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(71) Applicant: **VRIJE UNIVERSITEIT BRUSSEL**
1050 Brussel (BE)

(72) Inventor: **Hebbelinck, Sven**
9400 Ninove (BE)

(74) Representative: **Van Malderen, Joelle et al**
Office Van Malderen,
Place Reine Fabiola 6/1
1083 Bruxelles (BE)

(54) A flexible tensioned structure and method of calculating such a structure

(57) Tensioned structure, essentially for use as a temporary shelter, comprising at least one unit (100), said unit comprising a net of longitudinal elements (1), said net consisting of:

- a first and a second family of longitudinal elements (1a,1b), said elements of each family being essentially parallel in a flat condition of said unit, each of said elements having a variable length,

means (2) for holding together said longitudinal elements of said first family and said longitudinal elements of said second family in the nodal points, being the points where said elements of said first and second family overlap, said means (2) allowing elements of both families to rotate and to slide relative to each other.

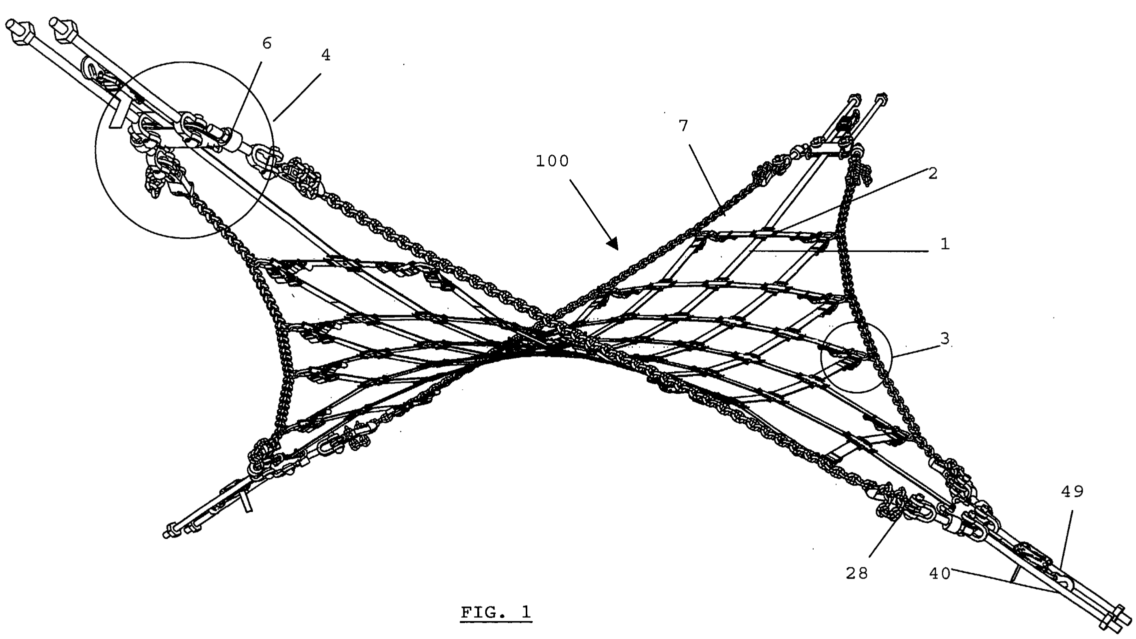

FIG. 1

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Description

Field of the invention

[0001] The invention is related to tensioned structures, especially temporary and relocatable tensile shelters which are frequently used at open air events or as portable venues.

State of the art

[0002] Many specialised temporary constructions are asked for at present day special events such as stage covers, halls, pavilions, sheltered walkways, covered public space etc. Tensioned membrane or cable net structures are used for their lightweight character, as well as for the possibilities of demountability they can offer. As suggested, in the range of pre-stressed and double curved surfaces, two main solutions are offered in the current state of the art: membranes and cable nets.

[0003] Membrane structures are known which are either specifically designed for a special purpose, or built up of a number of standard elements, all having a given and constant shape. In all cases, these structures consist of relatively large pieces of flexible membranes (textile or other) tensioned between a number of fixed supports such as arches or beams. The documents US-A-5,899,028, FR-A-2,668,788 and US-A-4,593,710 can be stated as examples of this kind of structure.

[0004] A disadvantage of the one-design membrane structures is the fact that the shape of the membranes of these customised structures is fixed. Besides that, these structures are related to a high cost for design and manufacture, especially compared to the possibly rather short period the structures are used. As indicated, the combining of predefined modules into larger entities is known, but these modules also have fixed shapes and lead to repetitive structures.

[0005] Cable nets are another form of tensile structures. They are used mainly in large span permanent roofs and are made up of steel cables connected together in fixed, rotating nodes. This makes cable nets more flexible than continuous membranes. They can not take any shear forces and can thus adapt more easily to different shapes as long as the lengths of the cables used allow it. Due to the fixed nodes, however, the flexibility of the forms of these existing cable nets is limited. Specific cable net systems have been described such as in US-A-4,581,860 in which a saddle shaped dome is proposed consisting of two cable nets connected by intermediate compression struts or US-A-4,452,017 where an inflatable bubble roof is presented in which the inflated body is held in place between two cable nets and a compression ring. Applying a flexible net to hold inflated bodies in place forming thus a temporary structure is presented in FR-A-2,706,207. The structure however is not a roof construction but rather a wall to be applied as a projection screen or the like.

Aims of the invention

[0006] The aim of the present invention is to propose a low cost tensile structure exhibiting a larger degree of flexibility of the forms obtainable by said structure, in comparison with the prior art.

[0007] The present invention equally aims to propose a method of calculating such a structure and a computer program performing said calculation.

Summary of the invention

[0008] The present invention is related to a tensioned structure, essentially for use in temporary shelters, comprising at least one unit, said unit comprising a net of longitudinal elements, said net consisting of:

- a first family of longitudinal elements, said elements being essentially parallel in a flat condition of said unit, each of said elements having a variable length,
- a second family of longitudinal elements, said second family of elements being essentially parallel in a flat condition of said unit, said second family of elements being at a variable angle to said first family of elements, each of said elements of said second family having a variable length,
- means for holding together said longitudinal elements of said first family and said longitudinal elements of said second family in the nodal points, being the points where said elements of said first and second family overlap, said means allowing elements of both families to rotate and to slide relative to each other.

[0009] In the preferred embodiment, said longitudinal elements are flat belts, preferably polyester belts.

[0010] Said means for holding together belts of both families preferably consists of a sliding nodal clamp. Using buckles at the ends of the belts at the outermost meshes of the net, the length of the belts can be adjusted to pre-calculated sizes, thus changing the net's overall shape. Due to the fact that tension in a continuous prestressed cable is the same in every part of the cable, a system of two continuous cables, tensioned one over the other, will have only one equilibrium form depending on the lengths of the cables and the tension applied. In the polyester belt net presented, each node consists of such a system of two continuous longitudinal elements, preferably belts. By pre-stressing the net, the nodes will slide into their equilibrium positions. Due to the shape of the nodal clamps, the nodes will be held in position when a certain level of tension is induced in the belts. The higher the tension in the belts, the more difficult it will become to move the nodes out of position because friction induced by the nodal clamp increases with increasing tension. When the net is dismounted and pre-stress taken away, the friction in the nodes decreases and the nodes can slide again.

[0011] Basic units are made using the principle stated above to create a set of units to be used to generate cable or belt net roof surfaces for temporary use out of re-usable units. Belts with lengths such that they can generate a predefined double curved shape that is the maximal configuration of the unit are used. The length of the belts in the unit can be adjusted using a special corner element based on clamping buckles. Thus the net can be given a predetermined shape according to a form-finding calculation being made using an accompanying software tool, based on the force density method, determining the lengths of the different belts to be set, taking into account the limitations of the units. The net is fixed to an outer edge cable or chain of pre-calculated length by the corner elements. Thus a cable or belt net to be pre-stressed into the predefined shape is made. Different units can be connected together and calculated as a whole forming a larger net.

[0012] The net build up as described is pre-stressed by applying tension to the edges. This has to be done according to the supporting structure which can be masts and guy cables, arches, trusses or a framework. The nodes will slide into their equilibrium position and become fixed when tension increases, forming a stable, pre-stressed cable or belt net roof surface.

[0013] Because all connections are reversible, the net can be reduced to its different units when dismounted. These can be reconfigured and reshaped by calculating and setting new belt lengths. When the new net is pre-stressed the nodes will slide into their new equilibrium positions.

[0014] The tensioned nets can be covered using membrane elements that are made compatible with the basic shapes of the units and that can adapt to the changes in shape using elastic connections. Overlapping panels or tiles could be used as well, connected, just like the membrane elements to the nodes of the net through the nodal clamps.

[0015] The nets can be supported by a wide range of supporting structures. These can be manufactured in a systematic way as an addition to the net elements to generate a complete tensile structure. The net elements can however also be added to existing supporting structure systems, in other words, the nets can be given shapes to be compatible with existing structural elements such as masts, arches or truss systems.

[0016] The nets can be used as tensile roofs covered with membrane sheets or panels, can be left completely or partially uncovered or can be used to stabilise inflatable bodies. In the case of permanent shell structures the fact of using the nets as supporting structure for a formwork made of flexible membrane material could be considered.

Short description of the figures

[0017] Fig. 1 is a perspective overview of one net unit of the smallest size in its maximal symmetric saddle shaped configuration.

[0018] Fig. 2a shows schematically the minimal configuration of a net unit.

[0019] Fig. 2b shows schematically the maximal configuration of a net unit.

[0020] Fig. 3 shows an overview of the different basic unit sizes and shapes.

[0021] Fig. 4 shows two more shapes of units, based on the same principles to be added to the set of elements.

[0022] Fig. 5 shows a standard net unit in flat and unused state.

[0023] Fig. 6a shows the different parts of the nodal clamp according to the invention; Fig. 6b shows how belts pass through the nodal clamp.

[0024] Fig. 7 shows the edge assembly connecting the net to a chain edge.

[0025] Fig. 8 shows how two units can be connected to the same chain edge.

[0026] Fig. 9 shows how two basic units can be connected into one continuous net.

[0027] Fig. 10 shows how the nets are to be connected to a free chain edge.

[0028] Fig. 11 shows how the nets are to be connected to a stiff arch or beam edge.

[0029] Fig. 12 gives an overview of the elements building up the corner assemblies of the net structures.

[0030] Fig. 13 shows a corner plate at the corner of only one single net unit.

[0031] Fig. 14 shows a composed corner plate at the common corner of two coupled units.

[0032] Fig. 15 shows a composition of five corner plates forming a top connection of a conical composition of five units.

[0033] Fig. 16 shows how the chain edges adapt to the desired lengths.

[0034] Fig. 17 gives an overview of the elements that build up the anchor assemblies for the net corners to be anchored on site.

[0035] Fig. 18 shows a singular corner anchor.

[0036] Fig. 19 shows a composed corner anchor.

[0037] Fig. 20 shows the application of pre-stress at an anchor point by means of a manual pulley.

[0038] Fig. 21 shows the application of pre-stress at an anchor point by means of hydraulic cylinders.

[0039] Fig. 22 shows the fixing and the tensioning of the nets diagonals.

[0040] Fig. 23 shows the application of pre-stress at a singular high point in a conical surface formed by five units.

[0041] Fig. 24 shows the connection of a net corner point to a supporting mast.

[0042] Fig. 25 is an isometric view of the special membrane cover element in its maximal configuration.

[0043] Fig. 26 shows the membrane cover's minimal configuration.

[0044] Fig. 27 shows the connection of the membrane cover to the units corner plates and edges.

[0045] Fig. 28 shows how the cover is attached to the chain edge of the net.

[0046] Fig. 29 shows how the cover sheets of two adjacent units are connected into one continuous cover.

[0047] Fig. 30 shows the connecting membrane elements and how they can adapt to the desired shape.

[0048] Fig. 31 shows how the cover is attached to the nodes of the net.

[0049] Fig. 32 shows a detail of such a connection.

[0050] Fig. 33a to 33d show some different stages in the graphic modelling and calculation method according to the invention.

[0051] Fig. 34a to 34d illustrate some exemplary forms obtainable by a structure according to the invention.

Detailed description of the invention

[0052] The cable or belt net structures according to the invention are built up out of at least one standardised, prefabricated unit 100, further called a 'basic unit'. One such unit consists of two families of essentially parallel longitudinal connections 1, preferably polyester belts, and of characteristic devices placed at the intersection points of said families. These units are to be manufactured in large series and to be taken from a stock when needed. Figure 1 shows a structure comprising one such unit, including means for attaching said unit to the environment. The following are the main building blocks, which will be described in more detail further in this description.

- polyester belts 1 connected by nodal clamps 2 into basic units that can adapt to different shapes by displacement of the nodal clamps 2 and changing of belt length by edge assemblies 3 comprising clamping buckles,
- cables or chains 7 to form edges, adaptable in length by adapters 28,
- corner assemblies 4, consisting of fixed steel plates 5 with rotating edge connectors 6 fixed to said steel plates by pinned joints,
- tension bars 40 to connect the fixed points of the net to anchor assemblies (not shown) and to tension the net edges,
- ratchet buckles 49 to tension the net's diagonal belts separately from the rest of the net in order to ensure additional stability of the surface.

[0053] In the description that follows, the design, function and use of these units and some additional elements, not shown in fig. 1, as well as the basic principles which the invention is based upon, will be presented in detail. Also, a computerised method for calculating and generating such a structure, will be described.

[0054] The main principle is disclosed as follows. A cable or belt can only take tension forces. When tensioned, the stress in every point along the cable is the same. When a weight is hung loosely from a tensioned cable it will immediately take on a unique equilibrium position determined by the mass of the weight, the geometry of the cable and the tension within it. A second continuous cable tensioned downward over the first one and at an angle to the first one, can replace the weight and will produce the same effect. In a system of two continuous cables in which the first one pulls down the second one while the latter is pulling the first one upward, the intersection point of both will have a unique equilibrium position in space depending on the geometry of the cables and their state of stress. In every part of each cable, the tension will be constant in this pre-stressed equilibrium state.

[0055] The nodes in a saddle shaped net structure according to the invention can be seen as the intersection points of such a system of two cables tensioned one over the other. Depending on the boundary conditions of the net and the amount of pre-stress desired within the links, only one equilibrium shape of the net does exist with which corresponds to certain specific cable lengths. When the boundary conditions of the net are changed and the cable lengths adapted to these new conditions, a new equilibrium shape will be obtained in which the nodes will have new positions.

[0056] Based on this principle, the present invention proposes the use of adaptable basic units. These can be used as such (fig. 1) or connected to similar units in order to form larger cable or belt net roof surfaces (fig. 34). Polyester belts 1 are preferably used in stead of cables. These belts have a better ability to slide over each other, are easily manipulated and have a large range of useful accessories readily available.

[0057] The basic shape of the units is based upon a diamond (angles 60° and 120°) and square geometry, see fig. 2a. The edge length refers to the distance along a straight line 12 connecting two adjacent corner points. This length may be about 3m for a basic unit. The units shown in figure 2 are made such that they can adopt shapes within a range from a flat minimal diamond or square with curved edges 11 (sag 10%) (fig. 2a) to an arch supported symmetrical saddle shape based upon a diamond or square with about 4m edge lengths (fig. 2b). This 4-meter length refers to the distance between points 102 and 103 in figure 2b. Every shape that has belt lengths larger than those of the minimal and smaller than those of the maximal shape can be generated by these units. The diamond shape with corners 60° and 120° and the compatible square have been chosen for their potentials to be composed into different larger shapes, in a plane as well as three-dimensionally. The basic flat shapes may differ from the ones shown in figure 2a : basic units may be used with straight edges in the flat version or with curved edges with a curvature less than 10%.

[0058] Taking the described basic units as a starting point, two series of larger units, relating to the basic ones (the diamond and the square) are designed. Secondary basic shapes do consist consequently of 4 times, 9 times and 16 times the basic shape (fig.3).

[0059] Based upon the basic diamond, more compatible unit shapes can be designed, using the same principles, described below, as in the basic units. A triangular and hexagonal unit are to be added to the set of units (fig.4).

[0060] The unit should be made of belts having lengths such that the predefined maximal anti-clastic shape can be obtained. Fig. 5 shows a diamond shaped basic unit, as it is taken from the shelf. It consists of two families of belts 1, each family consisting of a series of essentially parallel belts, laid out one on top of the other, the upper layer rotated 90° according to the underlying layer. The belts 1 are connected in their intersecting points by nodal clamps 2, holding the belts together, while allowing sliding of the belts 1 over each other.

[0061] These clamps 2 are shown in detail in fig. 6. They are composed of two plates 2a and 2b, riveted together by a rivet 14 in such a way that they still allow rotational freedom. The first belt 1a, that will be tensioned downward, passes through a slit 104 on one longitudinal side of the bottom plate 2a, runs over the topside plate 2b and into a similar slit 105 on the other longitudinal side of the first plate 2a. The second belt 1b, that will be tensioned upward, runs through the second plate 2b in the same way, through slits 106,107 but passes under the first plate 2a. Increasing tension in the belts 1 will make the nodal clamp 2 slide over the belts 1 toward an equilibrium position. When tension gets higher, the clamp 2 will be pressed between the belts 1 due to the curved path the belts 1 follow when they run over and under the nodal clamp 2 and the position of the node will be fixed by the friction induced by the nodal plates (2a, 2b) pressed in between the belts 1. The slits (104 to 107) through which the belts 1 run have to be wide enough. The slits (104,105) in the bottom plate 2a are turned upward a little, while those in the top plate 2b are turned downward a little, both of which are done in order to make sure that the belts 1 can slide into their equilibrium position before friction gets too high and the nodal clamp 2 gets fixed. Lips 110 comprising slits 111 may be provided, extending upward from the inside of the slits (105,106) in the top plate 2b, which are to be used to fix a textile covering to the net.

[0062] This nodal system makes sure the nets can take on different shapes when boundary conditions and belt lengths are changed by assuring the sliding of the nodal clamps 2, and thus the nodes into new equilibrium positions and generates a stable net surface that can withstand external loads such as wind and snow when sufficient pre-stress is applied. Tests have pointed out that pre-stress of about 200-250daN is required within all belts 1. Standardised, prefabricated basic units are produced in this way with loose ends of belt at their edges such as shown in fig. 5.

[0063] The adaptation of the belt lengths to the calculated lengths is made possible by an edge assembly 3 that connects two belts 1, one of each of the two original families, together at fixed positions along the edge 7 of the unit. This edge assembly 3 is shown in detail in fig. 7. It consists of a steel ring 15 to which two clamping buckles 16 are fixed so they can rotate about the ring 15. The belts 1 each pass through a buckle 16 and are clamped in place at the desired position, thus setting the length of the belt 1. A safety pin 17 may be added to the standard buckle 16 to make sure that once the belt 1 is positioned, the buckle 16 won't open anymore. The loose end of the belt 1 is rolled in a small parcel 18 and strapped to the fixed end of the belt.

[0064] The same edge assembly 3 also connects the net to its edge 7 by a means 19 for connecting the ring 15 to the edge, which can be a cable, a chain, a stiff beam 20 (fig. 11) or arch or maybe a wall. A shackle 19 is used in case of a chain edge or a rigid beam, as shown in figure 7 and 11 respectively.

[0065] A double shackle 21 may connect two adjacent basic units to the same chain edge 7 (fig. 8), thus connecting two basic units in such a way that the curvature of the surface can change direction between the two units. The edge 7 will be tensioned upward when the units are pulled down or vice versa. The shackle 21 comprises one bolt that passes through a chain link and two steel clamps, in each of which the ring 15 of an edge assembly 3 is placed.

[0066] An assembly similar to the edge assembly of fig. 7, but with four clamping buckles 16 connected to a ring 112 in stead of two (fig. 9), is used to connect two units in such a way that they form one continuous larger net. This element is used in the same way as the edge assembly 3 of fig. 7. It should be used to connect units to form larger net surfaces with continuous curvature. When curvature changes direction from one unit to the other, the connection to a common edge 7 as shown in fig. 8 has to be used.

[0067] The boundary conditions of the nets assure that they are tensioned into a certain predefined shape. The edges 7 and edge assemblies 3 of the composed nets are thus very important elements. By taking a planar shape with curved edges as the minimal unit shape (fig. 2a) and a symmetrical saddle shape with two arches as edges as maximal unit shape (fig. 2b), it is made sure that the nets can adopt different edge conditions ranging from free curved edges formed by cables or chains (fig. 10), to stiff straight edges and stiff arches (fig. 11). Each edge has to be given adequate connection devices so the nets can be connected to them by shackles (19/21) connected to the rings (15) of the edge assemblies 3 (fig. 7) in the calculated positions. In the case of a free edge, using a chain 7 as edge gives the easiest solution. The shackles (19/21) fit into the chain links at the desired distances from each other (fig. 10).

In the case of a steel cable or synthetic rope edge, a specialised clamp has to be manufactured that is clamped onto the cable or rope in the desired position and into which the shackle 19 connected to the ring 15 of the edge assembly 3 is fixed. The clamp should be such that it can be taken from the cable after use and re-used, leaving the least possible damage to the cable or rope. Similar clamps should be manufactured to connect the nets to rigid edges such as beams, arches, trusses. The design of the clamp will depend on the edge element's features and dimensions. A possible example is given in fig. 11, where a clamp 22 is shown, connecting the edge assembly 3 to a rigid beam 20, on a desired fixed position.

[0068] The nets could possibly be connected to a wall if anchorage points can be fixed to the wall in the desired positions.

[0069] When free edges are applied (cables or chains 7), the nets have to be fixed to their surroundings at their corner points. The corner assemblies 4 used to do this are shown in figures 12 and 13. These assemblies consist of steel plates 5 to which the edge cables 7 are fixed. The angle the edges 7 form with the corner plates 5 depends on the shape of the net and the position of the corner. Therefore, adaptable corner plates are to be used. In each corner assembly, two interconnected parallel steel plates 5 of equal shape, are combined with two rotating edge connectors 6 that are fixed by pins 23,25 in between the steel plates 5, the pins going through holes 116 (fig. 12&13). The edge connectors 6 consist of a steel plate 113 to which a steel tube 24 has been welded. Through said tube, a threaded pin 9 may be driven, and fixed by a bolt 26. To the latter the edge chain 7 is fixed using a shackle 120 that fits into a forked connector 114 located on one end of the thread (fig. 12). The edge connectors 6 are connected in between the steel plates 5 by a pin 23 through a round hole in which they can rotate and another pin 25 through a curved slit 115 that limits their possible rotation. The angle between the two edge connectors 6 of a corner assembly can thus vary from 25° to 120°.

[0070] A doubled version of these edge connectors, consisting of two times the steel plate 113 with smaller pieces of steel tube 27 welded to them in such a way that they can connect the plates 113 by putting in the thread 9, is used to build up composed corners, i.e. fixed corner points in places where several units come together. The thread 9 through the tubes constitutes a pin jointed hinge so the composed corner elements can adapt to different shapes and positions. In fig. 13, a simple corner plate for the corner of one unit can be seen. fig. 14 shows a composed corner plate that connects two units at the edge of a composed net. fig. 15 shows a connection of 5 corner plates forming a ring to which five units are connected, thus creating a conical net surface.

[0071] Free edges connected to the corner assemblies 4 have to be given a predefined length too, just like the belts 1 forming the net itself. The required lengths are calculated by a from finding process as described later. Chains are proposed as tension edges 7. Shortening clutches 28 do exist to shorten chains link by link. These are very appropriate to be used in a structure of the invention to create adaptable edges. Connecting two chain ends together can also be done easily using existing chain connectors 30 (fig. 16). Using this technology, an adaptable edge system is designed, consisting of adaptable chain ends and additional chain ends. The adaptable chain ends are to be given a maximal length of half the length of the maximal free edge of the smallest unit. This is the curved edge of the free edge version of the basic units maximal symmetrical saddle configuration, having a sag of 10% (fig. 1). This edge is then generated by connecting together two of these adaptable chain ends using a chain connector. Edges of larger units (fig. 3) are created by connecting together two adaptable chain ends by means of one or more intermediate chain ends 31, the length of one such piece to be derived from the free edges length of the maximal symmetrical saddle shape configuration of the unit consisting of four basic units (fig. 16). For units based on nine times the basic unit, two intermediate chain ends 31 shall be used, for those based on sixteen basic units, three ends.

[0072] For the sake of low weight it can be favourable to use steel cables or synthetic ropes as edges. These are however more difficult to connect to each other and to shorten in a reversible way without damaging them. To connect the net-ends to them, specialised clamps are to be developed too, as was stated before. They can however be used within the scope of the present invention.

[0073] Pre-stress is induced in a tensioned structure of the invention by applying stress at the fixed corner points which direct the tension forces to the edge cables. Tension can be applied either by pulling the lower fixed points anchored to the ground, by pulling or pushing singular points within the surface (e.g. high points in conical surfaces) upward or by pulling apart rigid edges 20 such as arches within which the net is hung.

[0074] To anchor low points of the nets to the ground an anchor assembly 120 (fig. 17,18) is presented, consisting of base plates 32 to be fixed to the ground by (preferably a maximum of 9) large stakes 33 to which two vertical plates 34 are welded in between which a steel block 35 can rotate. At this steel block 35 two more steel plates 36 are bolted. To form the simplest type of anchor assembly, two base plates 32 are placed one next to the other and pinned to the soil (fig. 18). The plates 36 connected to the rotating steel blocks 35 are then connected by two new steel plates 37 in between which two hollow steel blocks 38 are fixed in such a way that they can rotate around an axis which is essentially perpendicular to these plates 37. Inside these hollow blocks 38 a last steel block 39 with a hole drilled through it is fixed in such a way that it can rotate in a plane essentially perpendicular to that in which the hollow blocks

38 rotate. Full rotational freedom of the fixing points is thus obtained.

[0075] The complete connection is shown in figure 20. Through the hole in the steel blocks 39, threaded bars 40 pass that are connected to the corner assembly 4 of the net unit by eyes 41 at their ends, these eyes 41 fitting into shackles 42 connected to the corner plates 5. The pins of these shackles 42 are those 23 around which the edge connectors 6 rotate. When heavier anchorage is required, for example in the case of composed corner plates (fig. 14) or larger units, more base plates 32 have to be added together and connected. The pivoting connection blocks (38/39) are placed at the required distance from one another and the corner assembly 4 is again connected to them by threaded bars 40. In fig. 19, the anchor for a double corner, connecting two units together, is shown. In each anchor assembly, a shackle 121 is present centrally. To this shackle, the diagonal belt of the net will be attached, as is explained further.

[0076] Tension can be applied at these anchor blocks in two ways, manually or hydraulically. The basic principle is that the corner assembly 4 should be pulled toward the anchor thus inducing tension in the edges 7 and the net. The threaded bars 40 that connect the assembly 4 to the anchor block will slide through the holes in the blocks 39 they pass through. When sufficient pre-stress is induced, a bolt 43 on the threaded bars 40 can secure their position and thus the induced state of pre-stress will be maintained. To pull the corner assembly 4 toward the anchor, a manual or motorised chain hoist 44 can be placed in between the assembly 4 and the anchor and fixed to both by the hooks 45 and the chain 122 (fig. 20). For this purpose, a hole 46 needs to be present in the plates 5 of the corner assembly. One of the hooks 45 is then attached to the central shackle 121 of the anchor assembly, the other is attached to said hole 46.

[0077] Alternatively, hollow hydraulic cylinders 47 could be placed on the threaded bars 40, pulling them back (fig. 21). The anchor blocks should be adapted to this solution by adding an additional steel plate 48 on four bars in front of each block 39 that holds a threaded bar. The bolt 43 to secure the position of the threaded bar 40 should be placed behind this plate 48 while the cylinders 47 pull the threaded bars 40 into position. It will temporarily hold the threads 40 in place while the cylinders 47 are being removed and the bolt behind the steel block is screwed in place. The cylinders 47 as well as the hoist 44 can be taken away after securing the threads 40 and can be used elsewhere, thus reducing equipment costs, as well as the chance to get expensive equipment damaged.

[0078] After applying tension to the net's edges 7 and in that way to the net belts 1 connected to these edges, the diagonal belts 1 of the nets are to be tensioned. This is done using standard ratchet buckles 49. Being connected to the anchor assembly at the shackles 121, the diagonal belts are tensioned by the ratchet buckles. This tensioning has to be done separately from the tensioning of the edges 7, in order to assure a good tensioning of the edges 7 first. When the diagonal belts 1 should be connected to the corner plates 5, tension applied at the latter would be divided between the two edges 7 and the central diagonal belt 1, resulting in too high forces in the diagonal belt 1 and too low forces in the edges 7. The net will consequently not take on the calculated, constant force equilibrium shape. Tension applied at the diagonals will induce some additional tension within the net's belts 1 thus increasing the stability of the pretensioned net surface. The end of the diagonal belts 1 has thus to be connected directly to the anchor blocks and runs in between the parallel corner plates 5 (fig. 22).

[0079] As was said before, tension can also be applied by pulling or pushing upward a singular high point in the surface. A high point brings together three, four or five units by connected corner plates 5 (fig. 23).
The ring of corner plates all connected together is fixed to a smaller hoisting ring 50, which is preferably resting on a supporting pole or suspended from a high point. Pieces of chain 51 connect the corner plates to the hoisting ring. The diagonal belts 1 of the different nets run through the corner plates 5 and are fixed to the hoisting ring 50 also.

[0080] As shown in figure 24, the connection of corner assemblies 4 to supporting masts 52 and other elements of the surrounding supporting structure is done in a fixed way, ensuring that sufficient tension can be applied at the anchored low points or singular high points. The corner plates 5 should be connected to the supporting element 52 by a fixation element 123 and by two (chain) links or even turnbuckles 53 fixed at the shackles used for the connection of the threaded bars 40 to the corner plates 5 in the case of the anchored low points. The diagonal belt 1 should run between the corner plates 5 and be fixed to the supporting element 52 in between the two plate connectors 6 (fig. 24). A ratchet buckle 49 is present between the supporting element 52 and the corner plates 5 of the net. By pulling apart the masts 52 or other structural elements, in between which the net is hung, using guy cables, tension can eventually be applied to the net at these connection points.

[0081] After tensioning the net applying one of the methods described above, pre-stress can be adjusted at several points in the structure. At first, the bolts 43 securing the threaded bars 40 that connect the low edge points to the ground anchors can be turned a little more. The edges 7 are also fixed to the corner plates 5 using threaded forked connectors 9. These can be tensioned by turning the bolt that holds them in place. At last, the ratchet buckles 49 at the diagonal belts 1 of the units give opportunity to induce some more pre-stress. These means of adjustment enable the user to cope with inaccuracies in the adjustment of the units and the placement of the fixed points of the net.

[0082] The composed nets described above are stable load bearing tensile structures. They can be used as support for a non-structural cover that is attached to the edges 7 and nodes 2 of the net structure. Therefore it should only be able to take up small loads acting on the small areas formed by the meshes of the supporting net. A system of lightweight adaptable textile cover sheets, based upon the same dimensions and limits as the basic units, is added to the set of elements building up the nets. The covering system consists of main sheets 54 that can adapt to the different shapes of the units and connection sheets 65 (fig. 30) to fill up gaps that occur in between units, between units and supports or at conical high points when composed nets are covered.

[0083] The main sheets 54 (fig. 25), corresponding to the basic shapes of figure 2, consist of four basically triangular pieces 55 of a light coated textile material. They are connected by pieces of the same material 56 welded in between them and folded under the triangular sheets. Steel eyelets 57 are applied all along the connections. Through these eyelets 57 the triangular pieces 55 of cloth are laced together using elastic rope 58. In this way a sheet 54 is made that can adapt shape by applying tension at its edges, remaining watertight. The edges of the membrane sheet 54 follow a 10% curvature. The dimensions of the textile sheets (55/56) and the lengths of the elastic laces 58 are determined such that the maximal extended sheet (fig. 25) has the same dimensions and thus covers the maximal units configuration of the symmetrical saddle shape with free curved edges (fig. 1). When tension is loosened, the elastic laces 58 will shorten and the sheet will take on a smaller form. At the corners of the sheet, the textile will have to be folded underneath the main sheet, see folds 59 on fig. 26. In that way the minimal shape of the sheet can be generated. In the parts that may be folded inwardly and may thus be unused in certain configurations, there is no more elastic lacing 58 but separate elastic straps 60 connecting the opposite eyelets 57.

[0084] The sheets 54 have to be connected to the edges of the net (fig. 28) when the latter has been spread out to be erected. According to the set edge lengths, pieces of the membrane sheet 54 shall be folded in between the net and the membrane cover (fig. 27). The sheet 54 is connected to shackles 61 connected to the corner plates 5 of the net using mountaineer safety hooks 62 going through the last not folded eyelet 124.

[0085] At the edges of the membrane cover sheet, also a series of eyelets 57 are fixed. A second strip of membrane 63 is welded on top of the edge to form an overlap covering the holes made by the eyelets. Both edges have a small synthetic rope, also called keder 64, fixed to them for reinforcement. This double edge ensures connection of the sheets 54 to the edges (fig. 28) of the nets or to connecting sheets 54 forming a larger membrane cover in a watertight way (fig. 29). Connection to the chain edges 7 of the net is made using mountaineer safety hooks 66 that are fixed into the chain links and the eyelets 57 at the membrane sheets 54 edge. The additional membrane strip 63 welded to the sheets 54 edge can be left unused in this case or an additional membrane element 67 can be connected to it and folded over the chain edge 7 thus covering the latter. Toggles 68 fixed at the additional membrane strip 63 at the cover sheets 54 edge pass through eyelets 57 in the membrane element 67 to be added to cover the edge of the structure, thus connecting the latter to the main sheet 54. Lashes sewn to the outermost edge of the added membrane element 67 will fix the membrane strip 63 to the mountaineer hook 66 connecting the main sheet 54 to the chain edge 7 after folding it over this edge. A similar element but with one straight edge is used to connect the main sheet 54 to a straight rigid edge 20, covering the gap between this edge and the curved edge of the membrane sheet 54.

[0086] The same toggles 68 will be used to connect two main sheets 54 together by means of an intermediate membrane sheet 65 (fig. 30). Now the toggles 68 run through eyelets 57 in the edge of the connection membrane 65 and through the those in the main sheet 54 thus clamping the connecting sheet 65 in between the two layers of membrane at the edge of the main sheet 54. To ensure watertightness, a keder 69 of considerable diameter is fixed to the edges of the connecting membrane 65, forming an obstacle for water that wants to invade through the connection. A rubber strip around the keder 69 can improve the watertightness. The connection membrane 65 has edges that follow the curved shape of those of the main sheet 55. Elastic lacing 70 and folded membrane 71 (fig. 30) makes sure that this connection membrane 65 can adapt to all membrane shapes within the minimal (fig. 2a) and maximal (fig. 2b) limits discussed before.

[0087] When the structure has been erected it is advised to connect the membrane cover 54 to the nodes 2 of the net (fig. 31). This may be done by straps 72 running through the slits 73 in the nodal clamps 2. These straps 72 are connected to a shackle 74 that is attached to one of the numerous lashes 75 underneath the membrane sheet (fig. 31). These lashes 75 are formed by belts 76 that are sewn discontinuously to the membrane cover sheets 54. These belts 76 start at the edges of the main sheets 54 and come together at the central corner point of the triangular pieces of membrane 55 forming the main part of the main cover sheets 54. Diagonally belts are sewn to the membrane sheets too in the same discontinuous way. Due to the multitude of lashes 75 thus formed, a lash corresponding to a node 2 is very likely to be found in any case (fig. 31). When the structure is to be taken down, transported and set up elsewhere, the membrane sheets can stay in place.

[0088] The belt lengths and the positions of the edge assemblies 3 of the units in the pre-stressed equilibrium state have to be determined according to a method which is part of the present invention. This method allows the designer to enter a ground plan for a structure, consisting of a given number of basic units 100, and end up with a list of prescribed belt lengths and edge assembly positions for each unit. For this purpose, a software tool is provided, allowing the different steps of said method. These steps include the entering of a number of data by the user, based on a design for a specific structure: dimensions, height, number of basic units, etc.... A graphical interface allows the user to enter these data.

[0089] As a first step, a ground plan is created by the user (fig. 33a), consisting of a number of basic units 100, having curved or straight edges, and being connected together, either by connection to a shared edge element (see fig. 8) or as a continuous net consisting of several units, by connections as shown in fig. 9. The software will provide a choice of basic units according to figures 2, 3 and 4, with given dimensions. Through the graphical user interface, the designer is allowed to draw a ground plan consisting of a number of basic units, and deform the edges of these units at will into curves or straight lines. The software of the invention makes sure that none of the edges or diagonals of these units exceed the maximum length or is lower than the minimum length obtainable with the basic unit selected. A message is given if this is the case, urging the designer to adapt the ground plan. The ground plan for an exemplary structure is shown in figure 33a, in perspective view.

[0090] Then the position of the fixed anchor points in space 130 is defined and a 3-dimensional contour is drawn of straight lines 131, between said anchor points (see fig. 33b). Also in this step, the software checks whether the minimal and maximal edge an diagonal lengths obtainable by the basic units, are not exceeded. A message is given if this is the case, urging the designer to adapt the design, for example by adjusting the position of some of the fixed edge points of the structure.

[0091] Then an initial 3-dimensional form of the edges is obtained by the following method (fig. 33c). In this, it is crucial that at the edges of each unit, be these free cable edges, rigid elements such as arches or beams or even another, coupled unit, two belts 1, one of each family, are connected in the same point to the edge. In that way a closed network with sliding nodes is being generated. These points are then connected to the edge by the edge assemblies 3.

[0092] Starting from the ground plan, each basic unit is treated as follows: from the centre point of the unit (cross section of two diagonals), rays 101 are drawn (see fig. 2a), dividing the straight line between two corner points of the unit's ground plan into equal parts. The number of parts may differ according to the size of the basic units used. In the units of figure 2, 5 equal parts are defined. In figure 33c, 9 equal parts are defined. The intersection of these rays with the ground plan of the desired edge shape (defined in step 1) gives the horizontal projection of the position of the edge assemblies 3. These are then projected onto the three-dimensional contour of the desired net. This may be done by first determining the shortest distance between each of these horizontal projections of edge assemblies to the straight line between edge points on the ground plan. Consequently, these distances are used to determine points at a horizontal distance from the straight lines 131 between edge points 130 in 3 dimensions (as determined in step 2). This results in an initial shape 132 of the three dimensional edges of the structure (fig. 33c), with a given position of the edge assemblies along said edges. Primarily in the case of chain edges, provision should be made to take the small distance into account between the outer intersection points of two belts, and the actual chain edge. This distance is caused by the presence of the ring 15 and shackle 19 in the edge assembly.

[0093] The method of the invention is not limited to one technique of finding such an initial 3-dimensional edge shape. The method using the rays and subsequent projections is only one of several possibilities.

[0094] Before calculating the equilibrium state of the net, initial positions of the nodes must be chosen. These positions may conveniently be chosen on ground level, such as shown in figure 33c. The lines 133 represent the initial belt positions. This means that the equilibrium calculation starts from a flat version of the basic units, connected (by connections 134) to the initial 3-d shape of the edges. When calculation starts, the length of the connections 134 is set to the actual distance from the net to the edge, taking into account the length of the shackles 19, connecting the net to the edge. The length of the connections 134 may for example be set to 7 cm.

[0095] When the initial shape has been generated in the above described way, it is recalculated based on the force density method. This will result in the form finding of the net, i.e. it will determine the equilibrium shape according to the given boundary conditions and desired pre-stress (fig. 33d). In particular, this step will result in the position of the nodal points of the net, and the form of the belts, in the equilibrium state, i.e. a prestressed tensioned state. The principle explained above is brought into practice here, namely that displaceable nodes will move to a unique position under the influence of the boundary conditions (as defined by the fixed corner points and edges and the initial position of the edge assemblies) and the forces present in the net. Another important principle is the fact that in each belt or cable of a net according to the invention, the force is constant.

[0096] The force density method is a known method to calculate equilibrium states of cable or belt nets with rectangular meshes by solving a set of linear equations. These equations are found by introducing a form parameter called the force density. The force density expresses the force in a cable link relative to said cable link's length, a link being defined as the part of a cable between two adjacent nodes. By giving all cable links in the net the same force density, an equilibrium shape will be found in which all links have approximately the same length and force. A net can be made according to this equilibrium form having fixed nodes (i.e. allowing only rotation, not sliding of the nodal points), at the calculated positions. In the case of continuous cables with nodes that have no fixed position, as in the case of the nets according to the invention, the force is constant for the entire belt, meaning that the force in each link of the same belt has to be equal.

[0097] The method of the invention uses an iterative technique based on force density, to end up with the right equilibrium state. As a starting point, an estimation of the forces present in each cable has to be entered by the user. These values can be derived from experience or on the basis of experimental results. Then the user enters an initial force density value for the complete net. Starting from the initial 3-d shape of the edges, the force density method is then applied a first time, resulting in a mesh with constant force density (i.e. the value entered by the user) in each link. The mesh should be understood to be the collection of nodal point's positions in space. The link lengths resulting from this first calculation are then combined with the desired forces, resulting in a new set of force densities, which are used as input for the second force density calculation.

[0098] This second calculation results in a new mesh with new link lengths, and with a potentially different force density value in every link. Once again, these link lengths are combined with the desired forces, to lead to yet another set of force densities.

[0099] The same process is repeated until the results of two subsequent calculation steps are lying sufficiently close together. The resulting mesh will necessarily have a constant force in each belt. This mesh defines the equilibrium state of the structure.

[0100] When the equilibrium form has been found, a load analysis is performed, applying various expected loads such as snow and wind on the model, analysing its behaviour. This may possibly lead to a new set of desired forces in the pre-stressed net, and a new iterative calculation procedure, as described above. The load analysis is performed according to a known method.

[0101] When the final shape and pre-stress levels have been determined, the length to be given to each belt 1 and each free edge 7 is calculated in order to get the calculated equilibrium shape. The software of the invention produces a list of belt and free edge lengths, for each of the basic units 100 and/or for each unit composed of several basic units. The output equally comprises the position of the edge assemblies along the edges. These belt and edge lengths can then be arranged by adjustment of the clamping buckles 16 and the shortening clutches 28, before installation of the units on site. This replaces the calculation of cutting patterns, usually done in order to make a membrane roof. The lengths data goes to the workshop where the units are taken from the stock, if necessary connected together into larger units, after which the calculated belt lengths are set. This process replaces the cutting and welding of membrane patterns into a preshaped membrane surface. The difference made by the new system is that the net generated by the system has reversible connections and is built up out of reconfigurable and readaptable elements.

[0102] Due to the multitude of shapes and combinations to be made with this invention as well as the possibility of adding or altering elements following the basic principles and within the spirit and scope of the claims without departing from such spirit and scope, it is intended that all matter contained within this accompanying description and specification shall be regarded as illustrative only and not in a limiting sense.

[0103] Using these connection details and the process stated above, taking into account the units limitations and possibilities, a lot of different tensile net roofs can be generated. Some examples of possible compositions can be seen in fig. 34a to 34d. These are but some examples and many more can be made using the system. The nets are shown in this figure in their uncovered state. Only in fig. 11d an idea about the covering of the net is given.

Claims

1. A tensioned structure, essentially for use as a temporary shelter, comprising at least one unit (100), said unit comprising a net of longitudinal elements (1), said net consisting of :

   - a first family of longitudinal elements (1a), said elements being essentially parallel in a flat condition of said unit (100), each of said elements having a variable length,
   - a second family of longitudinal elements (1b) said second family of elements being essentially parallel in a flat condition of said unit (100), said second family of elements being at a variable angle to said first family of elements, each of said elements of said second family having a variable length,
   - means (2) for holding together said longitudinal elements of said first family and said longitudinal elements of said second family in the nodal points, being the points where said elements of said first and second family overlap, said means (2) allowing elements of both families to rotate and to slide relative to each other.

2. A structure according to claim 1, wherein said longitudinal elements are flat belts, preferably polyester belts.

3. A structure according to claims 1 or 2, wherein said units have a basic flat shape chosen from the group consisting of a diamond with straight or curved edges, a square with straight or curved edges, a triangle with straight or curved edges, a hexagon with straight or curved edges.

4. A structure according to claim 2 or 3, wherein said means (2) for holding together said belts of said first and second families consists of

- a first plate (2a), comprising two slits (104, 105) at its longitudinal ends,
- a second plate (2b), equally comprising two slits (106,107) at its longitudinal ends,
- a rivet (14) connecting both said plates (2a, 2b) so that these plates can rotate one relative to the other around a rotational axis which is essentially perpendicular to said plates.

5. A structure according to claim 4, wherein said slits (104 to 107) are at an angle to said plates (2a, 2b).

6. A structure according to any one of the preceding claims, comprising means (7) for forming edges to the total net, formed by said units (100).

7. A structure according to claim 6, wherein said means (7) for forming edges are chosen from the group consisting of chains, cables, rigid beams or walls.

8. A structure according to any one of claims 2 to 7, wherein said units are connected to said edge means (7) by way of edge assemblies (3), said edge assemblies comprising:

- a ring (15), to which one of each family of belts is attached,
- two clamping buckles (16), said buckles allowing the regulation of the length of each of said belts,
- means (19) for connecting the ring (15) to the edge means (7).

9. A structure according to any one of the claims 2 to 8, further comprising corner assemblies (4), for connecting said structure to fixed anchor points, each of said corner assemblies comprising :

- a set of parallel plates (5), comprising holes (116),
- connected in between said parallel plates (5), and fixed by pins (23, 25), two side plates (113), having at least one ring (24,27) attached to them, said plates being allowed a limited rotation around one (23) of said pins, said rotation being limited by the second (25) of said pins,
- passing through said at least one ring (24,27) of each side plate (113), a threaded pin (9), connected to a fork (114).

10. A structure according to any one of the preceding claims, further comprising anchor assemblies (120), preferably placed on the ground, comprising :

- at least two base plates (32), fixed preferably to the ground by stakes (33),
- a construction consisting of plates (35,37), said construction being able to rotate around an axis essentially parallel to said base plates (32),
- blocks (39), connected to said construction of plates (35, 37), said blocks being able to rotate around a plurality of axes which are essentially parallel to said construction,
- threaded bars (40), connected between said blocks (39) and said corner assemblies (4).

11. A structure according to any one of the preceding claims, further comprising a hoisting ring (50) placed at a high point of the structure, and to which a number of corner assemblies (4) are attached, for example by way of chains (51).

12. A structure according to any one of the preceding claims, further comprising fixation elements (123), fixed to supporting elements (52), said fixation elements being connected to said corner assemblies (4).

13. A structure according to any one of the claims 2 to 12, further comprising at each anchor point on the ground or against a fixed supporting element (52), a ratchet buckle (49) connecting the diagonal belt of said unit to said anchor assembly.

14. A structure according to claim 13, wherein the diagonal belts of said units (100) are connected to said hoisting ring (50).

15. A structure according to any one of the preceding claims, wherein at least two units (100) are connected together in such a way that they share the same edge means (7).

16. A structure according to any one of the claims 1 to 14, wherein at least two units are connected together by additional rings (112), to which four belts, two of the first unit, and two of the second unit are connected.

17. A structure according to any one of the preceding claims, further comprising a covering, consisting of sheets (54), covering each unit, each of said sheets (54) comprising a plurality of sub-pieces (55), connected by additional pieces (56), welded in between said sub-pieces (55) and folded underneath said sub-pieces (55), said sub-pieces (55) being laced together by elastic rope (58).

18. A structure according to claim 15, wherein said sheets (54) comprise four triangular sub-pieces

(55).

19. A method of calculating a structure according to any one of the preceding claims, comprising the steps of :

- defining a ground plan of a structure according to any one of the preceding claims, said structure comprising at least one of said basic units (100),
- defining the position of fixed anchor points of said structure,
- defining an initial three-dimensional shape of said structure,
- calculating the equilibrium shape of said structure by iteratively applying the force density method.

20. A method according to claim 19, wherein said step of calculating the equilibrium shape comprises :

- a first force density calculation based on said initial shape and on an initial constant force density value,
- re-calculating the force densities in each belt link, said re-calculation being based on a set of desired forces, said forces being constant in each belt, and on the belt link lengths resulting from said first force density calculation,
- a second force density calculation based on said new force densities,
- repeating the previous steps of a re-calculation and a force density calculation, in that order, until two subsequent solutions of said force density calculation are lying sufficiently close together.

21. A method according to claim 19 or 20, further comprising a load analysis step, based on a predefined load, and leading to the acceptance or rejection of said equilibrium state.

22. A method according to claim 21, wherein said rejection leads to the repeating of the iterative steps of claim 20, based on a new set of desired forces.

23. A method according to any one of the claims 19 to 22, wherein after said steps of defining a ground plan and defining the position of fixed anchor points, a check is done, on whether the calculated belt lengths and/or edge lengths are lying between the minimum and maximum lengths obtainable by a specific basic unit.

24. A method according to any one of claims 19 to 23, further comprising the step of producing a list of belt lengths and edge lengths for each basic unit (100), corresponding to said equilibrium shape, as well as a list of positions of edge assemblies (3) along said edges.

25. A computer program comprising program code means for performing all of the steps of claim 19 to 24 , when said program is run on a computer.

26. A computer program comprising program code means stored on a computer readable medium for performing all of the steps of claims 19 to 24, when said program is run on a computer.

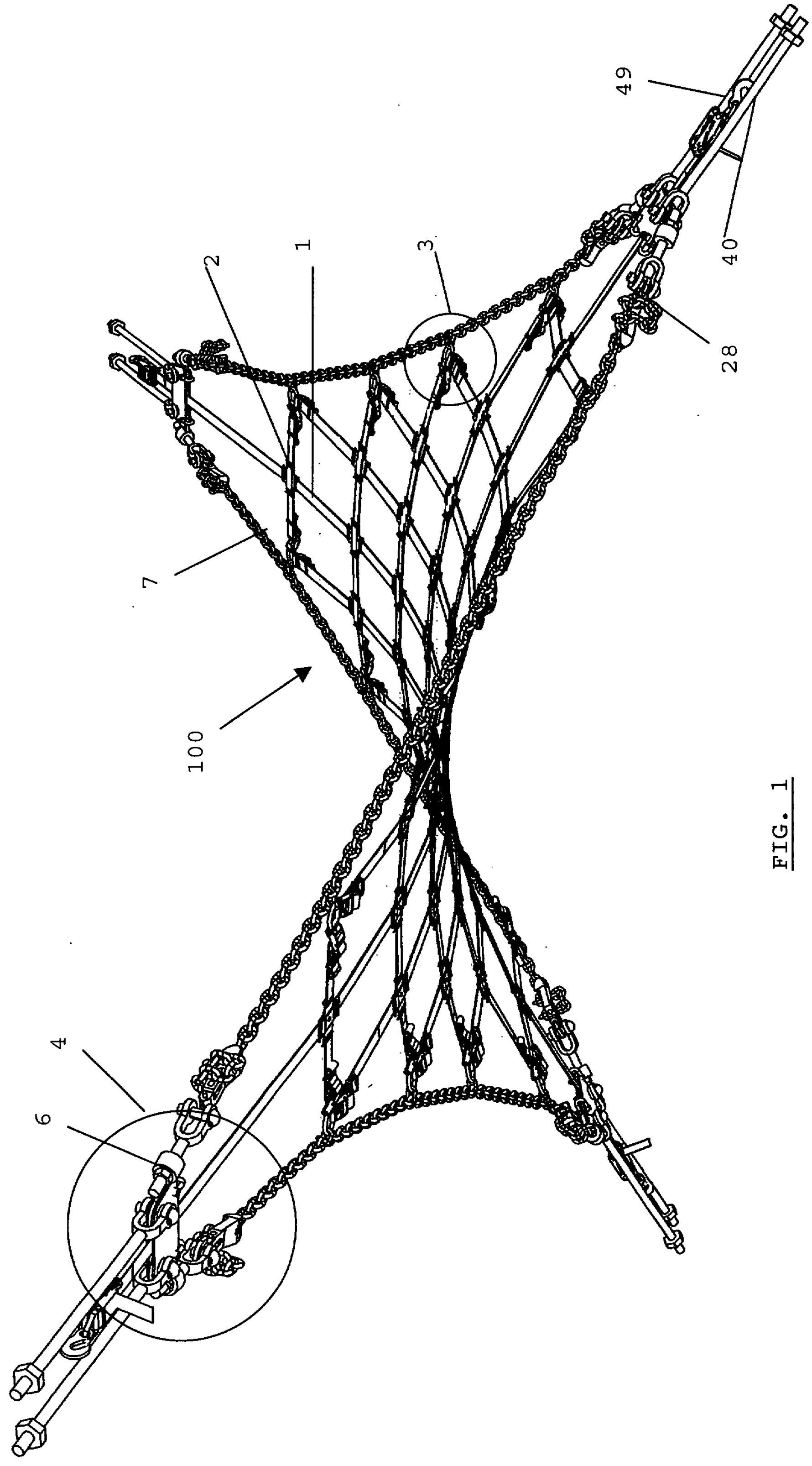

FIG. 1

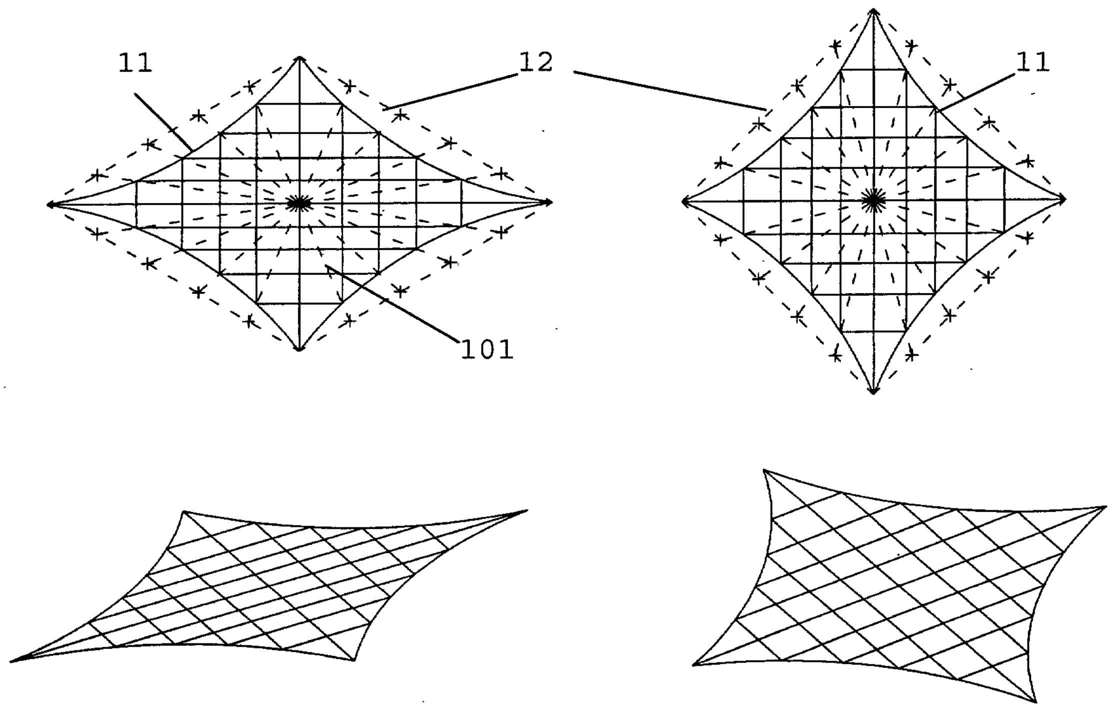

FIG. 2a

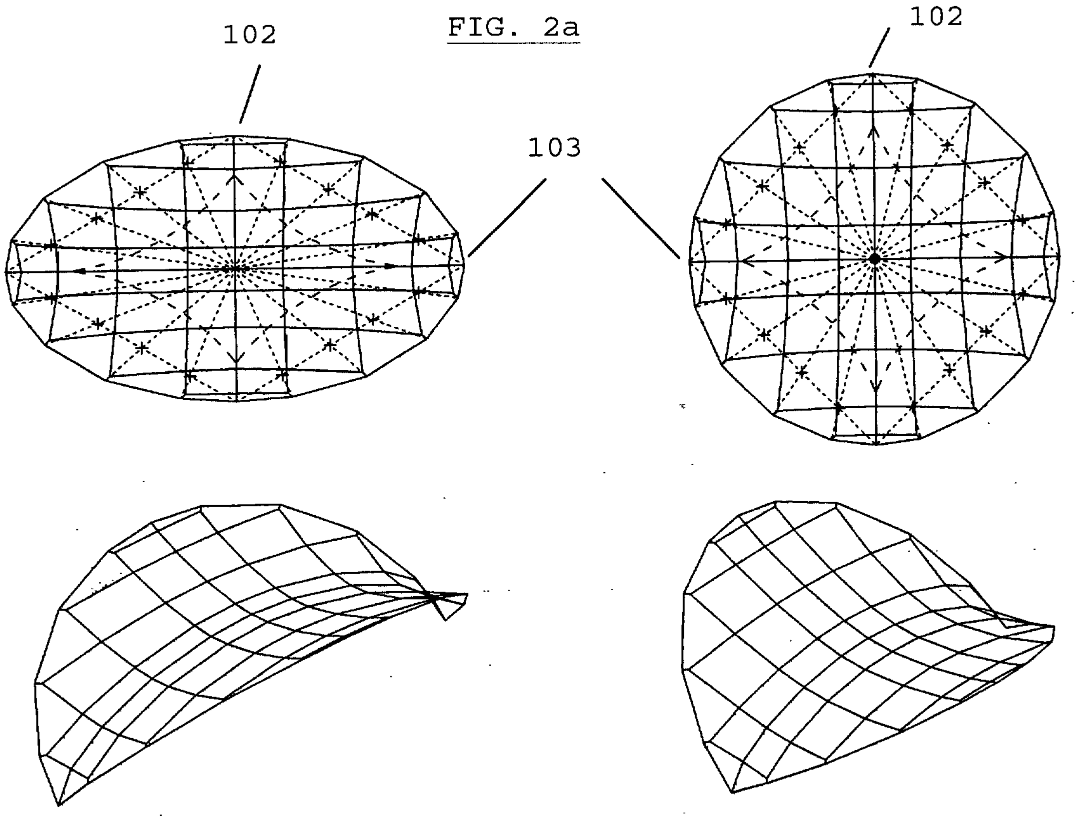

FIG. 2b

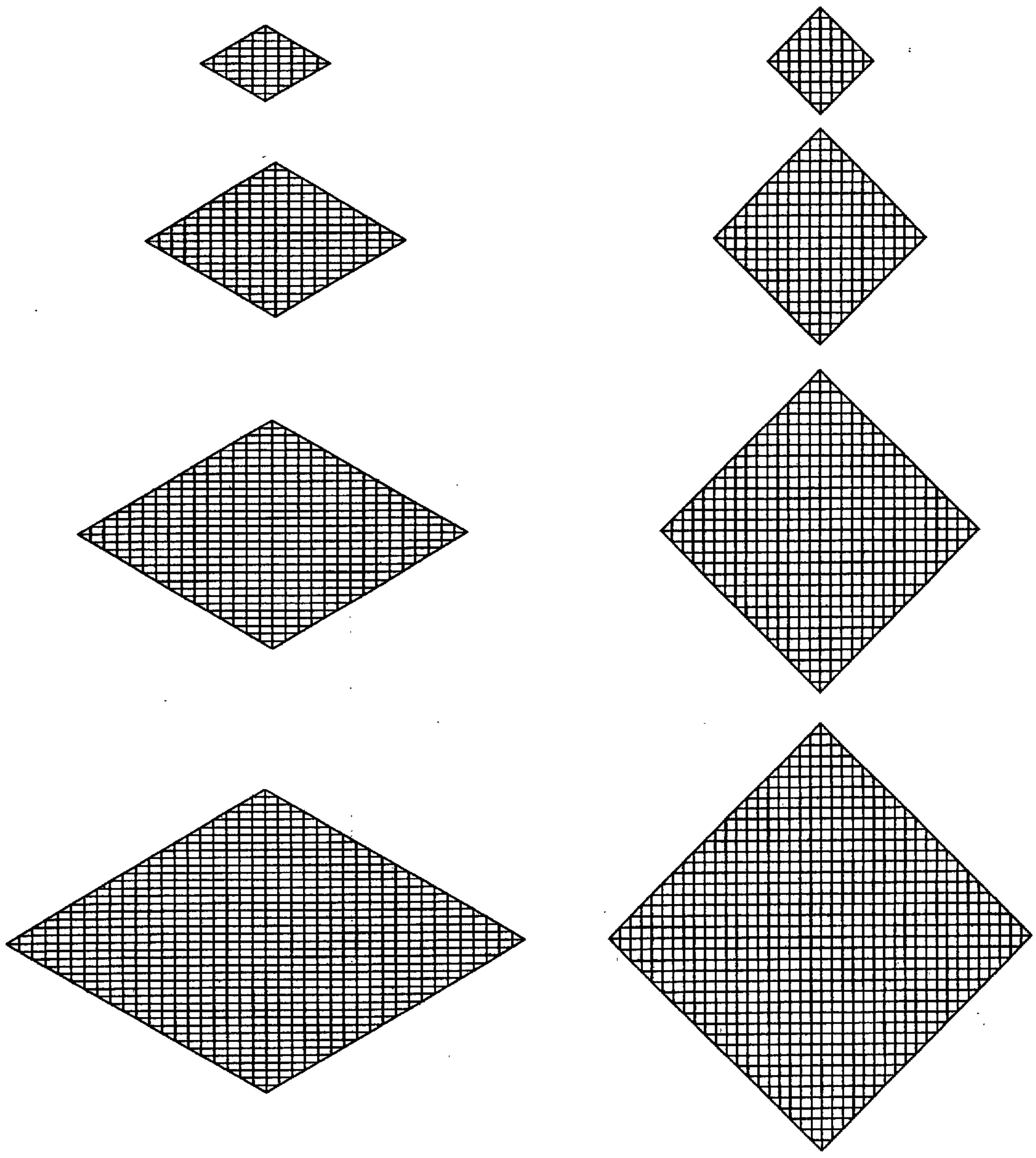

FIG. 3

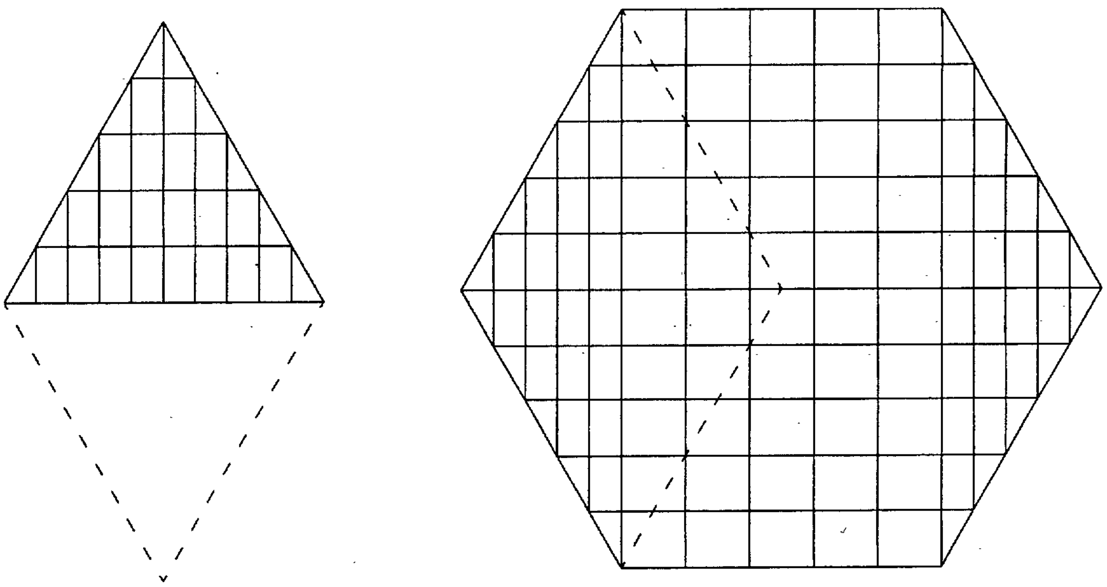

FIG. 4

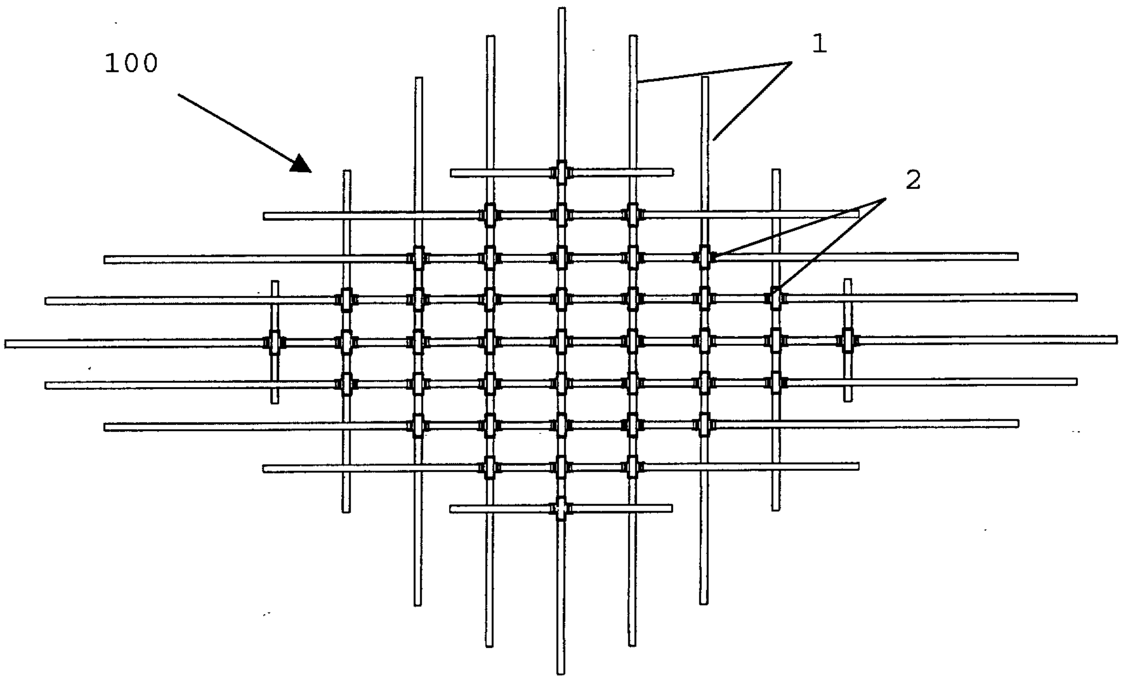

FIG. 5

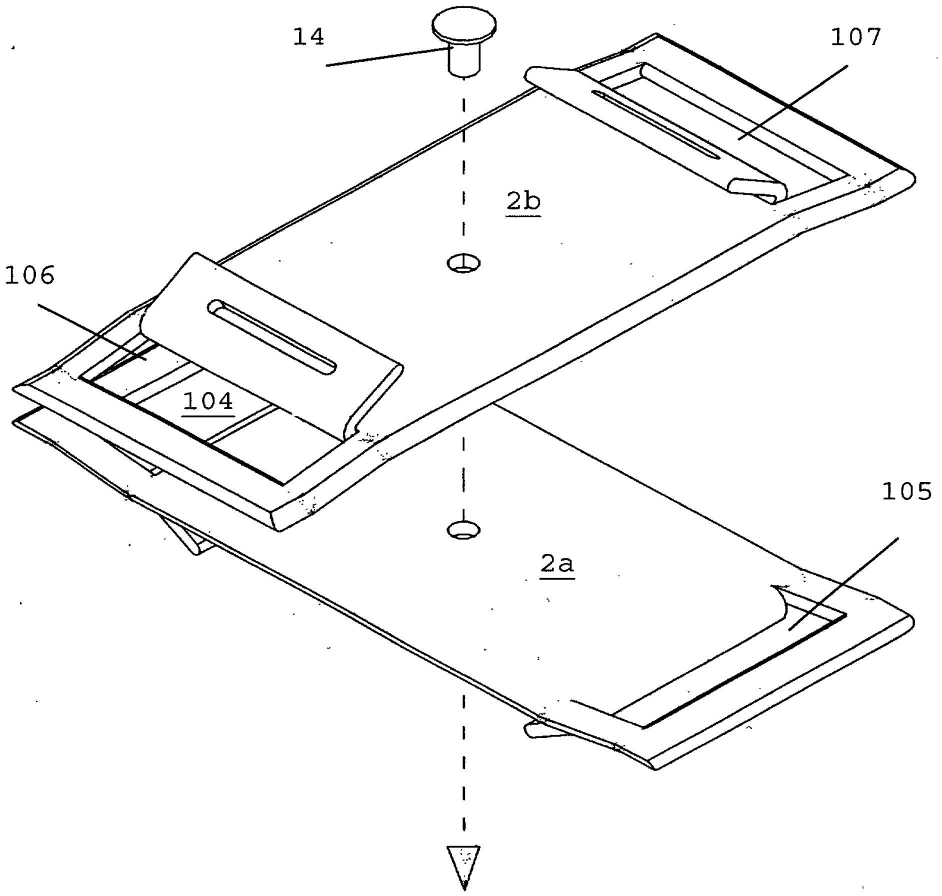

FIG. 6a

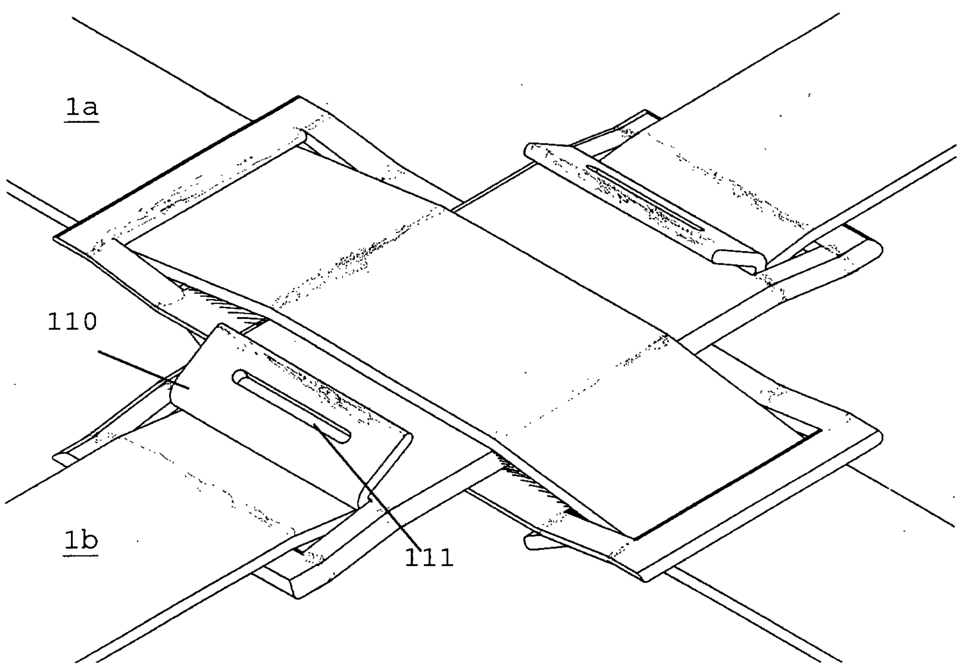

FIG. 6b

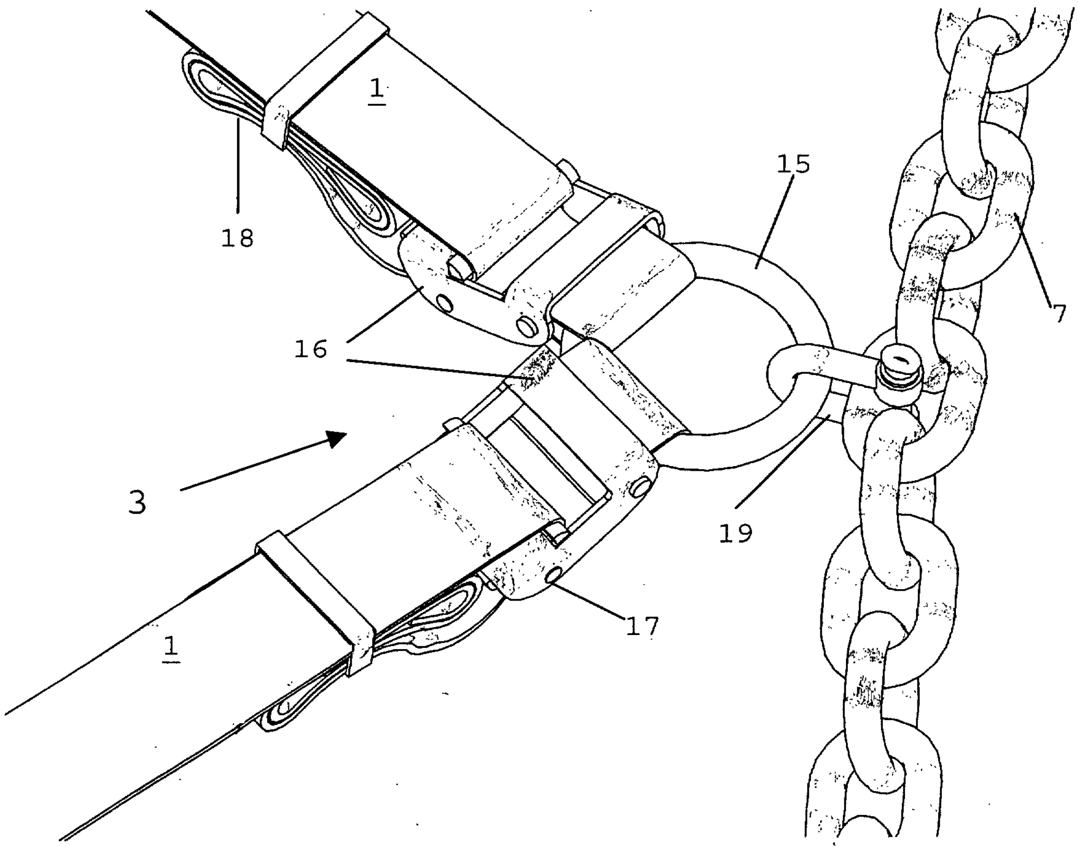

FIG. 7

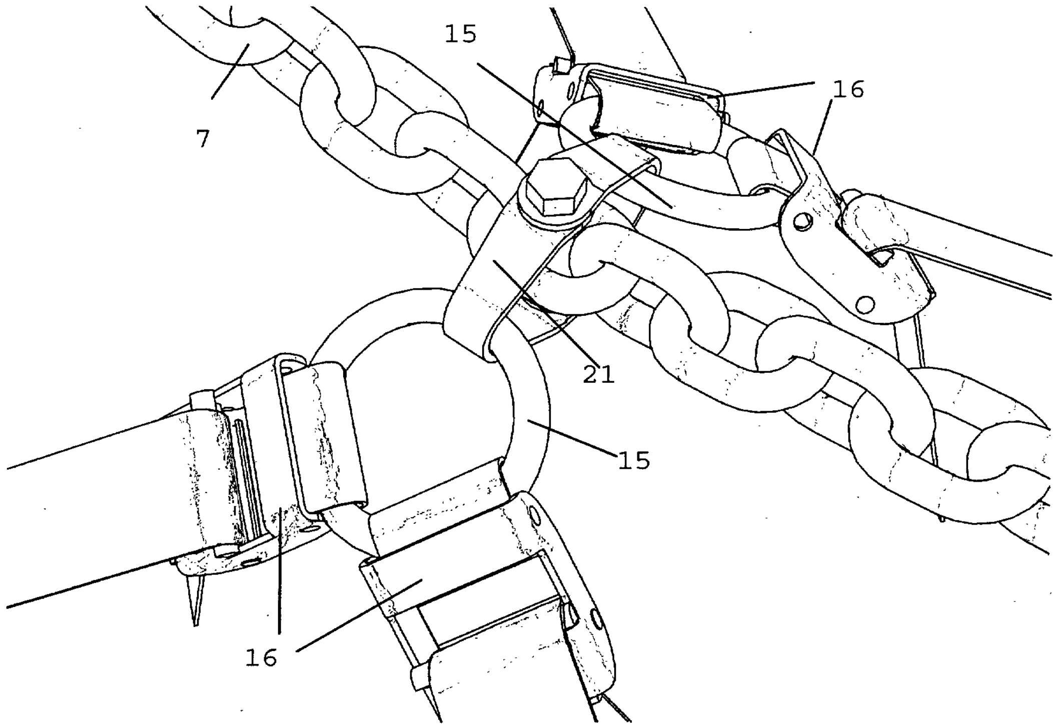

FIG. 8

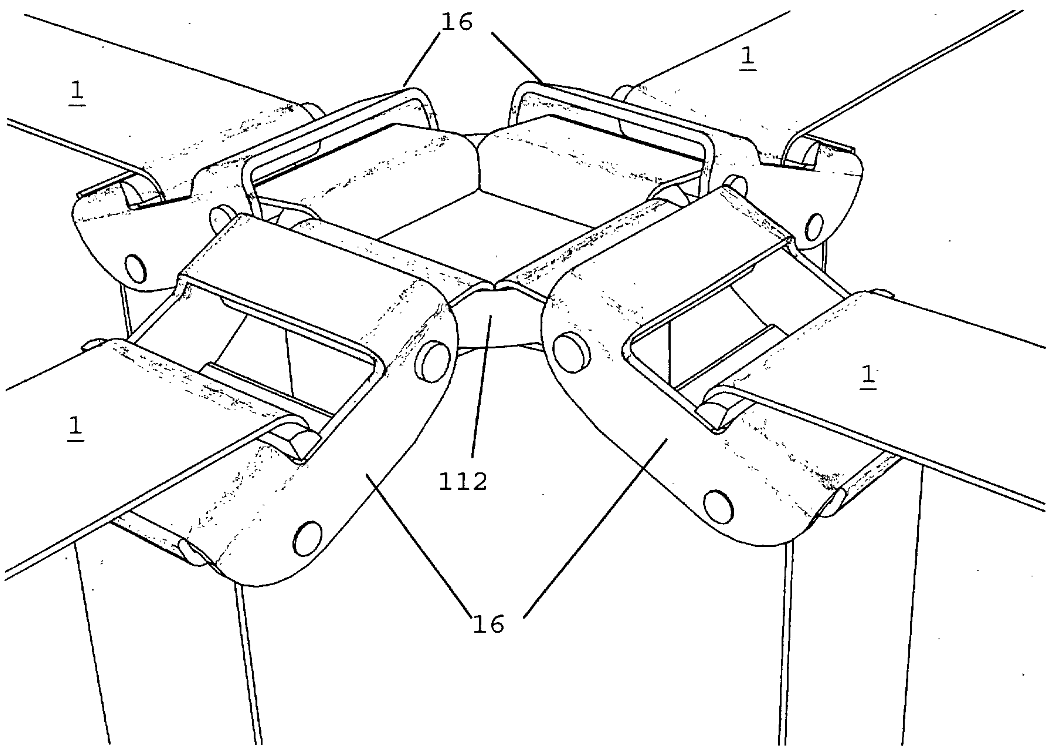

FIG. 9

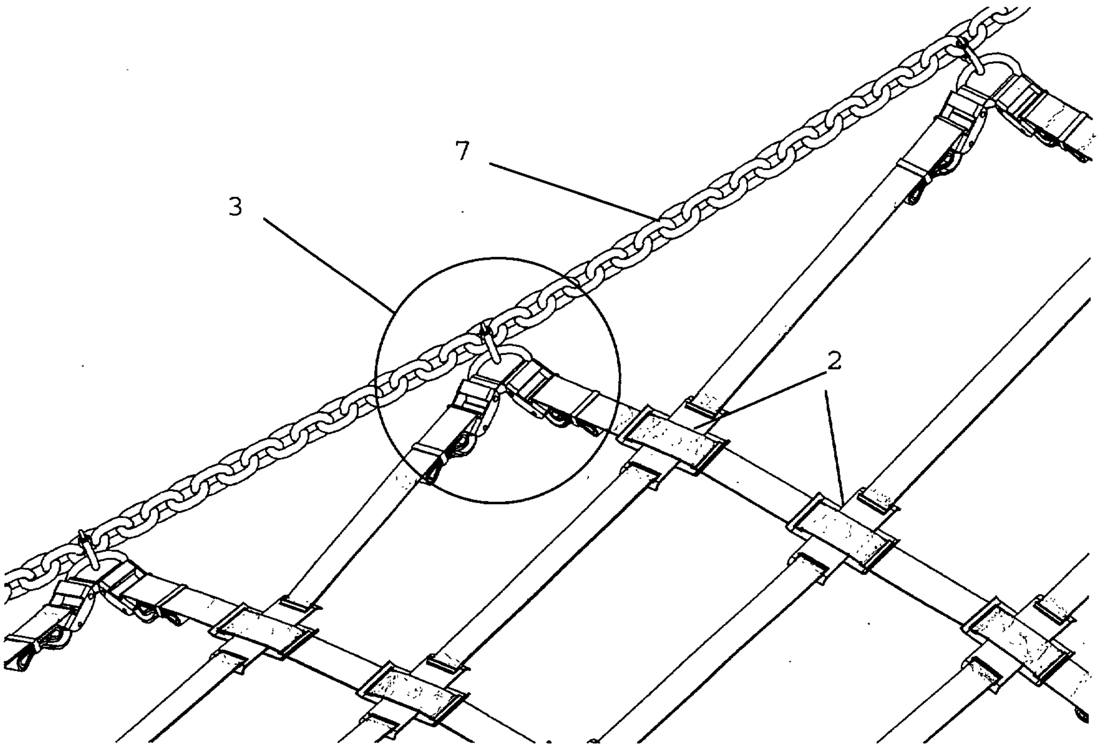

FIG. 10

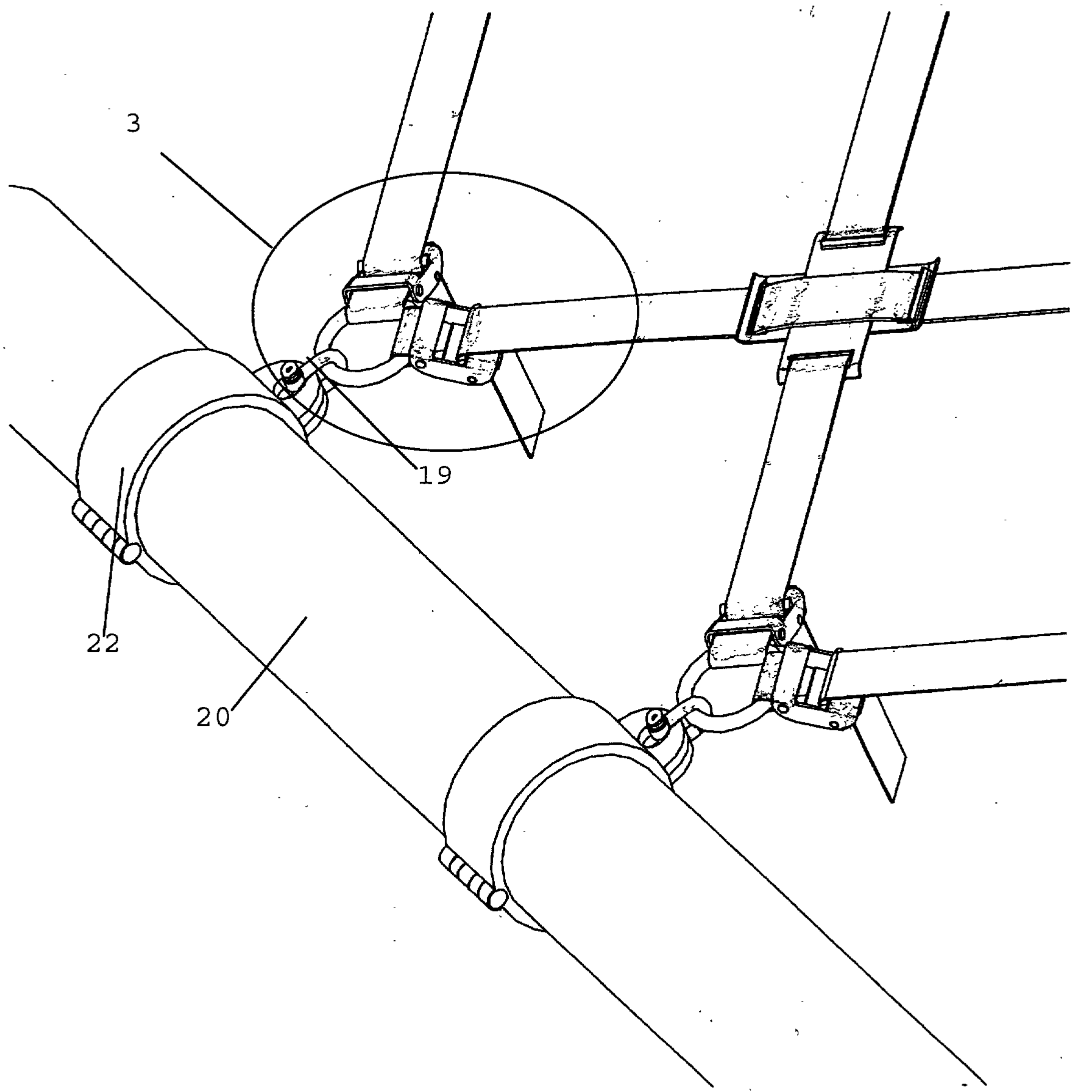

FIG. 11

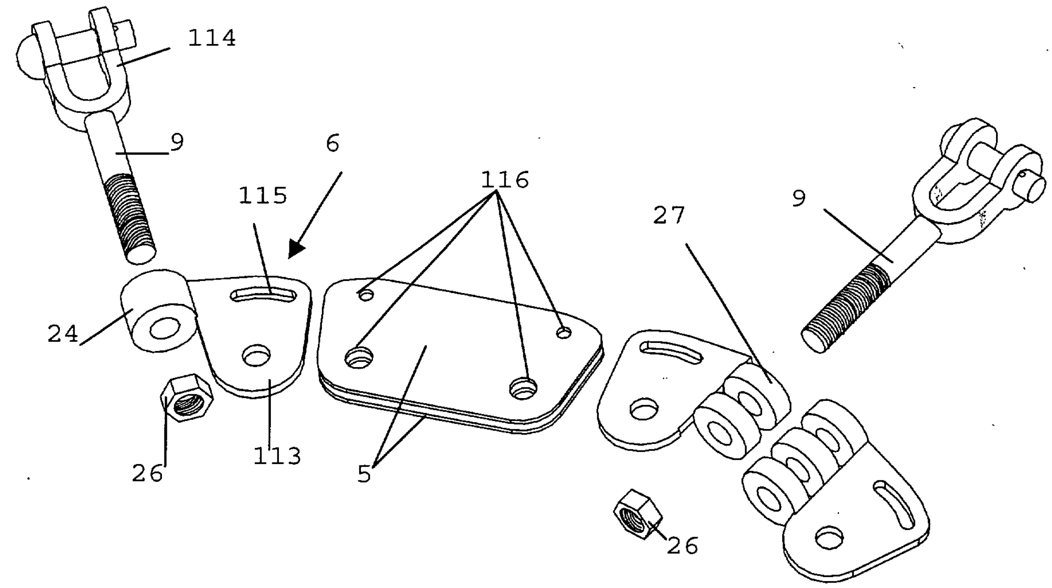

FIG. 12

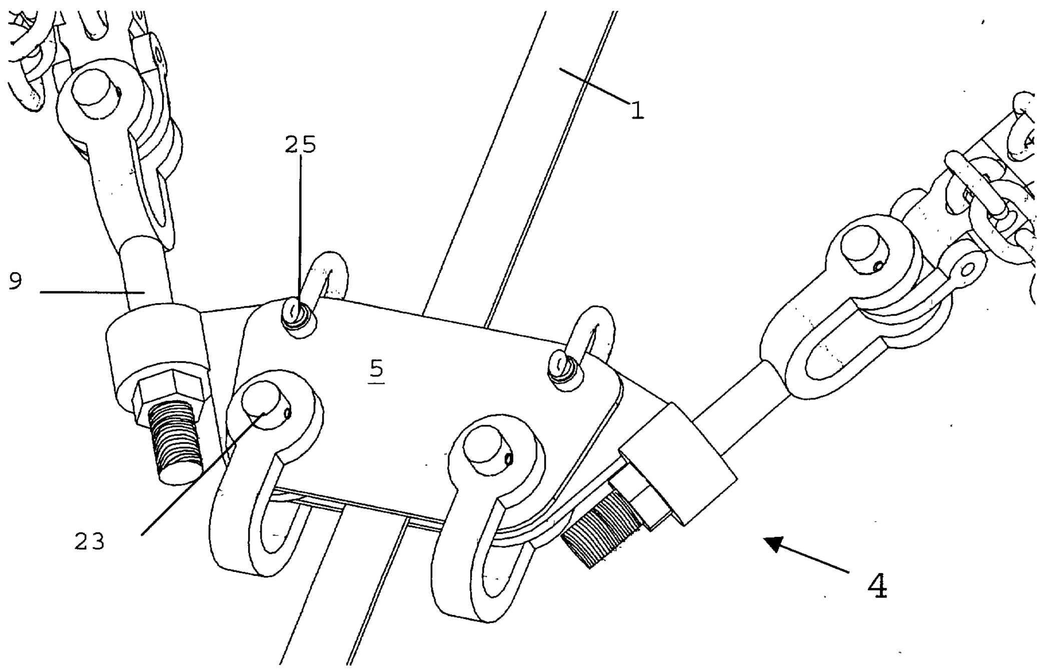

FIG. 13

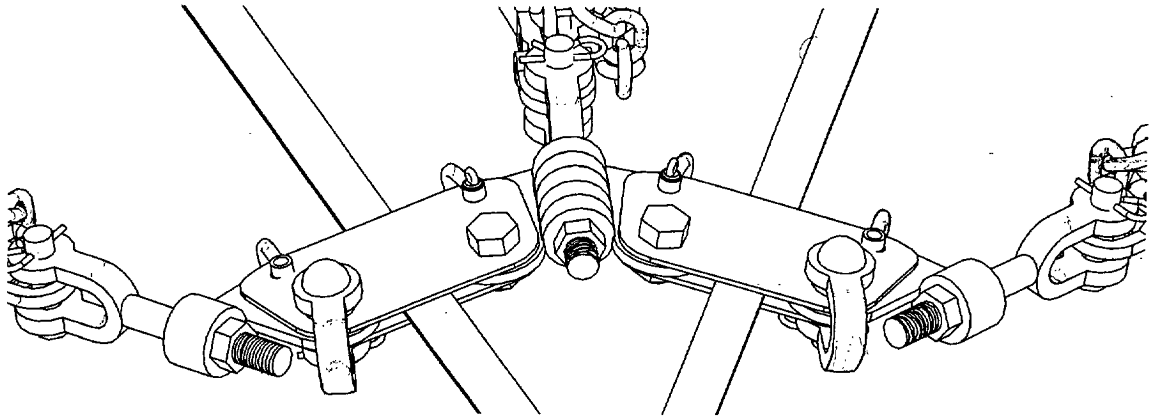

FIG. 14

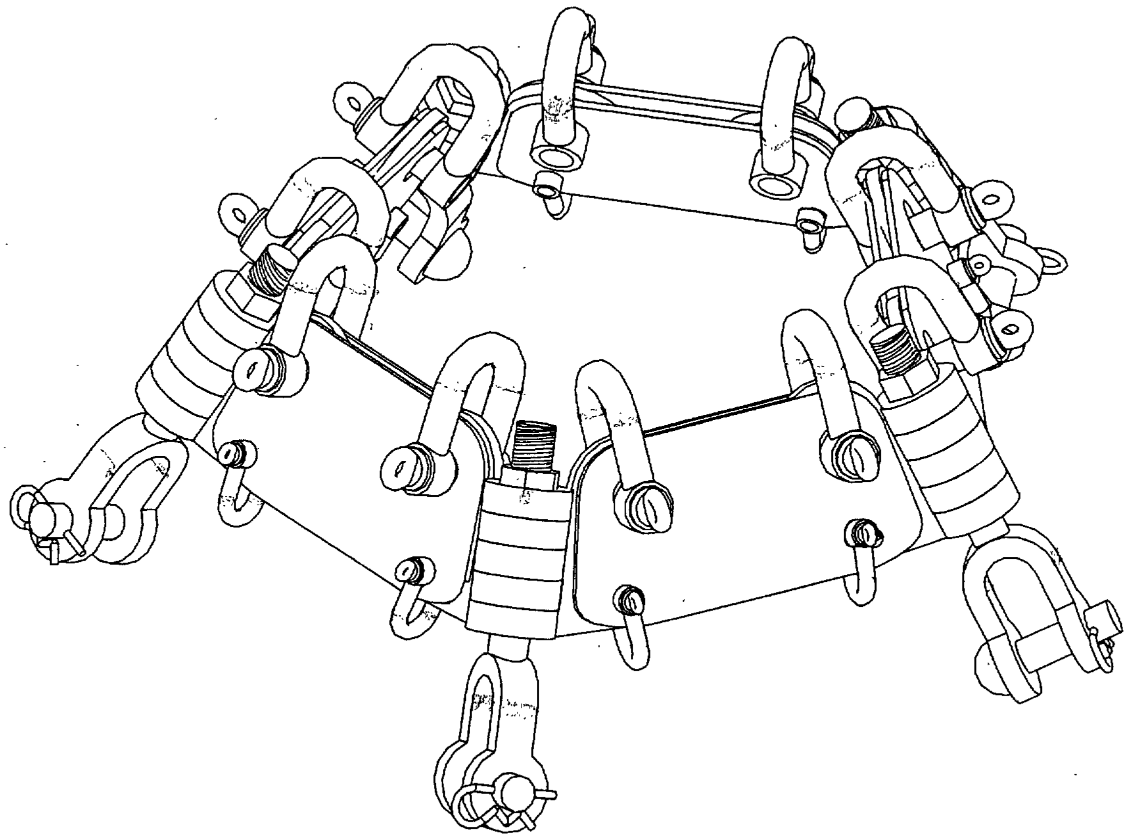

FIG. 15

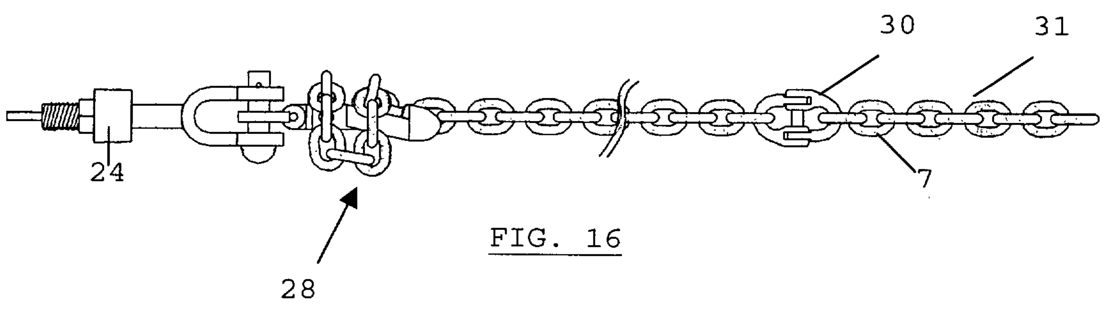

FIG. 16

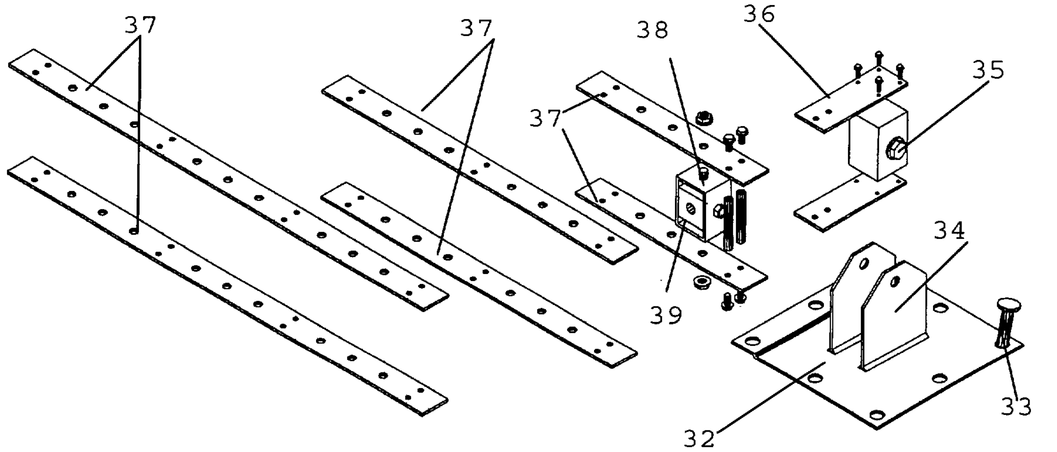

FIG .17

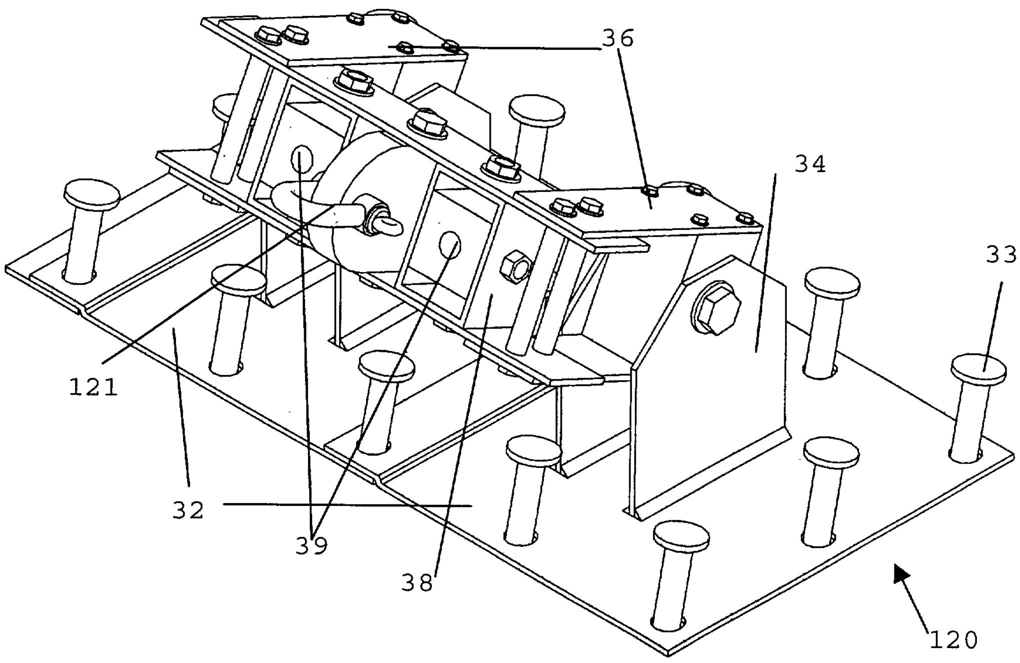

FIG. 18

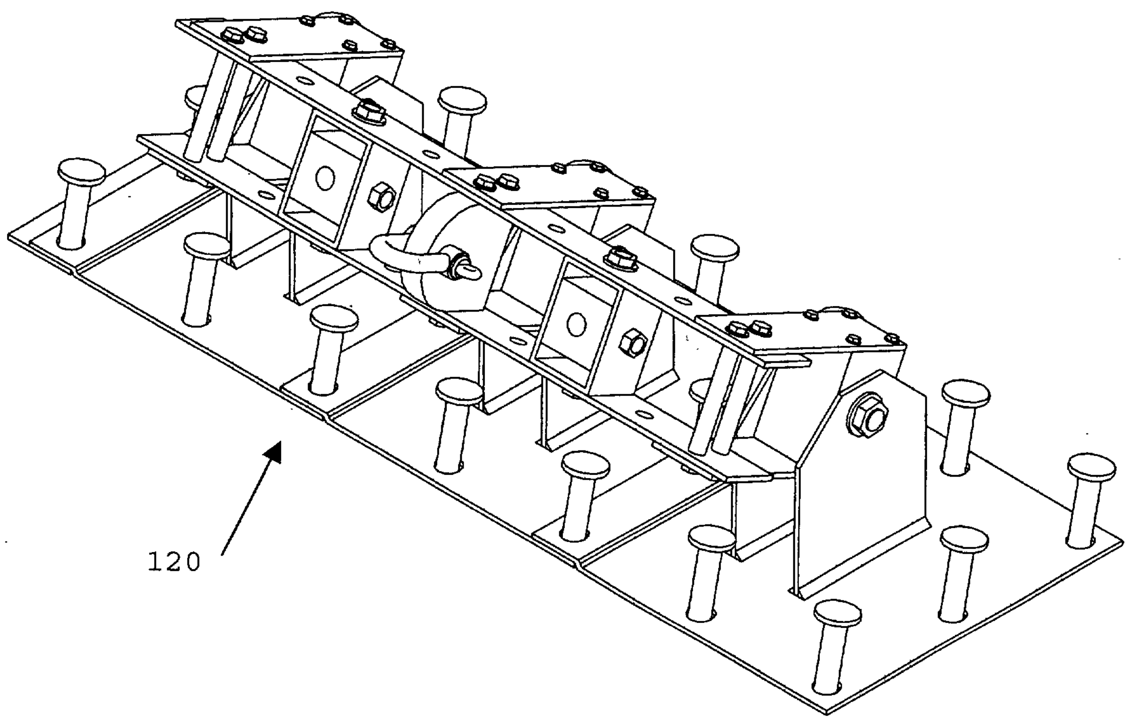

FIG. 19

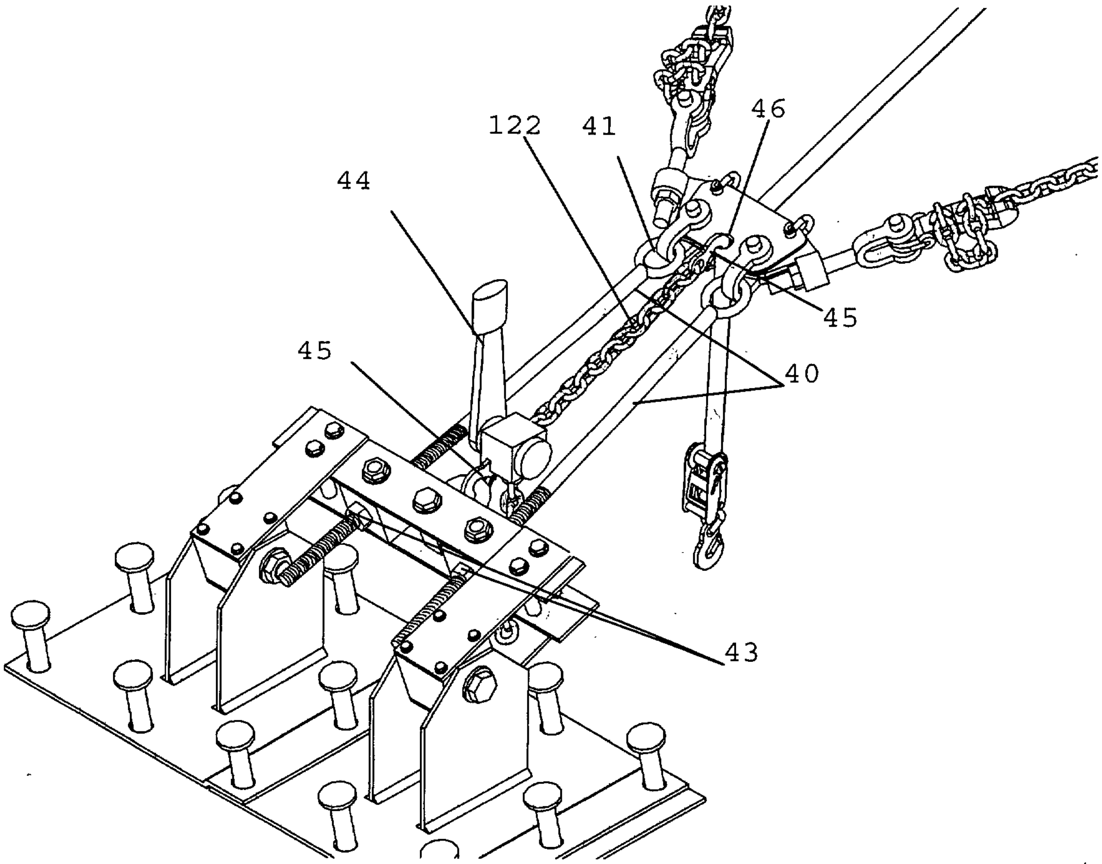

FIG. 20

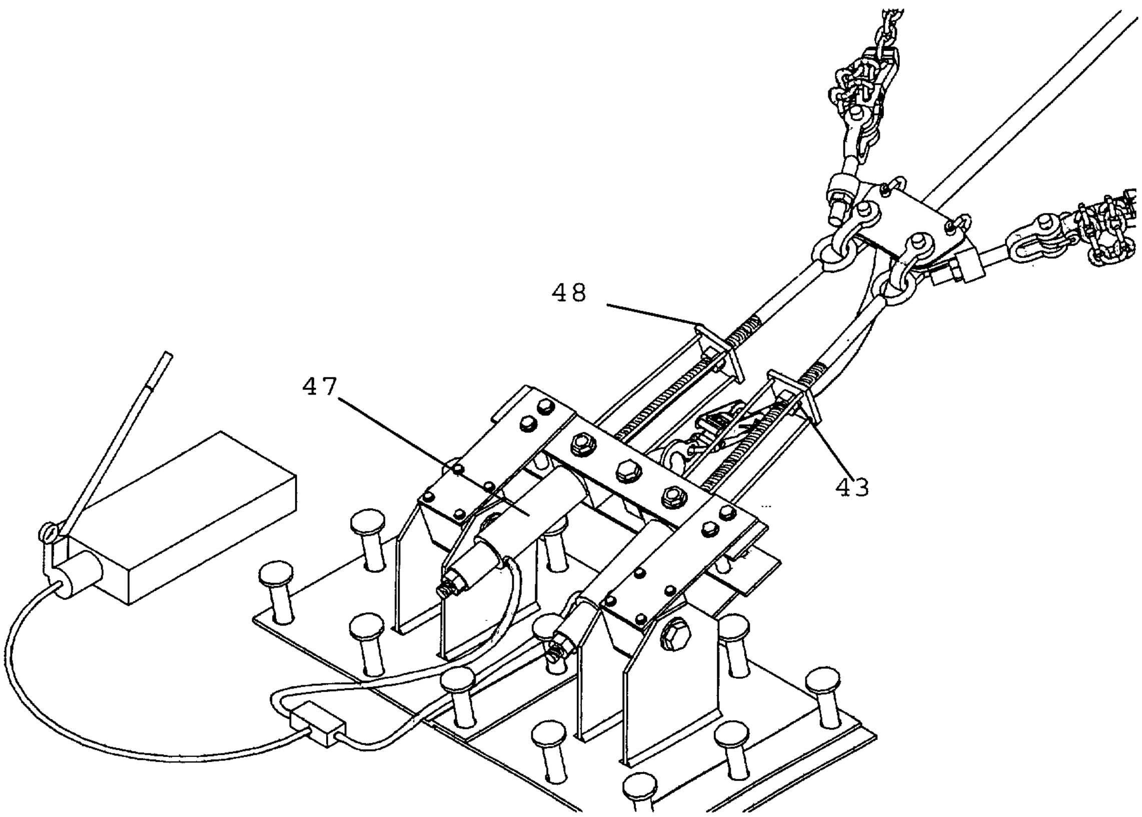

FIG. 21

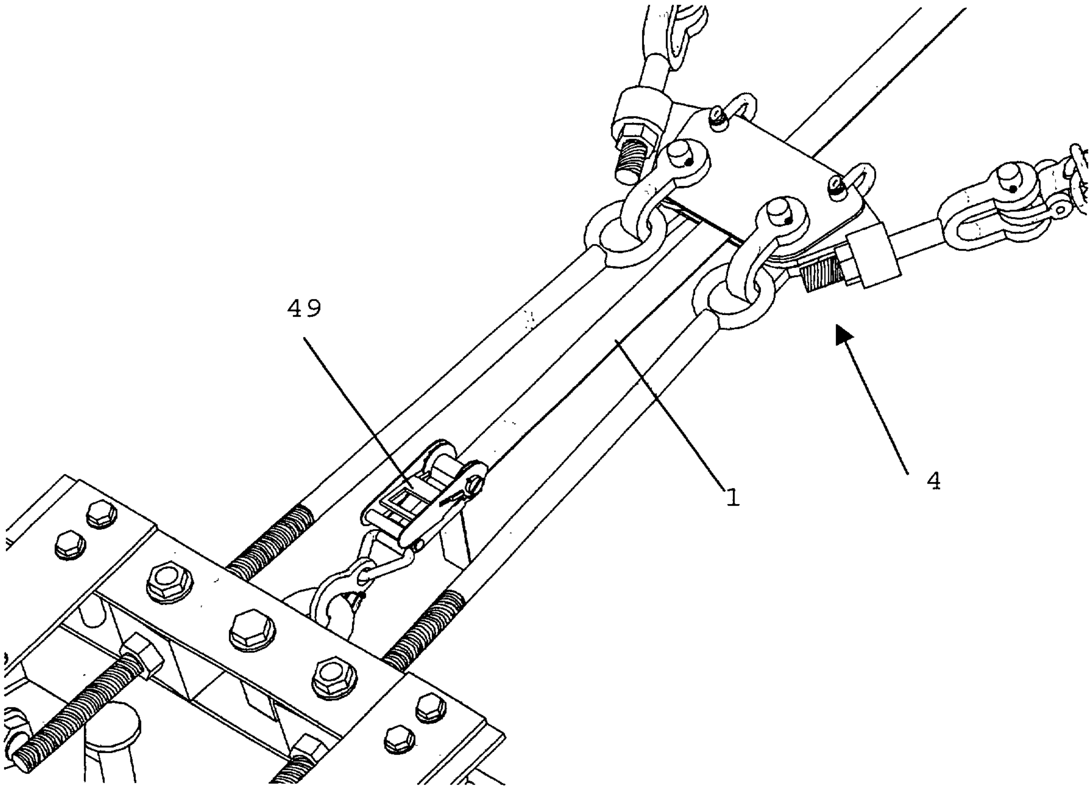

FIG. 22

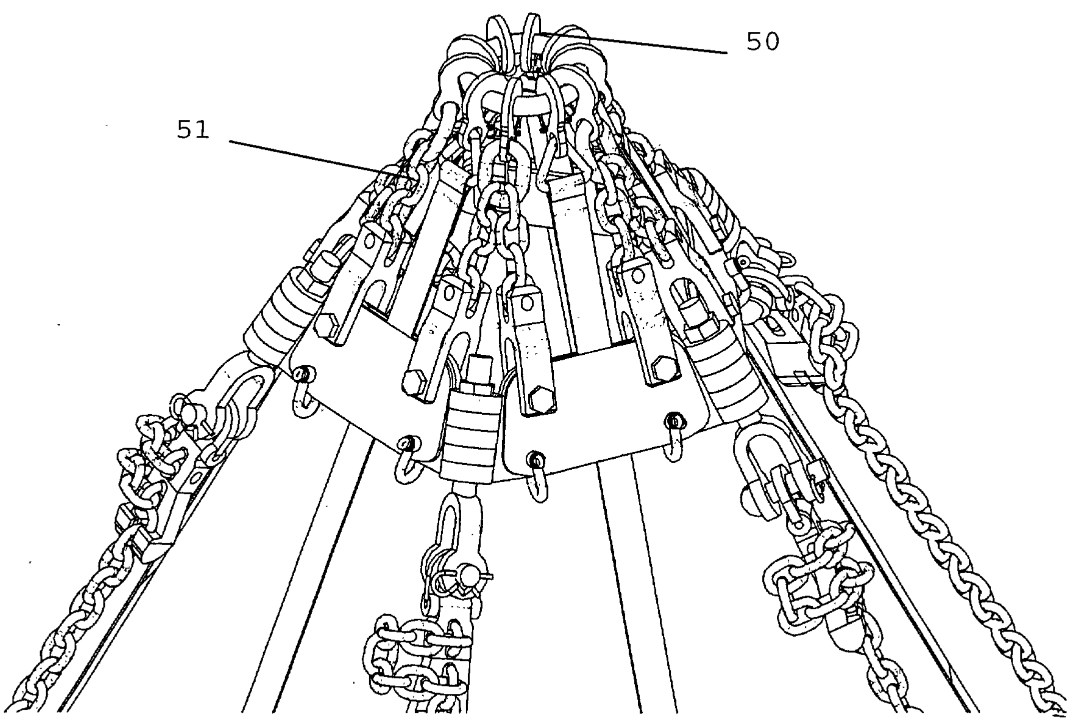

FIG. 23

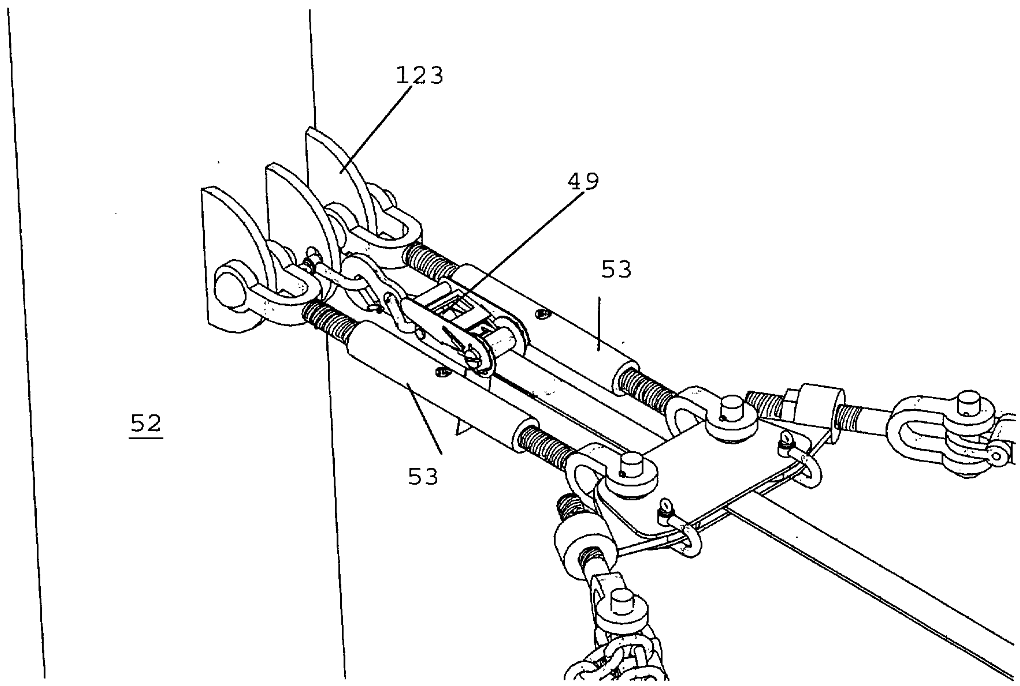

FIG. 24

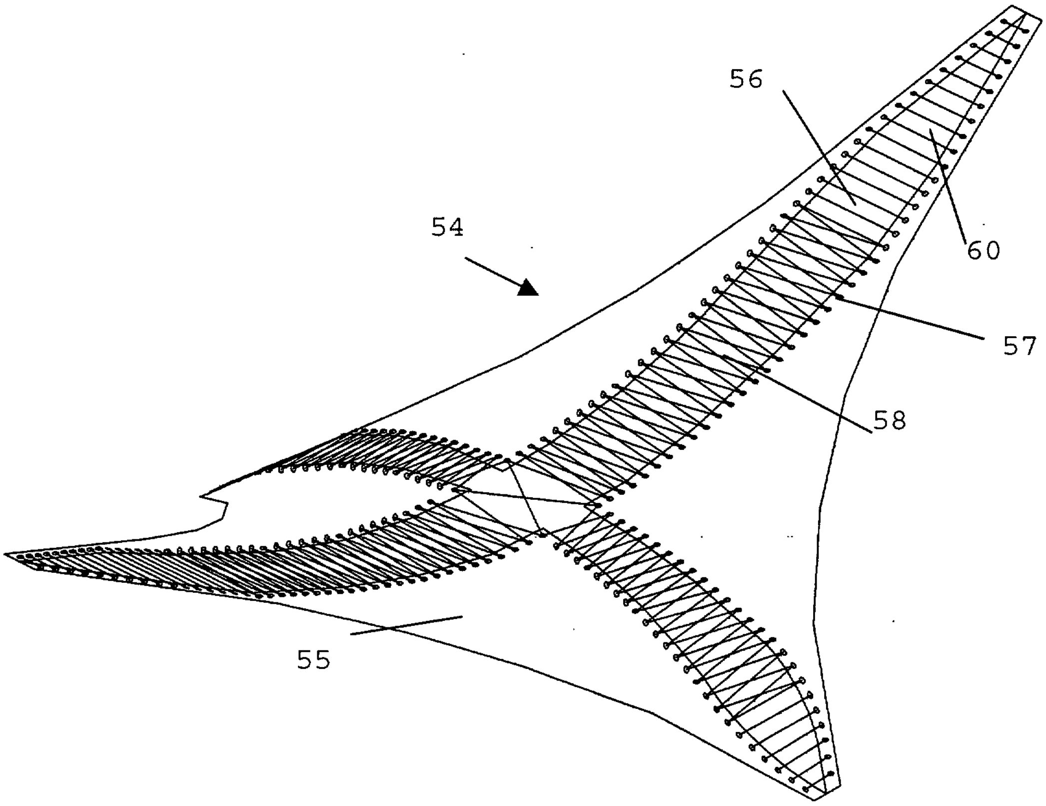

FIG. 25

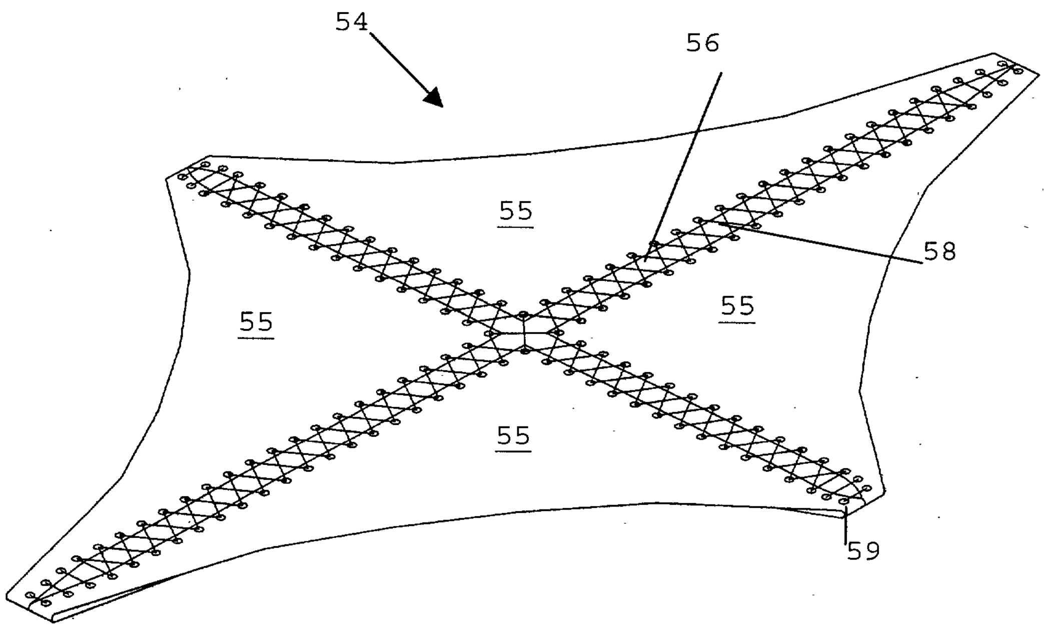

FIG. 26

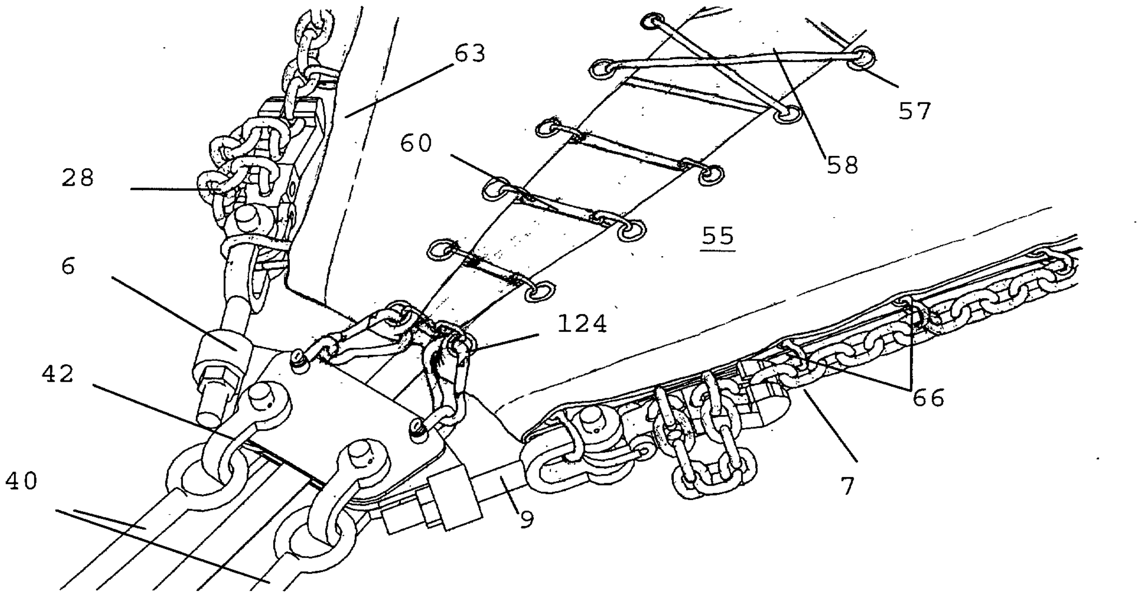

FIG. 27

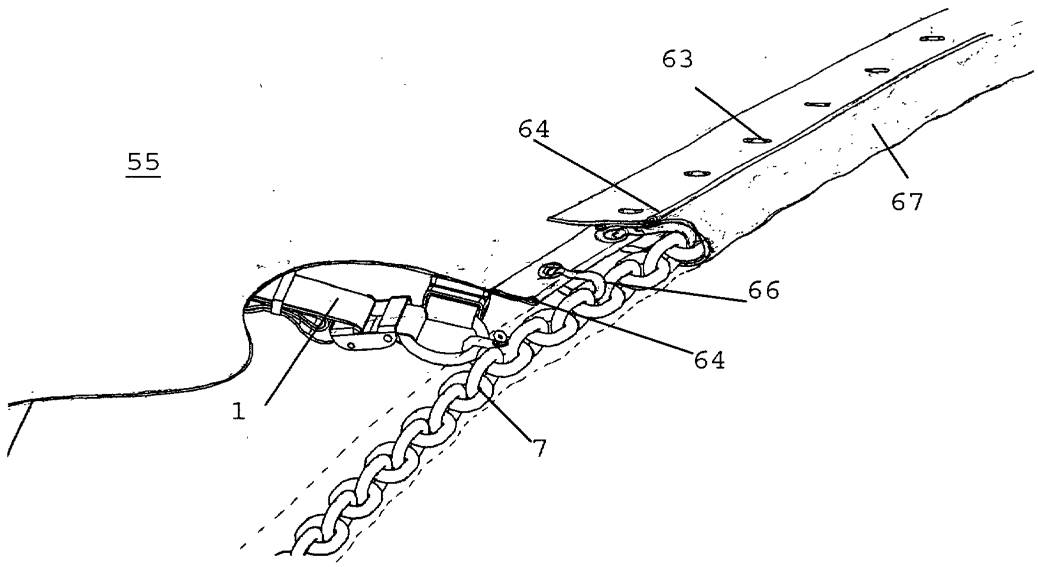

FIG. 28

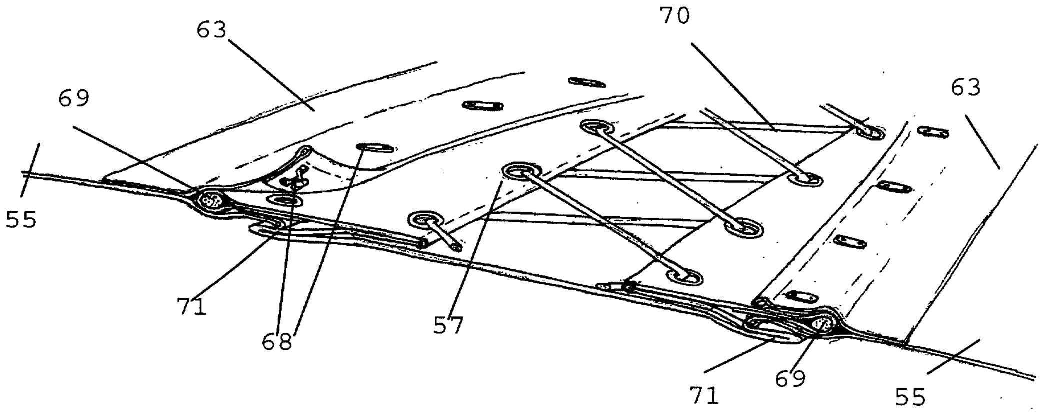

FIG. 29

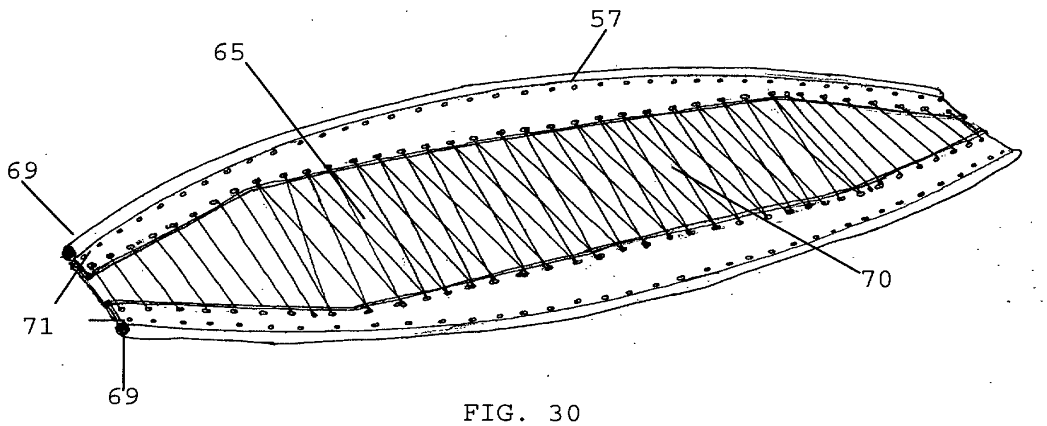

FIG. 30

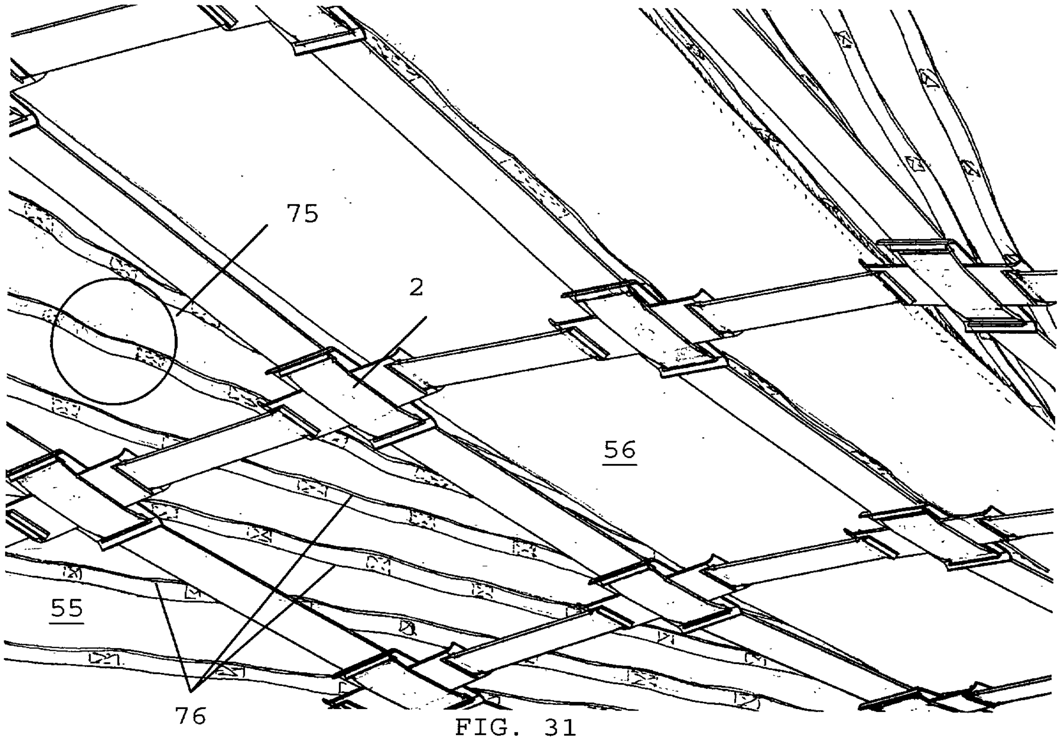

FIG. 31

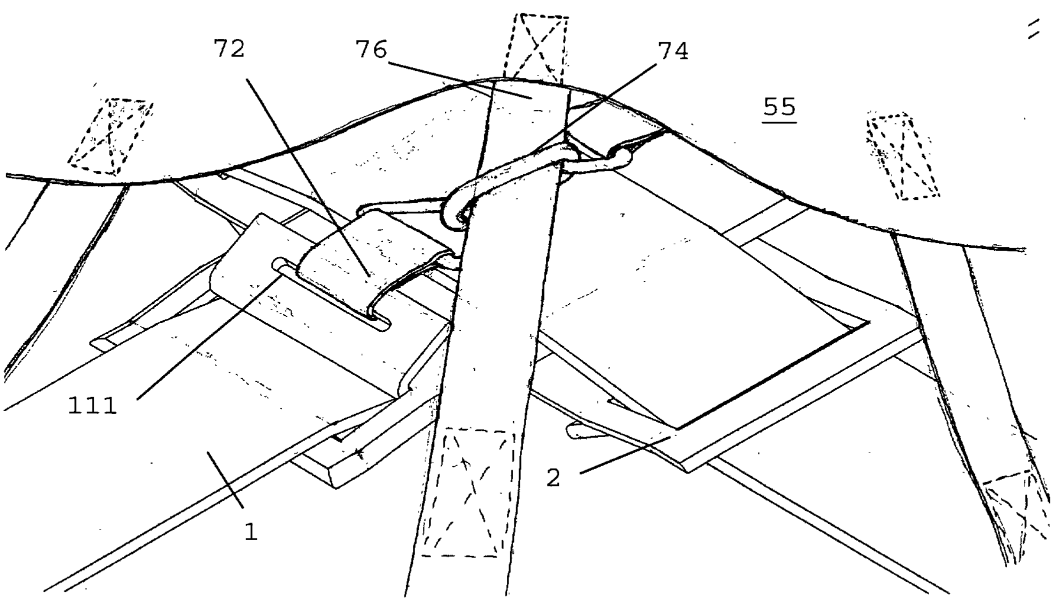

FIG. 32

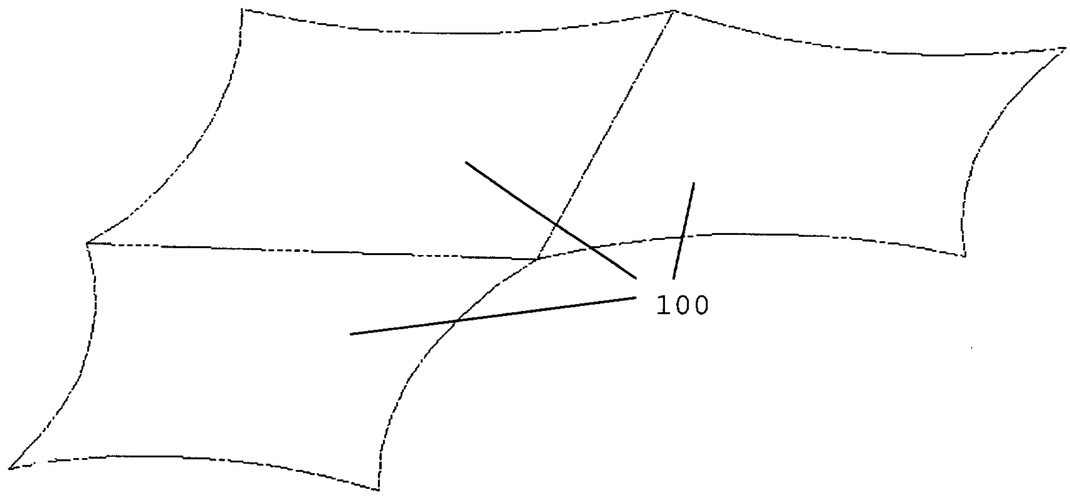

FIG. 33a

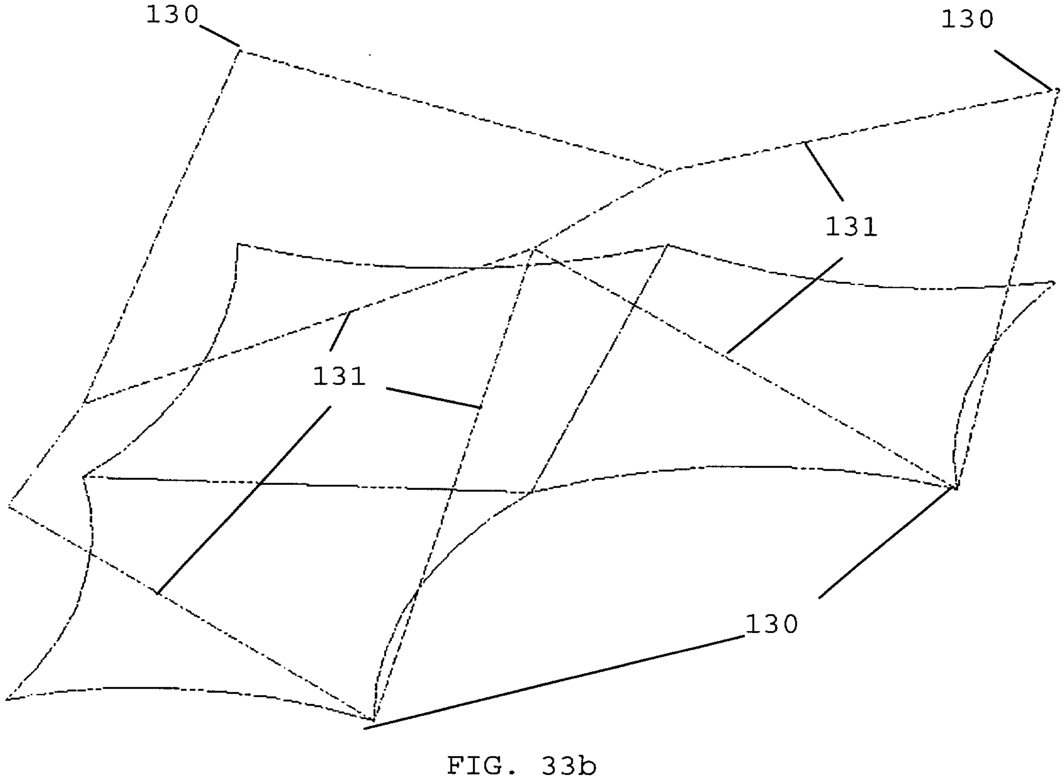

FIG. 33b

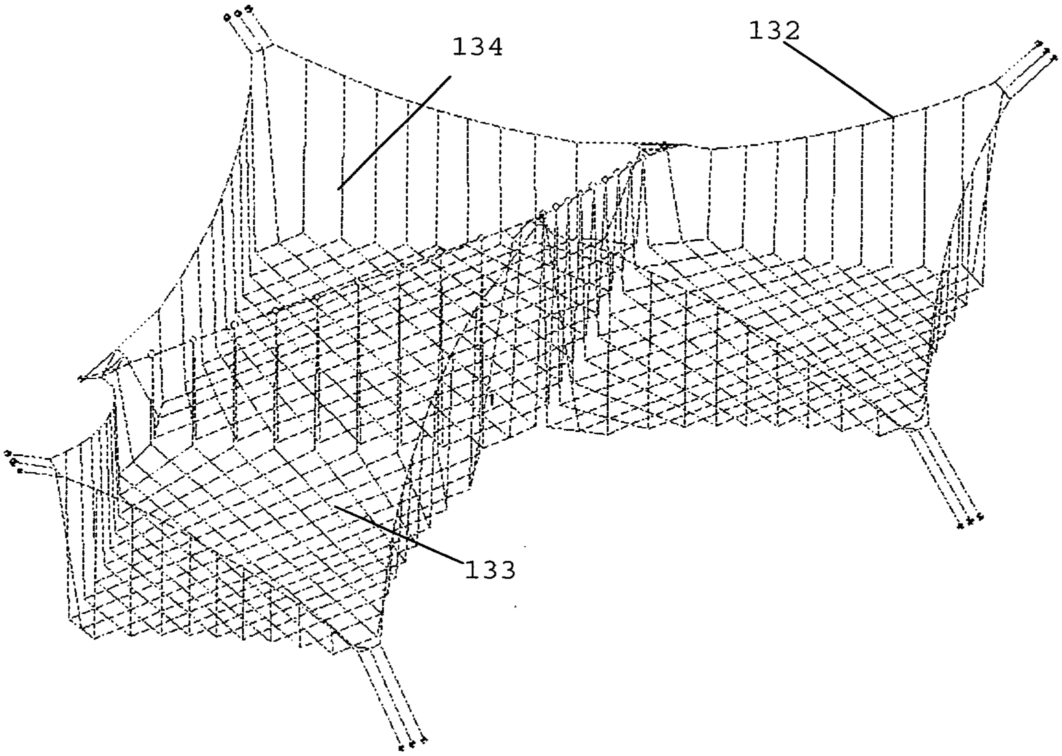

FIG. 33c

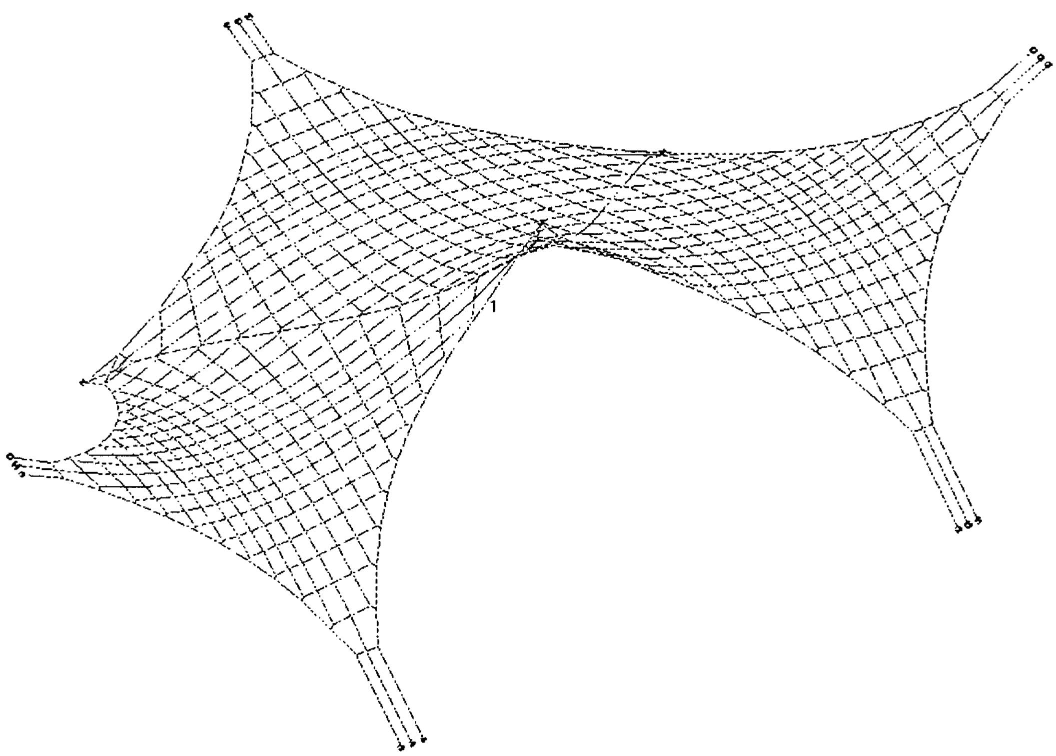

FIG. 33d

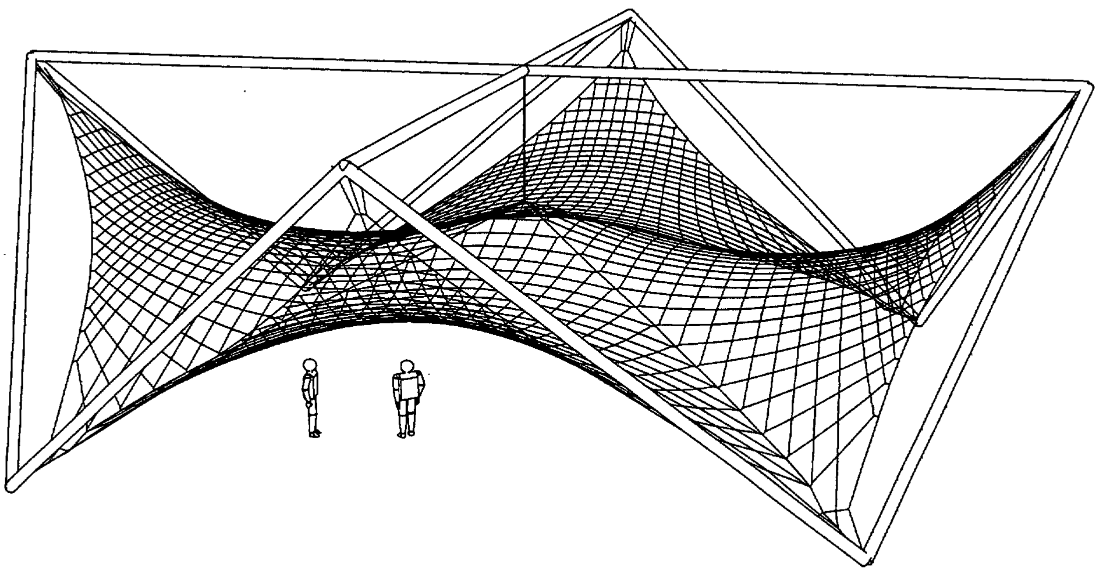

FIG. 34a

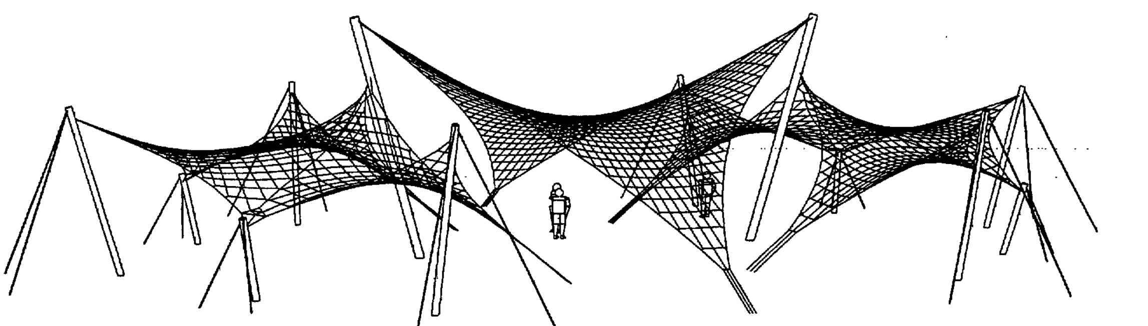

FIG. 34b

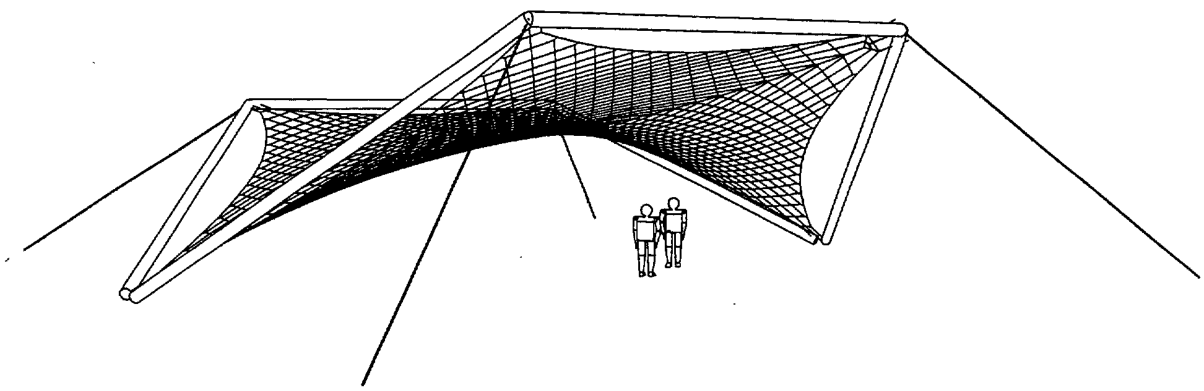

FIG. 34c

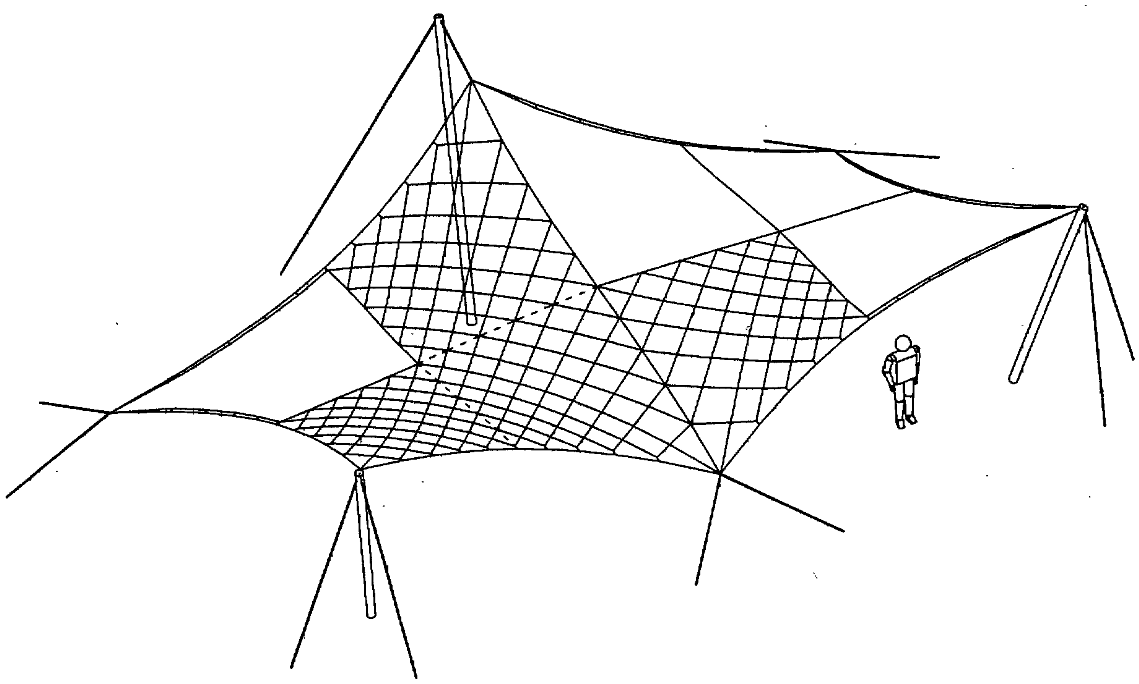

FIG. 34d

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EUROPEAN SEARCH REPORT

Application Number
EP 01 87 0099

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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A	US 3 699 987 A (HUDDLE CARL F) 24 October 1972 (1972-10-24) * column 2, line 35 - line 43 * ---	1	
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A	US 4 271 641 A (KAWAGUCHI MAMORU) 9 June 1981 (1981-06-09) * figure 2 * ---	1	
A	PATENT ABSTRACTS OF JAPAN vol. 018, no. 508 (M-1678), 26 September 1994 (1994-09-26) & JP 06 173456 A (TAKENAKA KOMUTEN CO LTD), 21 June 1994 (1994-06-21) * abstract * -----	1,10	TECHNICAL FIELDS SEARCHED (Int.Cl.7) E04H E04B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	12 September 2001	Delzor, F

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