual indicator that the panels (17) & (53) need to be re-tensioned by re-setting the clips (43), in order to maintain uniform tension throughout the membrane.

Depending on the expansion coefficient of the panel material and the air temperature at the time of installation, a tension adjustment may be required at higher temperatures, in order to have a smooth and tense panel surface over the entire operating temperature range. By pushing (56) on the clips (43), at the high end of the operating temperature, you ensure tension in the membrane panels (17) & (53) at any normal temperature.

Fig. 27 Using the method outlined above, the center clip (43) is set first. Then grabbing an end of the panel flaps (23) of both panels (17) & (53) together, pull in direction (52). With the panels (17) & (53) lying flat and smooth along (49) the strut (54), set a clip (50) near the end, in the same manner as the first clip (43). Do this at both ends of the panel flap (23).

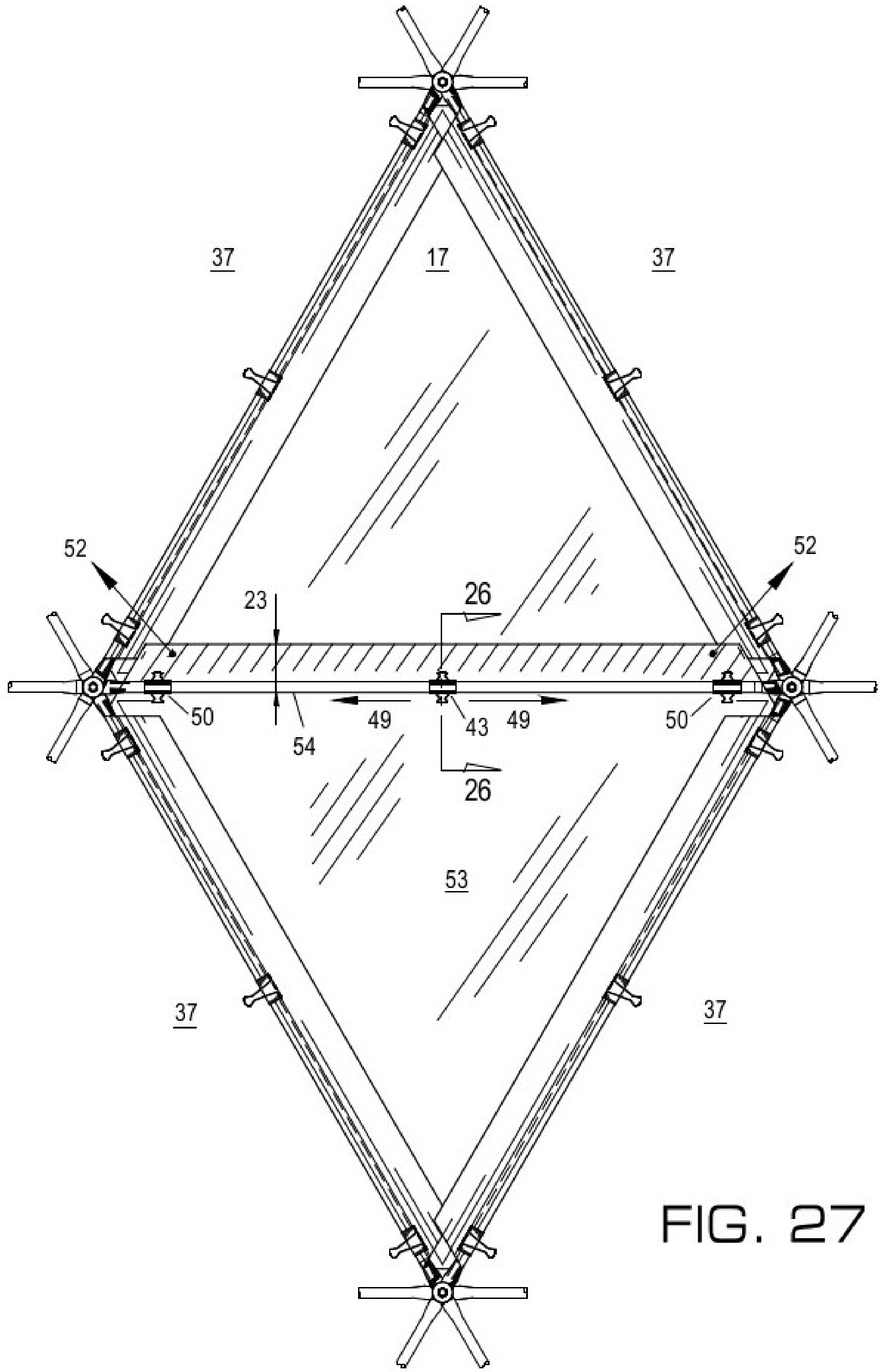
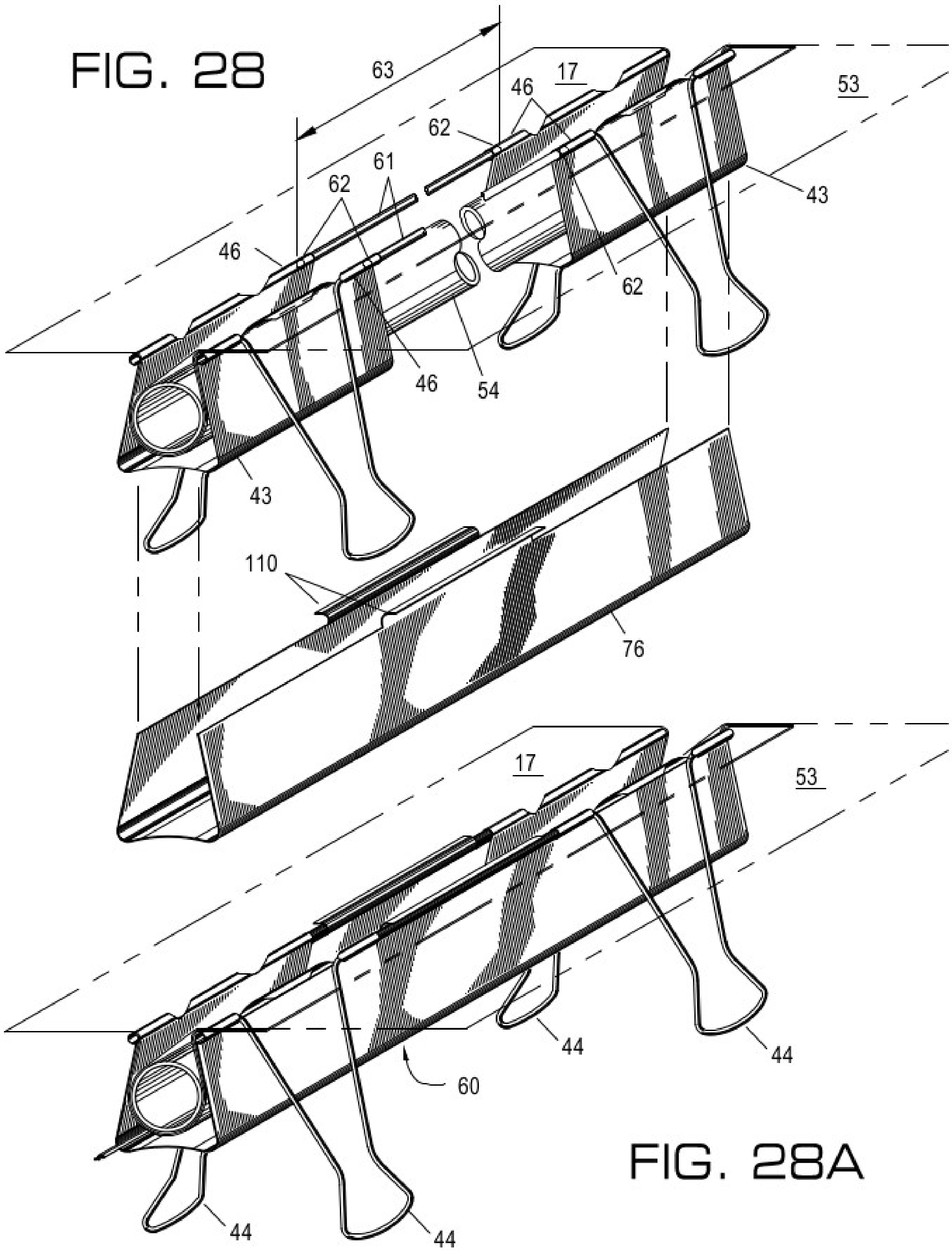


FIG. 27

After these three clips are in place, the remainder of most of the strut (54) length is clipped using Tension Bars. Tension Bars apply tension to the panels (17) & (53) along the length of the strut (54), reducing the total number of clips (43) needed on the structure.

TENSION BARS

As shown in Fig. 28, Tension Bars consist of two clips (43) connected by two rods (61) of equal length (63) and with a diameter sufficient to produce a friction fit at points (62) with the clip lips (46). The Clip Cap (76) is fastened to the clips (43), creating a single stable unit. The Clip Cap (76) is attached rigidly to the clips (43), by adhesives on the surface of the clips (43), or by rivets, clips, tabs, magnets, etc. Two tabs 110 on the Clip Cap (76) wrap around the rods (61) and are held in place between the rods (61) and panels (17) & (53) when installed. This serves to stabilize and mechanically restrain the Clip Cap (76). The Clip Cap (76) rides on the clips (43), but does not substantially contribute to the force exerted to the panels (17) & (53). The Clip Cap (76) can be any thin sheet material, which is flexible yet holds its shape. It is bent or folded to generally match the sides of the clips (43). The bridge rods (61) must be sufficiently rigid so that a constant force is applied to the panels (17) & (53) all along the strut (54). There is an



optimal length (63) and rigidity for the rods (61). A rod 61 that is not rigid enough will tend to bend under the loads, allowing the panel edges to bow toward the center of the panel and resulting in warps in the panels (17) & (53).
Rod lengths 63 can vary in length to facilitate effective coverage of the strut (54) with the fewest possible clips (43).

Fig. 28A shows the finished Tension Bar (60) assembly with handles (44) still in place.

Sheet 15 of 26

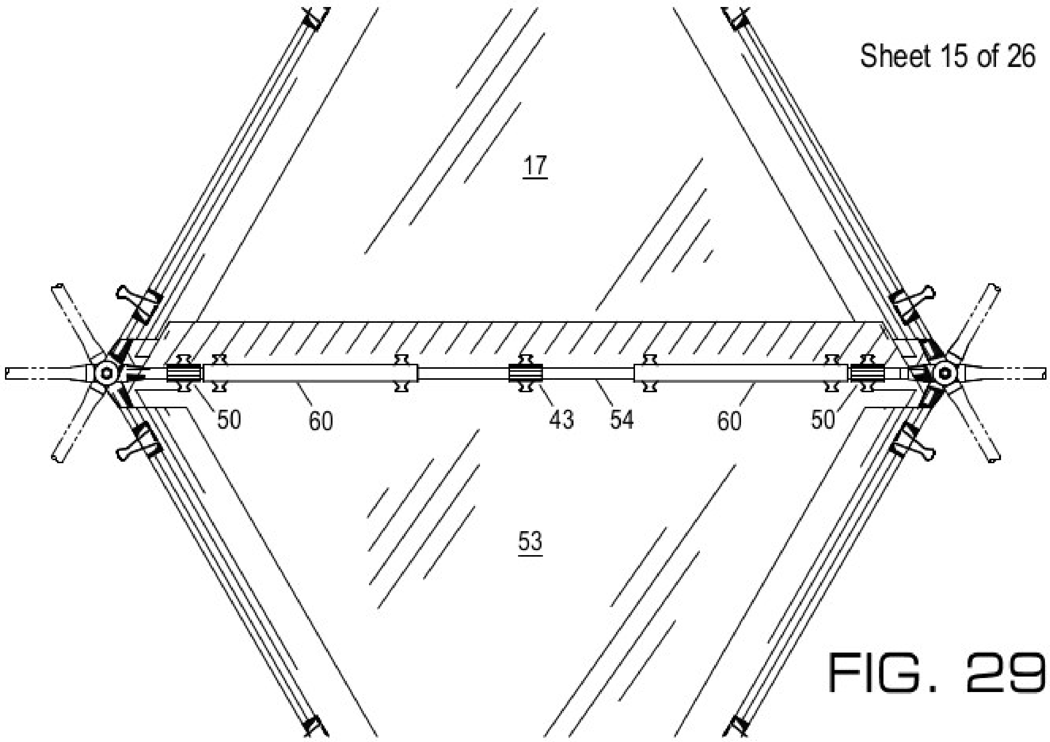


FIG. 29

Fig. 29 To install a Tension Bar (60) , squeeze it open and place it closely adjacent to, but not touching, the end clips (50) . Placing Tension Bars (60) does not require pulling and pushing like the first three clips (43) & (50) . Instead, they are merely set in place. They assume the same clip lip positions, relative to the strut, as the first three clips. Several additional Tension Bars (60) may be required to cover the entire strut (54), depending on the relative lengths of the Tension Bars (60) to the struts (54) . There are generally, three Tension Bars (60) per strut (54) are used. The objective is to leave no gap larger than a clip between clips (50) and Tension Bars (60) , so that tension is applied to the panels (17) & (53) more or less uniformly along the strut (54).

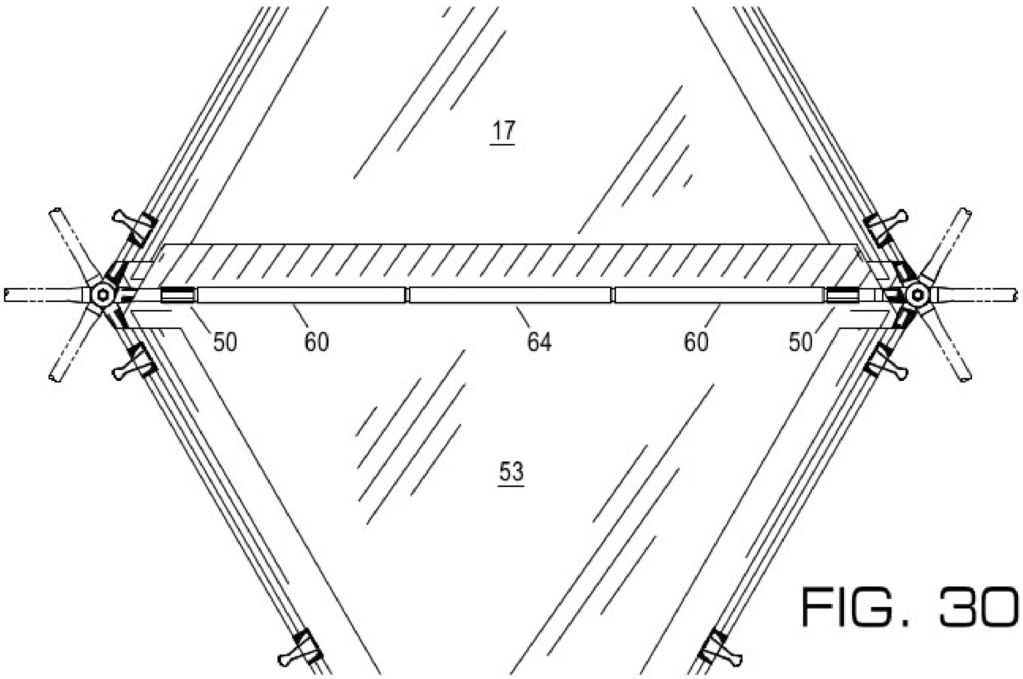


FIG. 30

Fig. 30 shows a finished installation with the middle clip (43) in Fig. 29 removed and replaced by a tension bar (64) . The handles are removed for a more uniform finished look and saved for future use.

The procedure described above is repeated for every facet desired on the tubular structure. You either have abutting panels or an edge as per Fig. 18. One of these two ways of panel attachment is used for every panel on a structure. An edge generally should be covered by Tension bars for uniform tension, restraint along the edge and a finished look.

PANEL WRAPPING

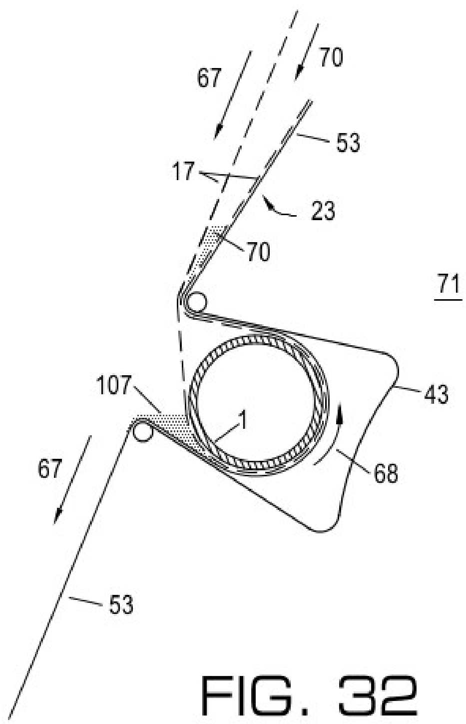


FIG. 32

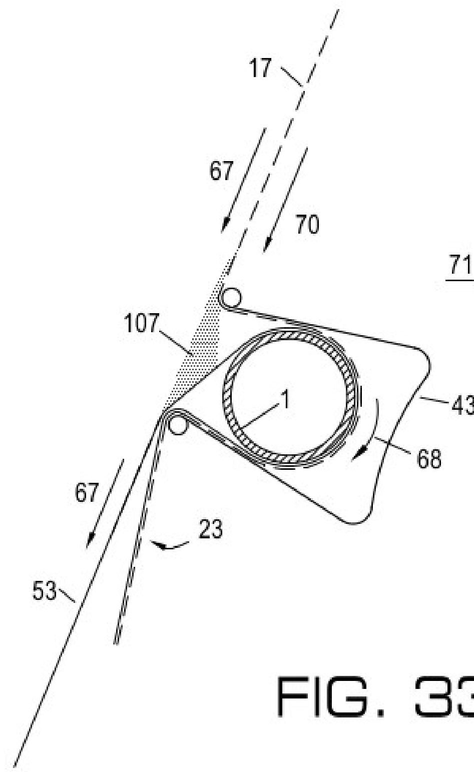


FIG. 33

Fig. 32 The direction (68) of the wrap of the panel flap (23) around the strut (1) is a consideration, depending on the use of the structure. Wrapping the panel flaps (23) in an upward direction (68) around the strut (1) collects external runoff (67) , channeling the water (107) toward the hubs. This can be an asset in greenhouse applications, where uncapped hubs allow this water (107) inside (71) of the structure. This is problematic for dwelling or storage. This wrap also tends to collect interior condensation runoff (70) between the panel flaps (23) and the upper panel (17), seeping down to the strut (1), leading to corrosion and the accumulation of dirt, etc. An upward wrap is required on lower panel (53) to accommodate the Hub Cap.

Fig. 33 A downward wrap (68) sheds runoff (67). The water (107) falls down the slopes. There is minimal accumulation of water. The downward curvature (68) also protects the struts (1) from interior condensation runoff (70), dirt accumulation, and the subsequent corrosion.

BASE CLIPS

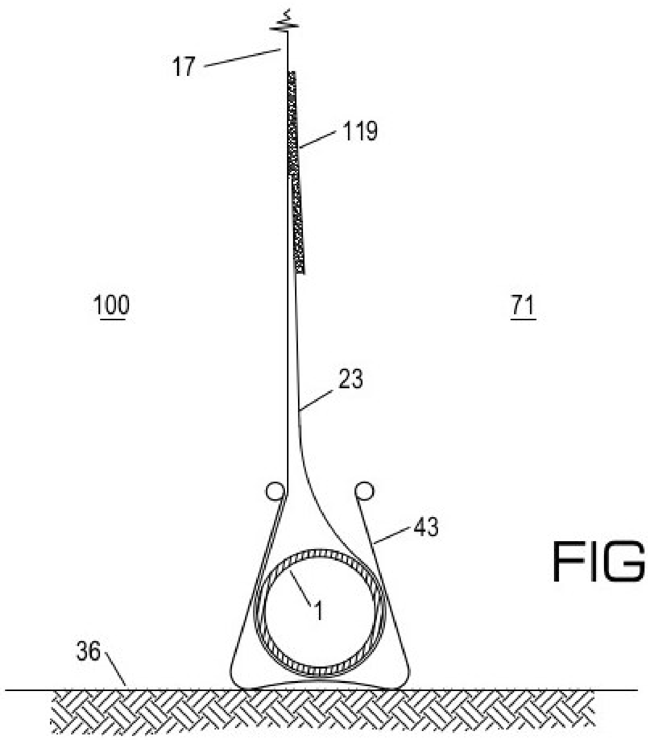


FIG. 34

Fig. 34 For most applications, where the membrane structure sits directly on the natural ground (36) or prepared surface, the panels (17) curve around the base struts (1) to the inside (71) and the panel flaps (23) are clipped 43 as per Fig. 18. It is important that the panel (17) lays smoothly on the strut (1) and in proper alignment with the struts and hubs. The panel flap (23) is taped (119) to panel (17) to help prevent accumulation of water/condensation and dirt around the strut (1).

Panel clips (43) can be set at various angles to the struts (1) and panels (17). The usual angle is the one that bisects the interior angle between the adjacent panels or panel and base (36). The clip angle can be adjusted by grabbing the membrane panel that is looping around the strut, pulling tight then slightly releasing, while the clip grip is slightly released and repositioned to the desired orientation. The membrane and clip are allowed to slide slightly relative to each other, while tension is maintained.

HUB CAPS

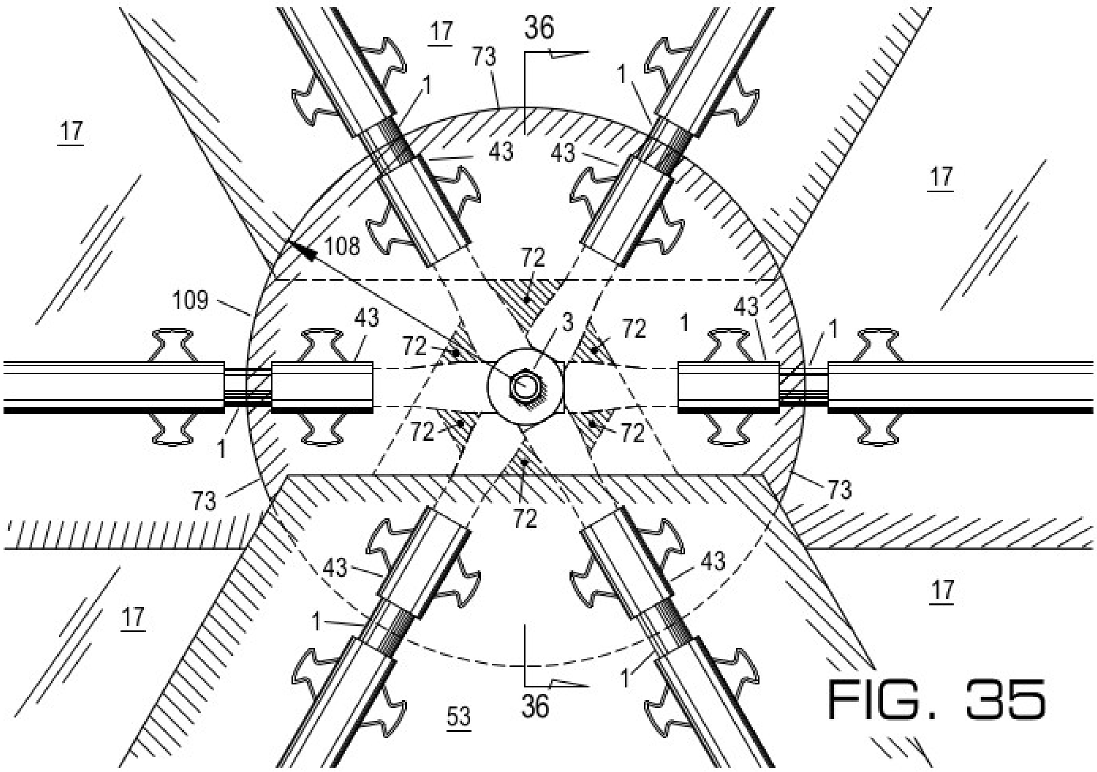


FIG. 35

In Fig. 35, as viewed from the inside of structure at the Hub (3), there are gaps (72) between the membrane panels (17) & (53). A circular Hub Cap (73) , usually made of the same material as the panels (17) & (53), is placed under the upper panels (17) and on the outside of at least one lower panel (53) , so that precipitation runoff is diverted over the gaps (72), similar to a typical roofing shingle. The Hub Cap (73) is cut to such a radius (108) that its outer edge (109) is just beyond the nearest panel clip (43) when installed. This is so that the Hub Cap (73) and the membrane panels (17) & (54) are clipped tightly and securely together, to help create an effective weather seal.

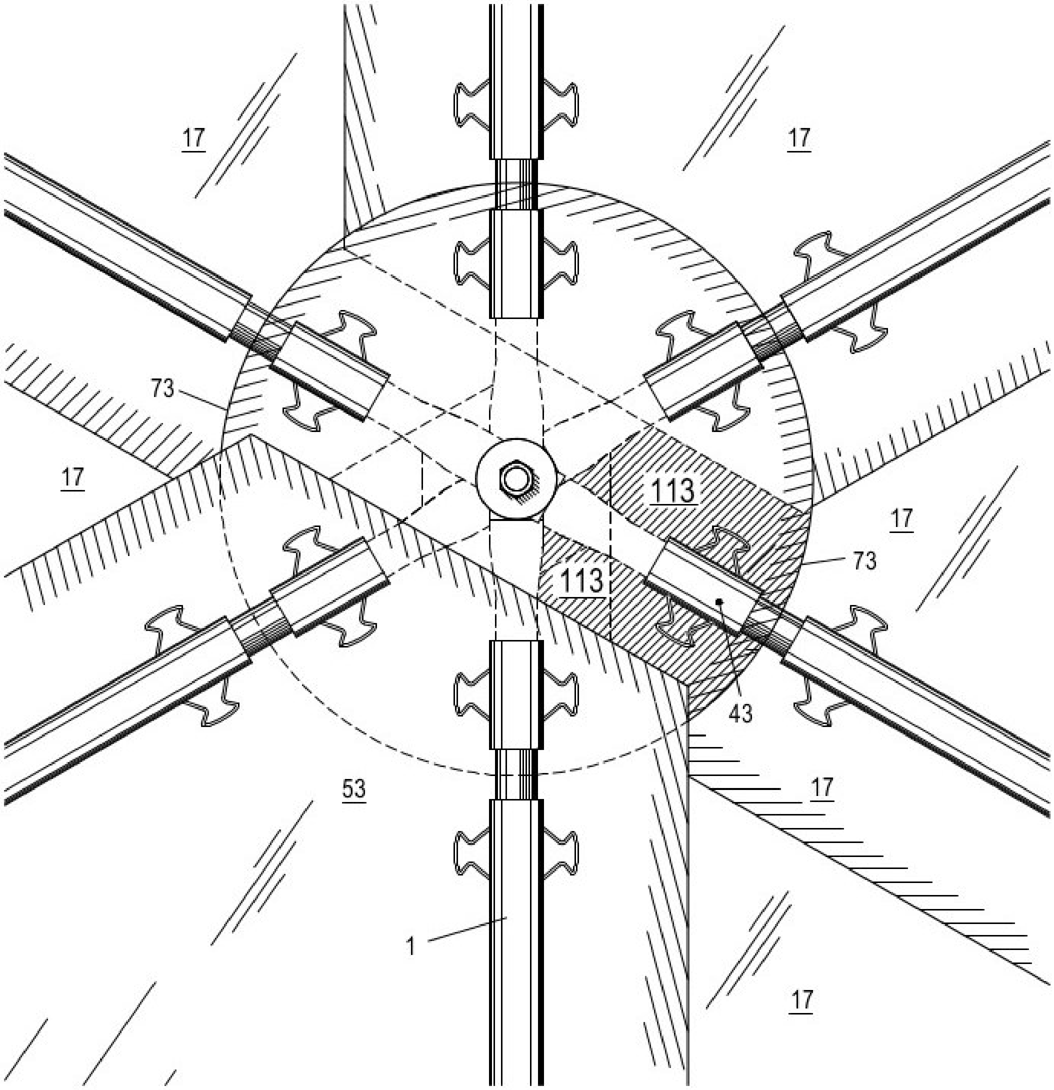


FIG. 35A

When a vertex has a strut (1) pointing vertically down, as shown in Fig. 35A, leakage can occur in the transition zone (113) from underlay to overlap. This zone is tilted sideways and provides a channel for leakage into the dome. This leakage can be stopped by applying a layer of sealant in this zone (113) between panels (17) and the hub Cap (73) and tightly clamping these pieces together with the panel clip (43). Filling the lower portion of the panel depression covering area (113) with sealant from the outside, also be done to help ensure a seal. This is the only location where sealant may be required. A water test should be run after installation to find and eliminate leakage sources, if being water proof is important.

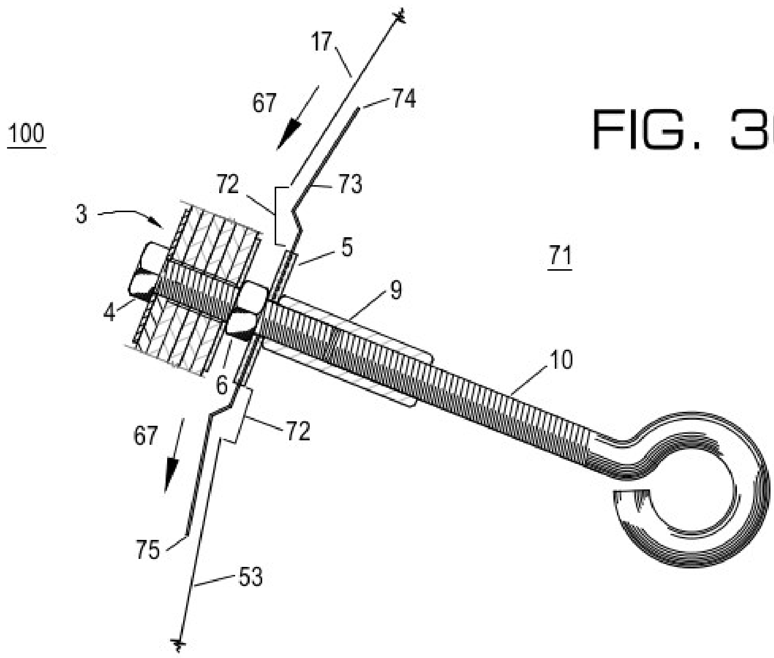


FIG. 36

A section through the Hub (3), Fig. 36, shows how the hub Cap (73) is placed such that its top portion (74) is under the upper panels (17) and the bottom portion 75 is over the lower panel (53). A small cut is made at the center of the hub Cap (73), so that the bolt (4) at the center of the Hub (3) can pass through. This hole is clamped shut between two washers (5), a nut (6) and a coupling (9). Runoff (67) is effectively diverted over the gaps (72) at the ends of panels (17) and 53.

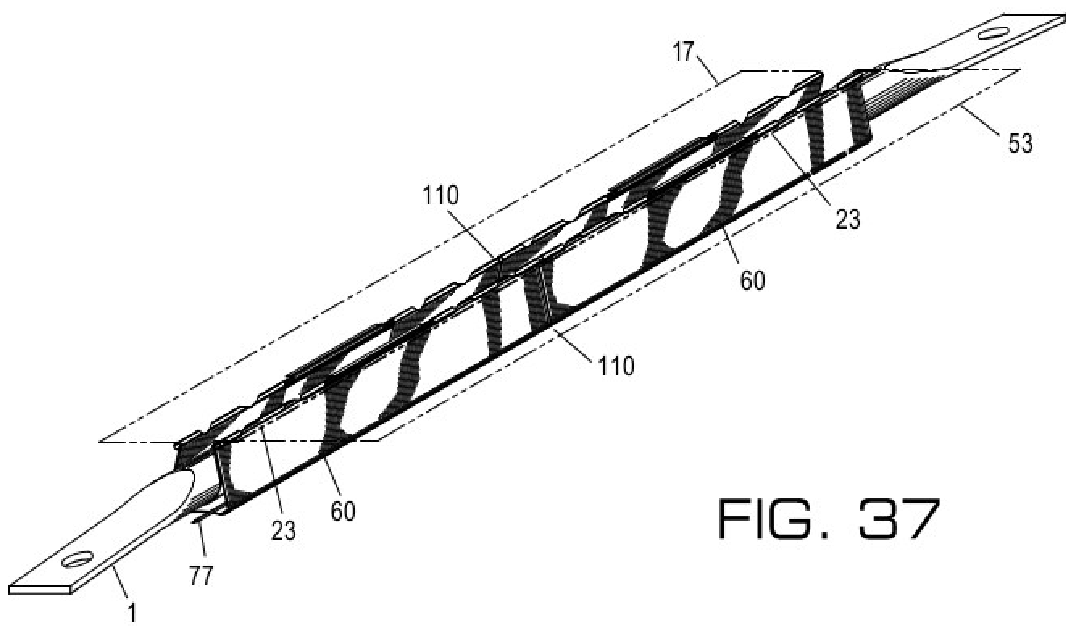


FIG. 37

Fig. 37 After the clips and tension Bars (60) are in place on the strut (1), the handles are removed, stored for future re-use and excess panel flap (23) material can be trimmed off. It is advisable to leave enough panel flap (23) to easily grip for re-tensioning. Leaving a very small gap (110) between tension bars (60) provides a clean and nearly continuous visual line along the struts, while allowing for thermal expansion. This gap (110) can be covered by extending the clip caps (76) beyond the ends of the clips (43) and then overlapping adjacent tension Bars (60). Tension Bars (60) can also be used as a chase for small Power, Control, Supply or Data lines (77) and as a mount for switches, controls, lights and other devices.

PROJECTIONS

FIG. 38

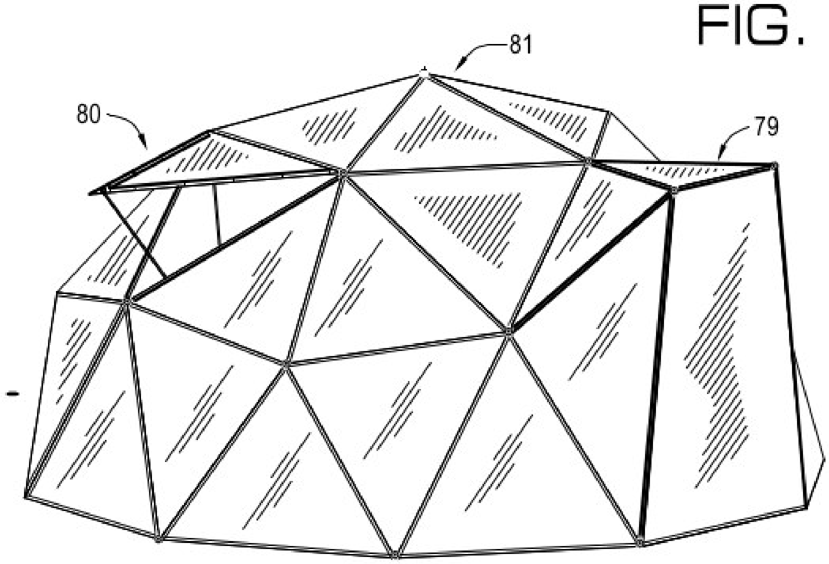


Fig. 38 This method of membrane attachment readily allows the covering of projections from a structure (81) , such as a walk-thru entry (79) or vent (80) , with the same continuously tensed surface as the rest of the structure. These openings are formed from struts (1) of the same material as the parent structure (81) per Fig. 3, but of different lengths and tongue (2) orientations.

TETRAVENT

FIG. 39

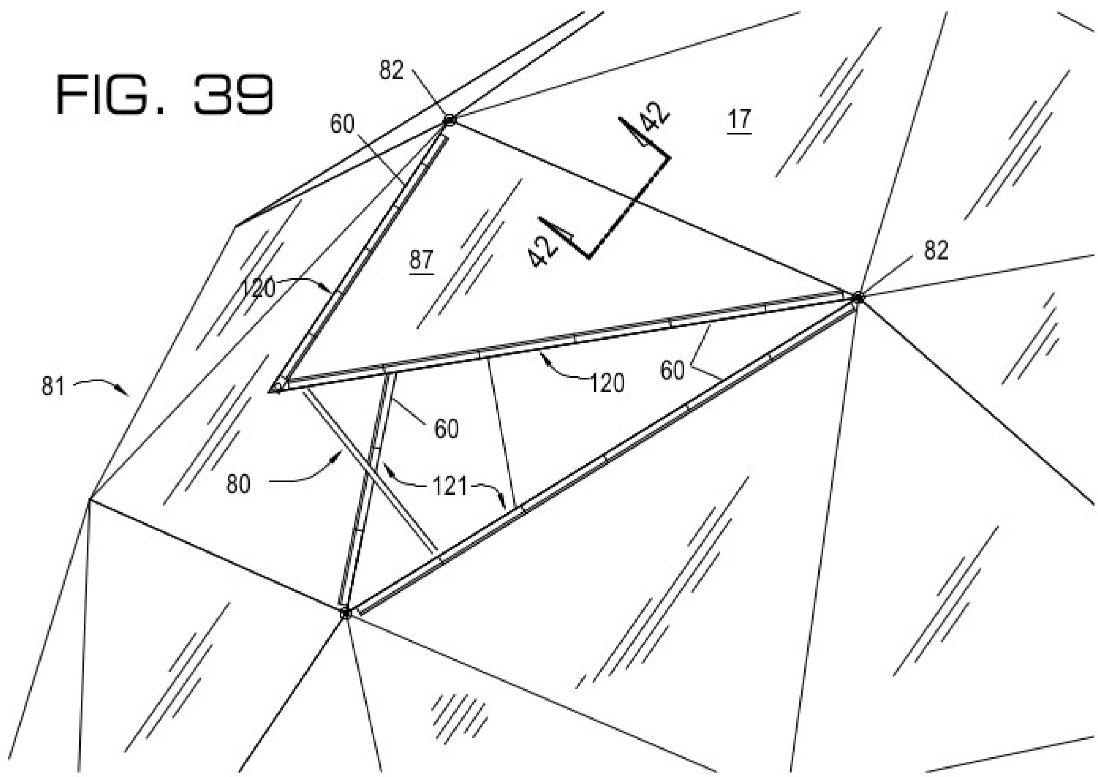


Fig. 39 A vent (80) can be created from a tetrahedral strut arrangement attached to the parent structure (81) at two points (82) and nesting in the structure. It is actuated by a tension element (rope, chain, cable, hydraulic or electric actuator, etc.) on the inside of the parent structure (81). This is called a TetraVent.

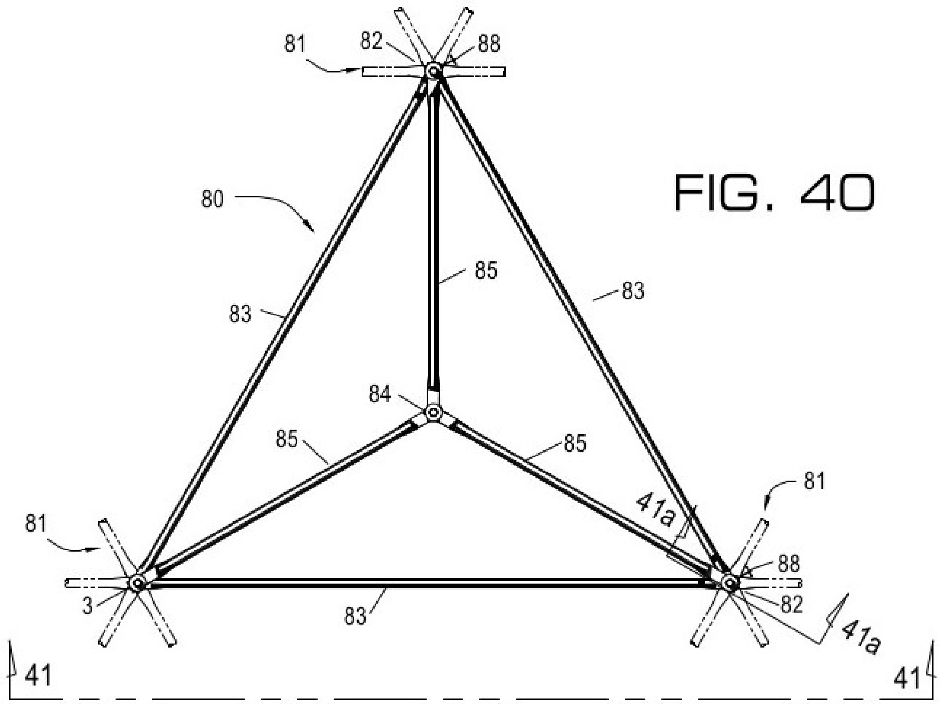


FIG. 40

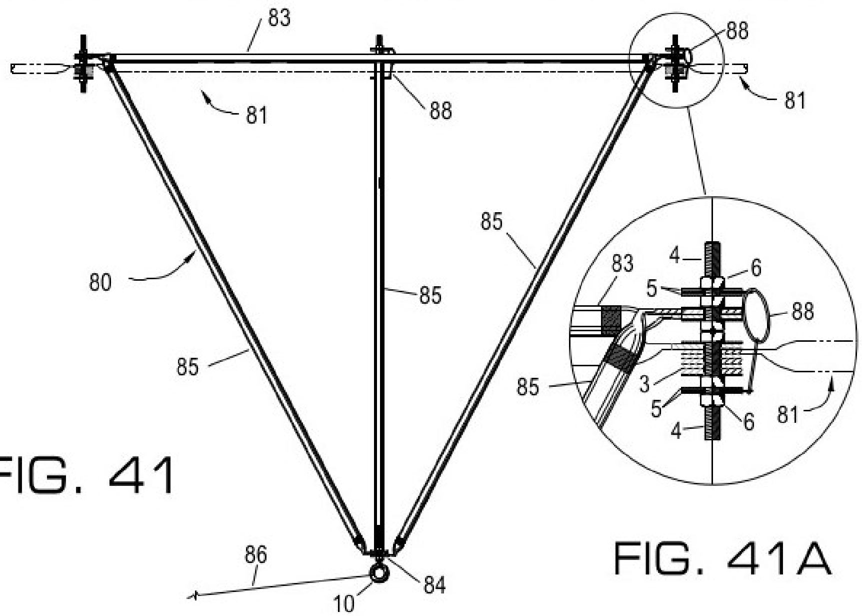


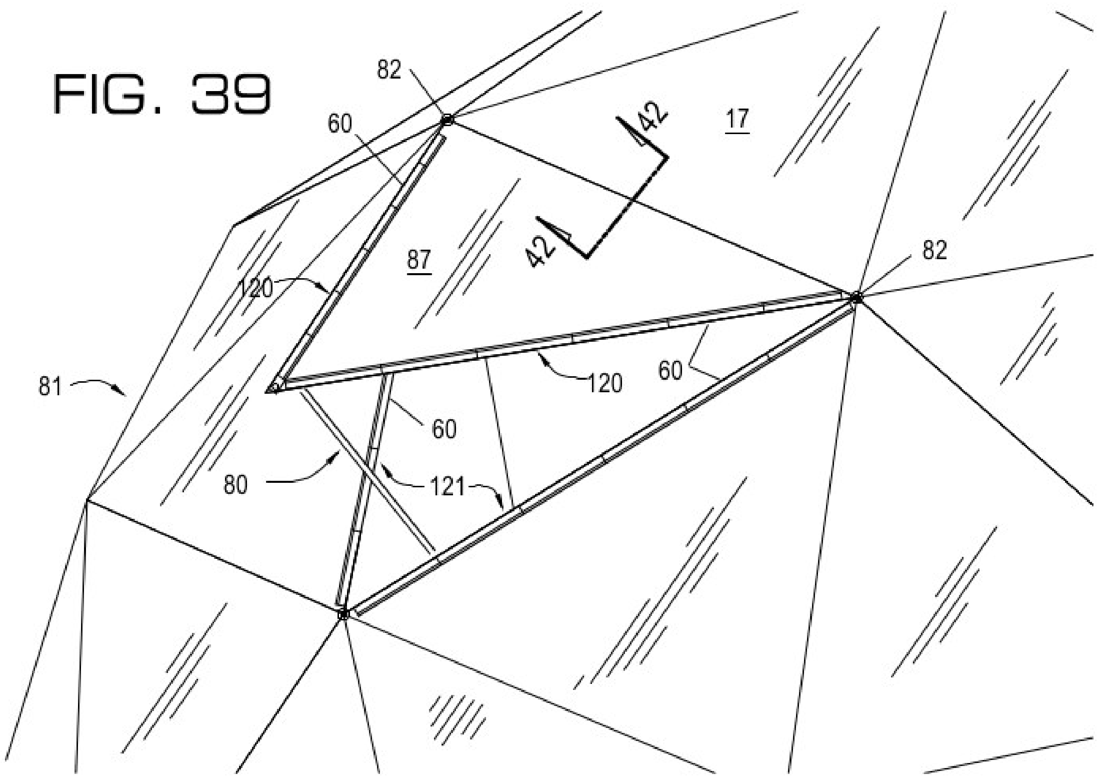
FIG. 41

FIG. 41A

Fig. 40 As viewed from the outside of the parent structure (81) , the top facet of the TetraVent (80) as defined by struts (83) , matches the facet of the parent structure (81) beneath it. This tetrahedral facet is the door of the TetraVent (80). The forth hub (84) of the tetrahedron and its struts (85), nest into the parent structure (81), serving to orient and center the TetraVent (80) upon closing. In most locations on a dome, gravity forces the TetraVent (80) to close by default. The tetrahedron is attached to the parent structure (81) at two points (82) by short tensile elements (88), which can be chain or rope, cable, etc.. This allows pivoting rotation around the line between these points (82), while securing the vent to parent structure (81). This is the TetraVent hinge.

Fig. 41 is the side view of the TetraVent structure showing the struts (85) of the tetrahedron nesting into the parent structure (81). These struts (85) reach over and attach above the vent door struts (83) as detailed in Fig. 41A. This arrangement allows the door struts (83) of the TetraVent and parent structure (81) to mate directly and seal. These struts (85) are connected at the forth hub (84) using an eye bolt (10), to which is connected to an actuator line (86) (rope, chain, cable, etc.), that can be used to open and close the TetraVent. The attachment points (82) are detailed in Fig. 41A, which shows how the TetraVent (80) is attached to the parent structure (81) by means of chain (88) clamped between washers (5) by nuts (6) on opposing (head to head) bolts (4).

FIG. 39



Referring back to Fig. 39, after the TetraVent (80) structure is attached, the membrane panel (87) is attached to the swinging edges (120) of the vent door by a row of tension Bars (60) that mate with the row of tension Bars (60) along the parent structure opening (121) when closed. The panel (87) is first attached to the vent door along the swinging edges (120) first, in a manner similar to Fig. 18, then to the parent structure (81) per the method for abutting panels, described starting at Fig. 23, along the hinge created between points (82).

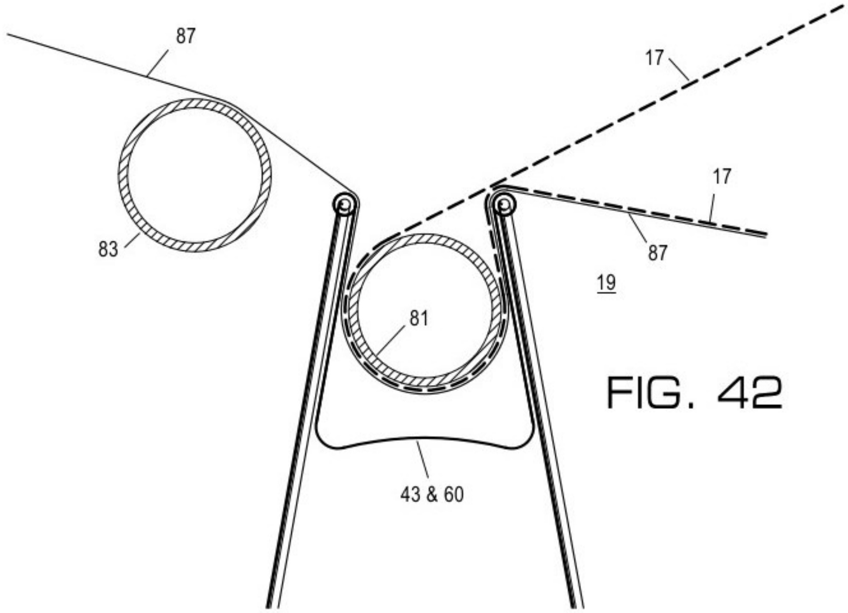


FIG. 42

Fig. 42 is a section through the vent hinge. The section line is shown on Fig. 39. The TetraVent membrane panel (87) curves over and around the vent door and is attached to the parent structure (81) strut, along with the adjacent panel (17), by clips (43) and tension bars (60) on the inside (19) of the structure in the manner previously described starting at Fig. 25. Tension in the vent panel (87) is created by the clips (43) and tension Bars (60) on this parent structure (81) strut.

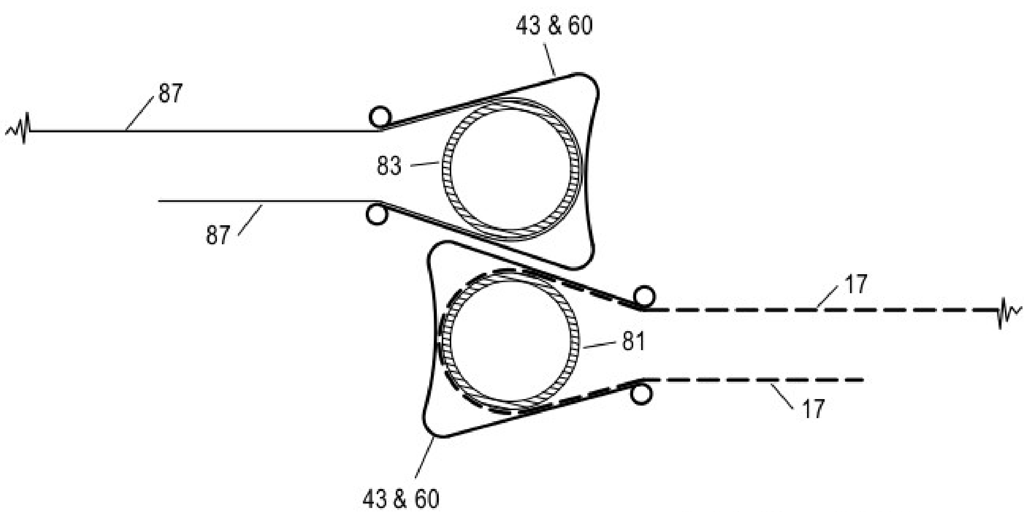


FIG. 43

Fig. 43 is a section through the vent door jamb where strut (83) and the matching side of the parent structure (81) come together when closed. The continuous rows of clips (43) and tension Bars (60) on these mating struts (80) and (81) provide durable edges that overlap when shut, as shown, to help prevent leakage into the structure and center the door when shut.

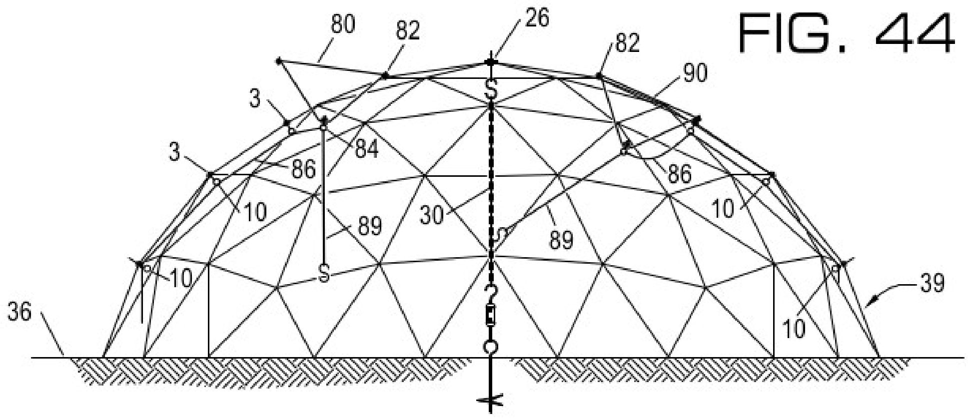


FIG. 44

Fig. 44 is a section thru a dome (39) showing two TetraVents (80) & 90 near the zenith (26). The left TetraVent (80) is opened using an actuator line (86) (rope, chain, cable, etc.) connected to the intruding tetrahedral vertex (84). This actuator line (86) runs along the inside of the dome (39) toward ground level (36) thru eye bolts (10) attached to the dome hubs (3) and is tied off to an eye bolt (10) at a convenient location. The actuator line (86) can be replaced by a remote controlled electro-mechanical or hydraulic actuator attached to a nearby Hub (3). The right TetraVent (90) is locked into closed position with a locking line 89 hooked back to the Zenith Anchor (30) chain.

SHADING

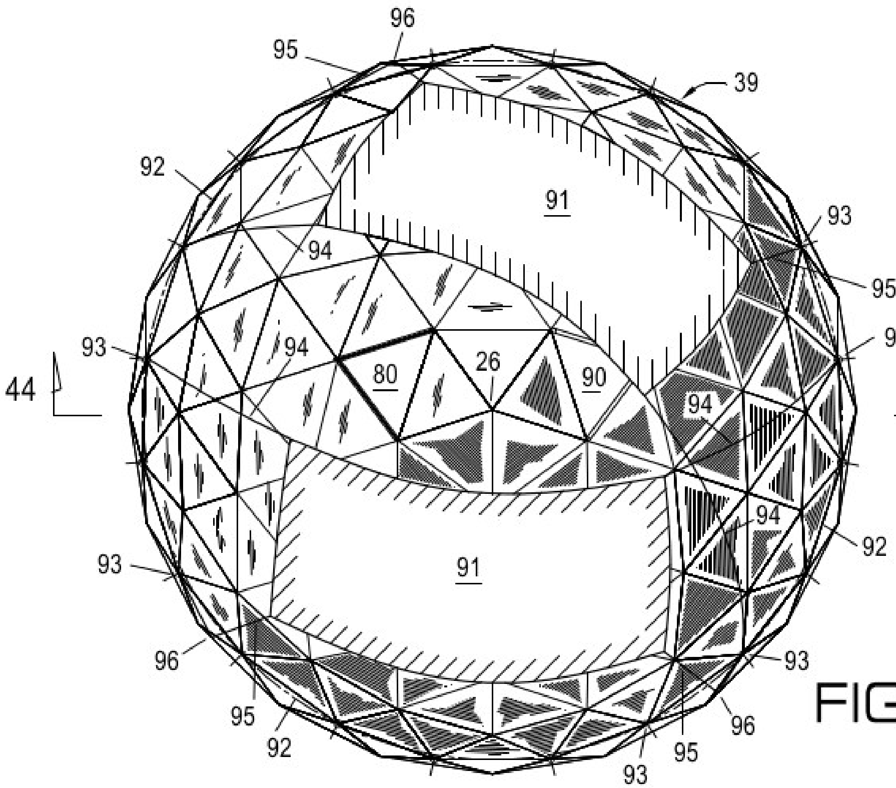


FIG. 45

Fig. 45 External shades (91) may be attached to a dome (39) over the structure and membrane panels with this system using low profile hubs as detailed in Fig. 5, over most of the dome and a ring (92) of hitching post hubs (93) around the dome perimeter (39) at a convenient height. These shades (91) and their top tie lines (94), when pulled tight between the hitching post hubs (93) to which they are attached, describe a geodesic (great circle) arc over the dome (39). These geodesic lines are very stable, in effect locking the shades location on the dome (39). It is this arc that is used to set the location of the shade (91). The lower ties (95) are tied to the base and other hitching post hubs (93) on this ring (92) in order to flatten the shade (91) and prevent it from flapping in the wind. These shades (91) can serve several uses. They can provide shade for the interior and provide added protection in storm conditions.

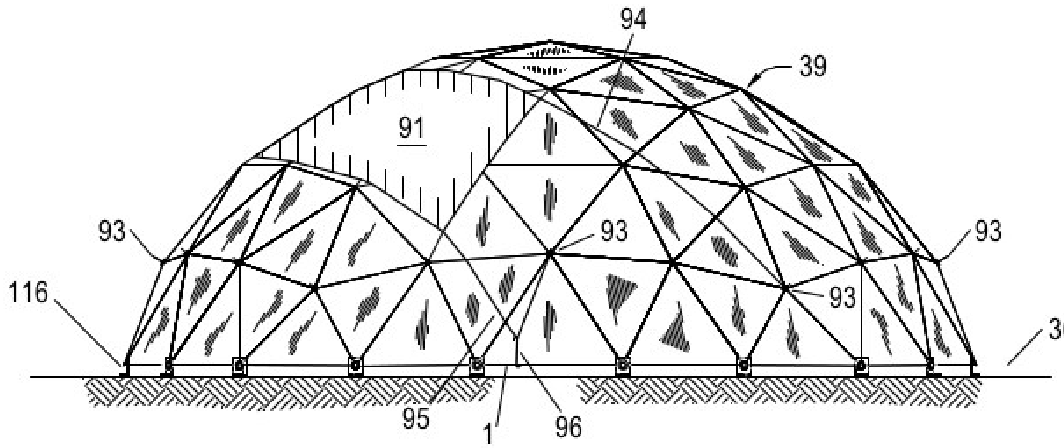


FIG. 46

As shown in the elevation view in Fig. 46, shade tie downs (94) & (95) can be made anywhere along the dome base by using “S” hooks (96) attached to the base struts (1) and then tied off to a hitching post (93) . This elevation shows a dome (39) that is elevated above ground (36) using feet (116).

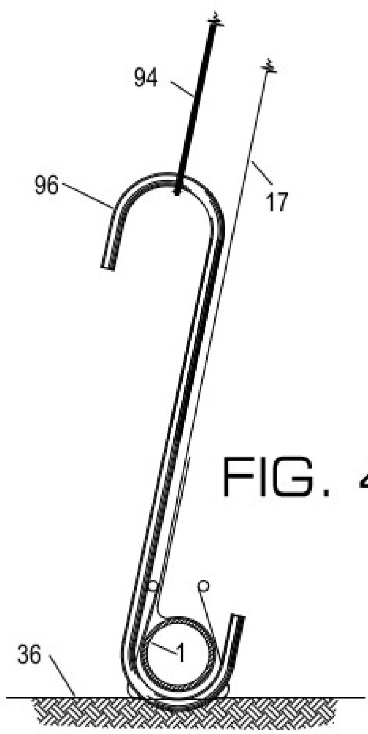


FIG. 47

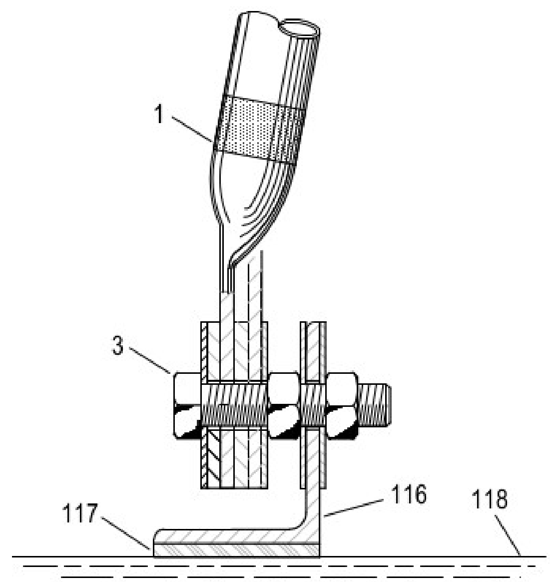


FIG. 47A

Fig. 47 The “S” hook (96) attaches to the base of the dome around the strut (1) to secure the tie line 94. On loose ground/soft earth, these hooks (96) can be laid flat on the ground (36), slid under the dome sideways between the strut (1) and the ground (36), then rotated and pulled into the upright vertical position shown. Fig. 47A, On a hard surface, adding feet (116) to the hubs (3) around the base gets the struts (1) off the surface and facilitates placement of the “S’ hooks and the shades and help minimize the impact to the base surface (118) by the dome. A rubber foot pad (117) is added on the bottom of the foot (116) to help protect relatively delicate surfaces (118), like basketball courts or painted/epoxy floorings. The foot shown is made of structural steel angle shape.

HITCHING POST HUBS

The Hitching Posts hubs (93) are constructed as shown in Fig. 48, with threads extending inside (71) and outside (100) of the structure. This enables two-way extensions from the hub via couplings (9). These extensions can be as simple as a bolt (4) (to cap the coupling as shown) or an eye bolt (10) to equipment such as antennas, lighting, camera, speakers, motion detectors, etc. The inside eye bolt (10) can be used to hang ceiling panels and wall partitions and run the TetraVent actuator, among other things. This hub (93) uses a threaded rod (105) at its core, onto which nuts (6) and washers (5) secure the stack (7) of struts (1) and clamp seal the membrane hub cap (8) between two washers (5). At dome zenith, detailed in Fig. 48A, a zenith cap (112) is installed on a hitching post hub, fastened with a nut (6) and washer (5) on the threaded rod (105) over a hub cap (8) , to help shed water, etc. at this horizontal location. This cap (112) can be bowl shape, as shown, conical or other shape with a rim (115) that is circular or fits with the geometry of the dome (e.g. hexagonal or pentagonal).

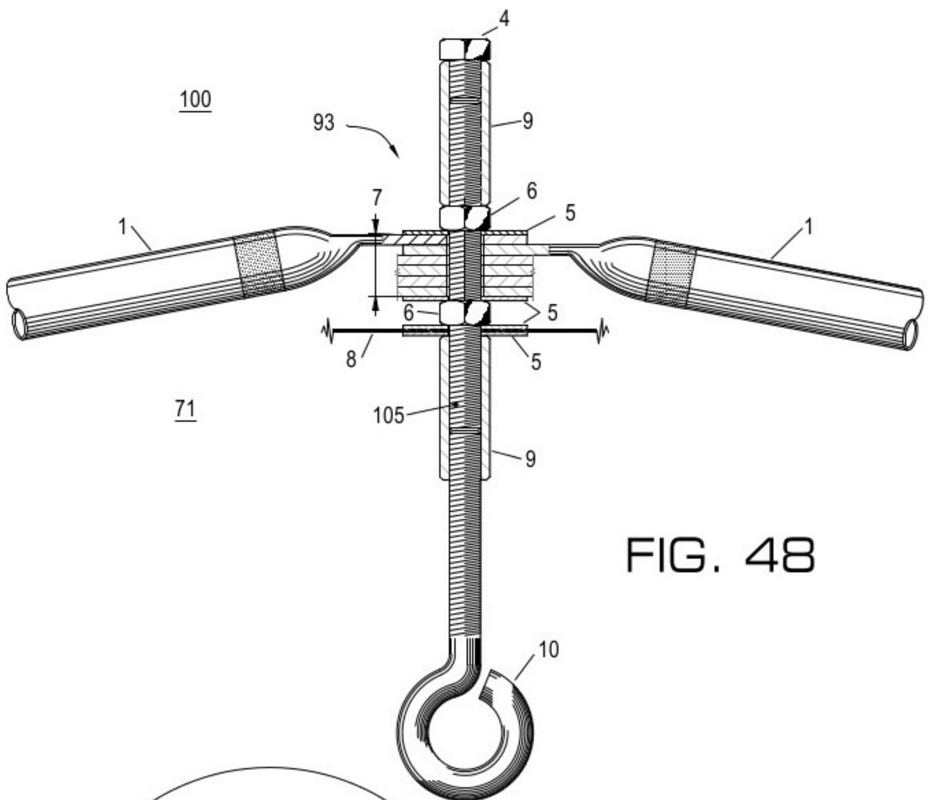


FIG. 48

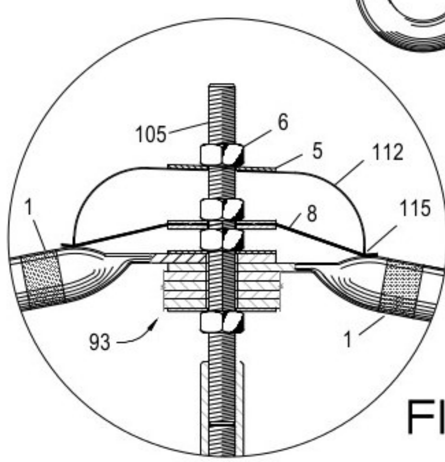


FIG. 48A

NON TRIANGULAR OPENINGS

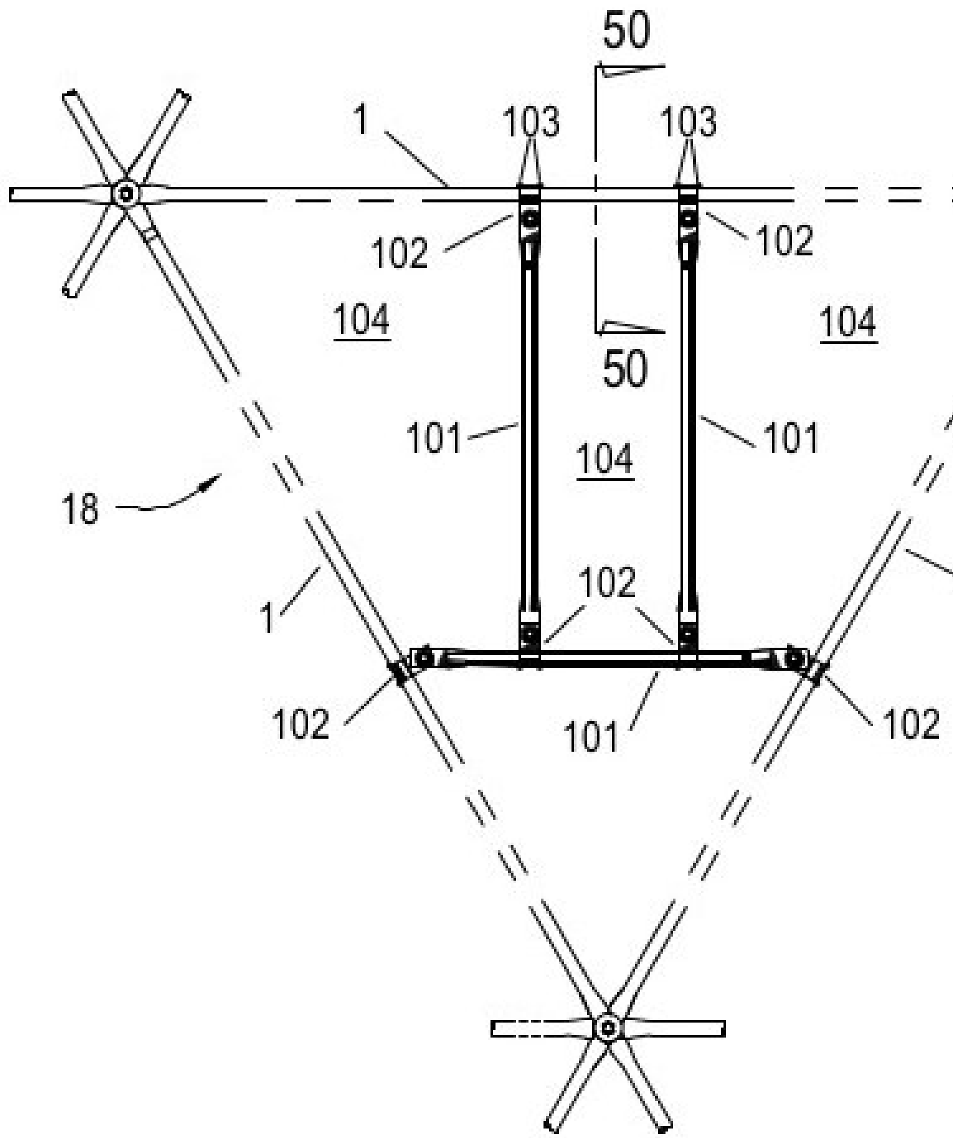


FIG. 49

Fig. 49 A triangular structural facet (18) can be subdivided to create non-triangular openings (104), for this membrane panel system, to create openings for doors, hatches, ports, mounts for equipment and other accessories. Shorter struts (101) are attached to primary structural facet struts (1) by way of perforated straps (102) clamped down and held longitudinally in place along the struts (1) by set screws (103). These smaller struts (101) are made in the same way as the regular structural struts (1), per Fig. 3.

NON TRIANGULAR OPENING CONNECTIONS

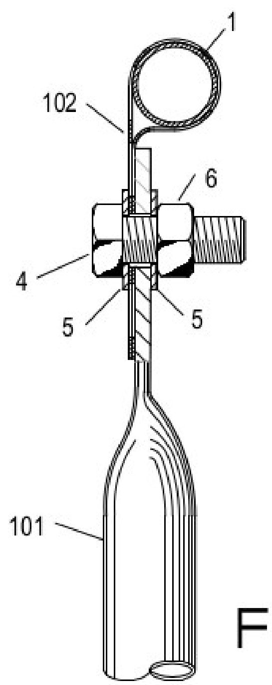


FIG. 50

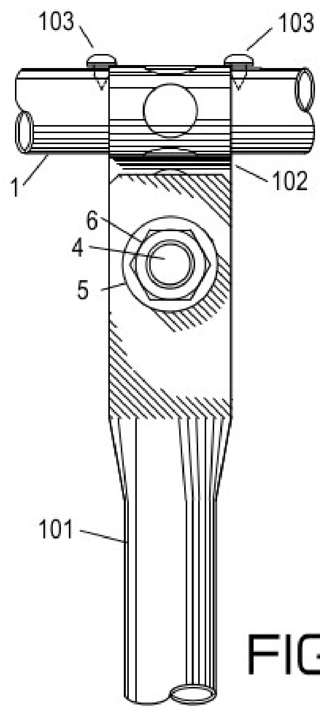


FIG. 51

This type of connection is not intrinsically stable like a standard geodesic or octet strut arrangement and should therefore be used sparingly, triangulated where possible and the application thoroughly tested for stability under loads.

A section view of this connection, Fig. 50, shows how the shorter strut (101) is attached to strut (1) by way of a strap (102) that wraps around the strut (1) and is clamped down by a bolt (4), nut (6) and two washers (5).

In the front view of the connection, Fig. 51, you can see how the strap (102) is held in place along the strut (1) by a set screw (103) on each side along with the clamping pressure of the bolt (4), washers (5) and nut (6) .

INTERNAL PARTIONING

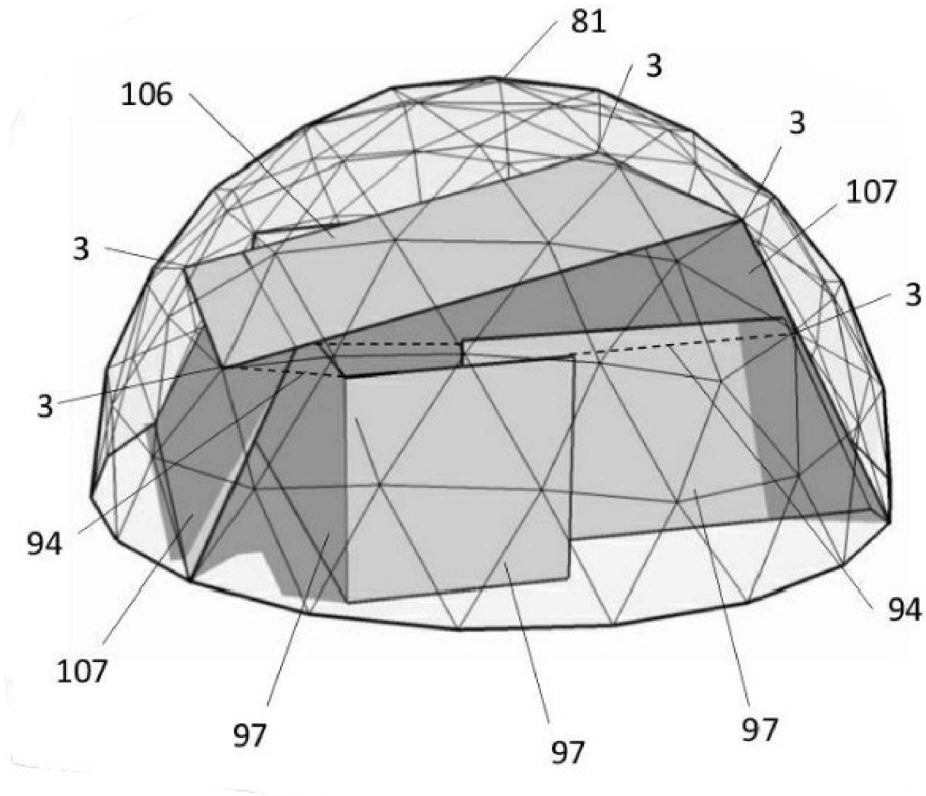


FIG. 52

Fig. 52 Both types of Hub (3) are designed so that an internal eye bolt can be available at every vertex of the parent structure (81) , enabling ceiling panels (106) , screens (107) and wall partitions (97) to be easily hoisted and securely attached to the structure. These elements can be attached directly to the hubs (3) or by lines (94) (rope, cables, chains, et al.) to create rooms, hallways and other interior spaces. This system allows for great flexibility in the use of a dome's interior clear span space. It is easily reconfigurable and can use a wide variety of materials.

GLOSSARY

Membrane – Thin film, fabric or laminate attached to a structure in order to clad, shade or otherwise enclose it.

Membrane Panel – A single membrane element. It is basically triangular shaped with truncated points.

Membrane Structure – A structure that uses a membrane to shade or enclose it.

Hub Cap – a circular membrane element attached at the hub to close that panel gaps at the hubs.

Glazing – The act of attaching membrane panels to a structure.

Abutting Edge – location where two membrane panels come together

Re-tension – To reinstall clips along panel edges to increase the tension in the panel.

Tubular – Having a circular cross section; being a linear right circular cylinder.

Tubular Framework or Structure – Structure made from and comprised primarily of tubular elements.

Strut – A single structural element of a tubular structure.

Tongue – flattened end of a strut that is drilled and used to connect to other struts.

Hub – Vertex or intersection of struts in a tubular structure with the struts held together with a bolt or threaded rod, washers and nuts.

Facet – Triangle or other shape on or within a structure defined by mutually interconnected struts. A face of a polyhedron.

Strut Pattern – Arrangement of Struts around a Facet, herein designated as starting with the shortest going clockwise.

Bare Struts – Struts that do not have membranes attached.

Geodesic – Shortest distance between two points in space or on the surface of a sphere.

Single Layer Geodesic Dome – A Geodesic Dome having most of its parts at the same radius from center, in other words, having no significant structural depth, as related to the center of the structure.
The Dome Base – the intersection of the dome with the ground, slab, etc. on which it sits.

Dome Center Point – Center of the dome base.

Dome Zenith – Very top or highest part of a dome. Often it is the hub at the center of a pentagon, but not necessarily.

Dome Layers – Starting at dome zenith, layers are the concentric ring of triangles that are the same average distance from Zenith. They are installed at about the same time. The dome is raised by the addition of layers.

Parent Structure – Larger structure like a Geodesic Dome or Space Frame to which a smaller structure, like a door or vent, is applied.

Operating Temperature – The range of temperature in which a structure or part operates; being the range of temperature to which a structure is exposed over the normal course of a year, taking into account outside and inside air temperatures, direct solar heating, rain, wind, freezing precipitation, etc.

Shading – Membrane or tarp material with the purpose of providing shade from or reflectance of the solar radiation.

Inside View – View from Inside of the Structure

Outside View – View from Outside of the Structure

Integrated Construction System - A building system using a small set of standardized parts and with the structure itself being the templates for the enclosing panels.