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Gillis

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(45) **Date of Patent: Jul. 9, 2002**

(54) **FLEXIBLE STRUCTURE AND METHOD**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/680,232**

(22) Filed: **Oct. 6, 2000**

Related U.S. Application Data

(63) Continuation-in-part of application No. 09/079,246, filed on May 14, 1998, now Pat. No. 6,145,527.

(51) **Int. Cl.**^{7} **E04H 15/36**
(52) **U.S. Cl.** **135/124**; 135/127
(58) **Field of Search** 135/124, 127, 135/87, 121, 156, 137

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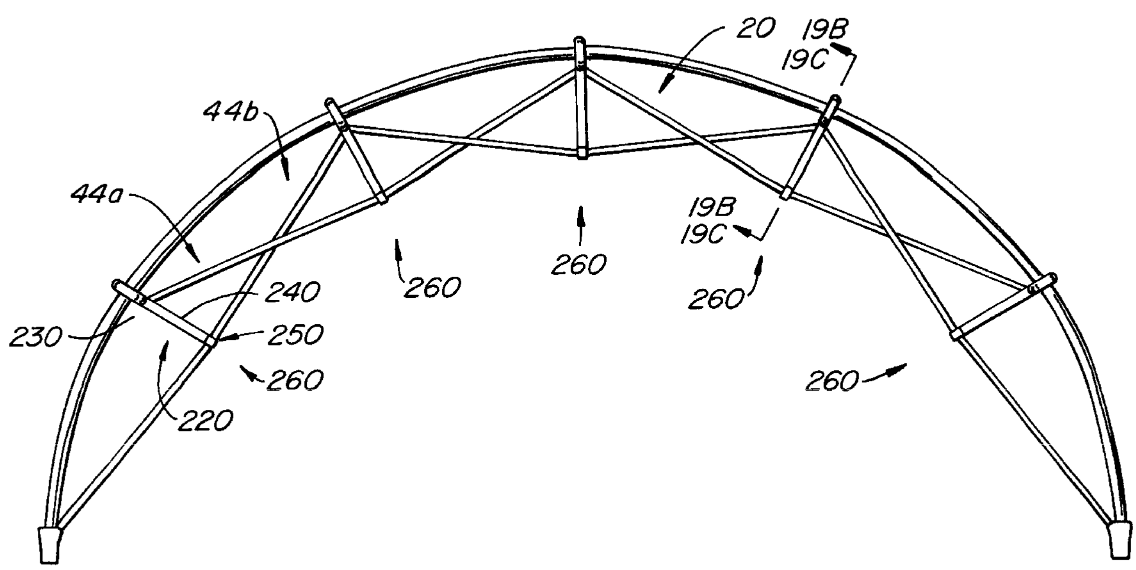
(74) *Attorney, Agent, or Firm*—Townsend and Townsend and Crew LLP

(57) **ABSTRACT**

A flexible structure is described having one or more deformable, resilient poles and one or more tension webs associated therewith, having strut members, and being coupled to the poles to maintain the pole(s) in a selected shape under tension and to impart strength and rigidity to the structure. A flexible membrane may also be provided to define a sheltered space.

20 Claims, 16 Drawing Sheets



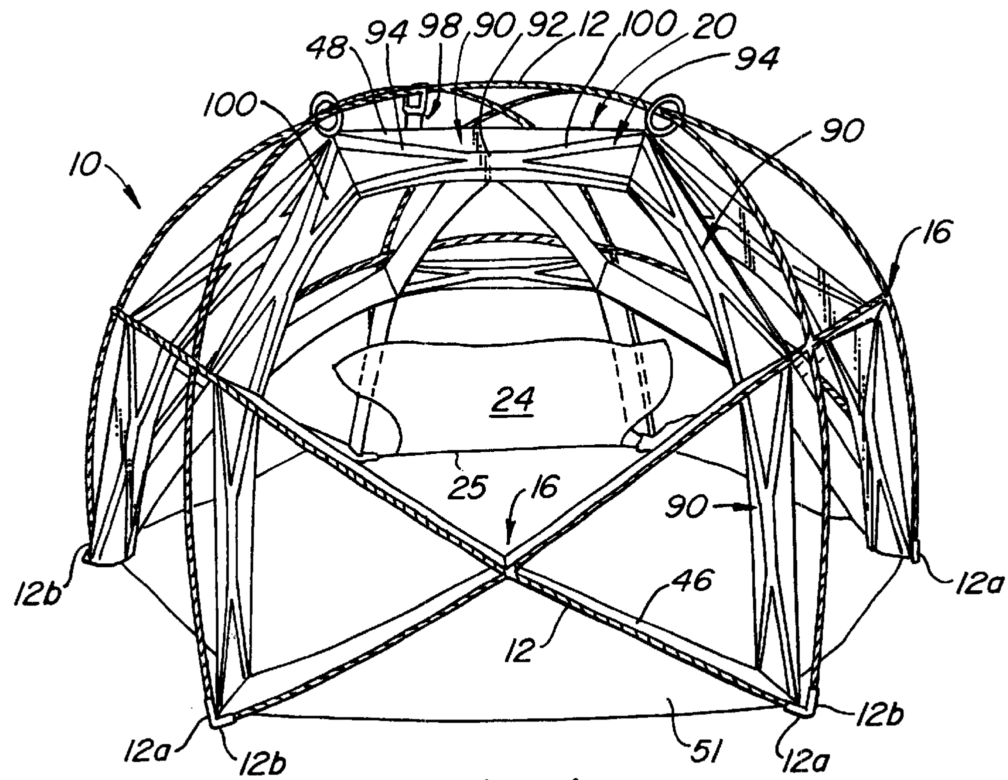

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FIG. 1.

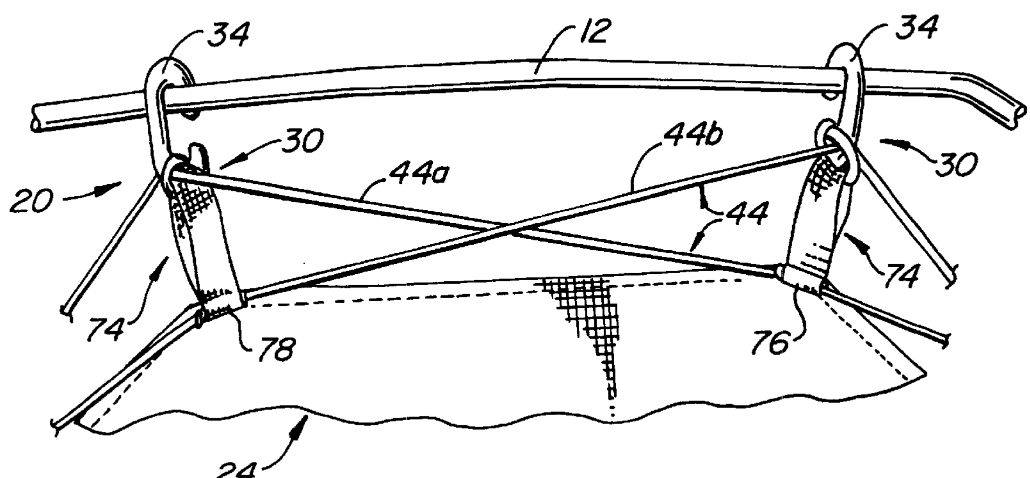
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FIG. 2.

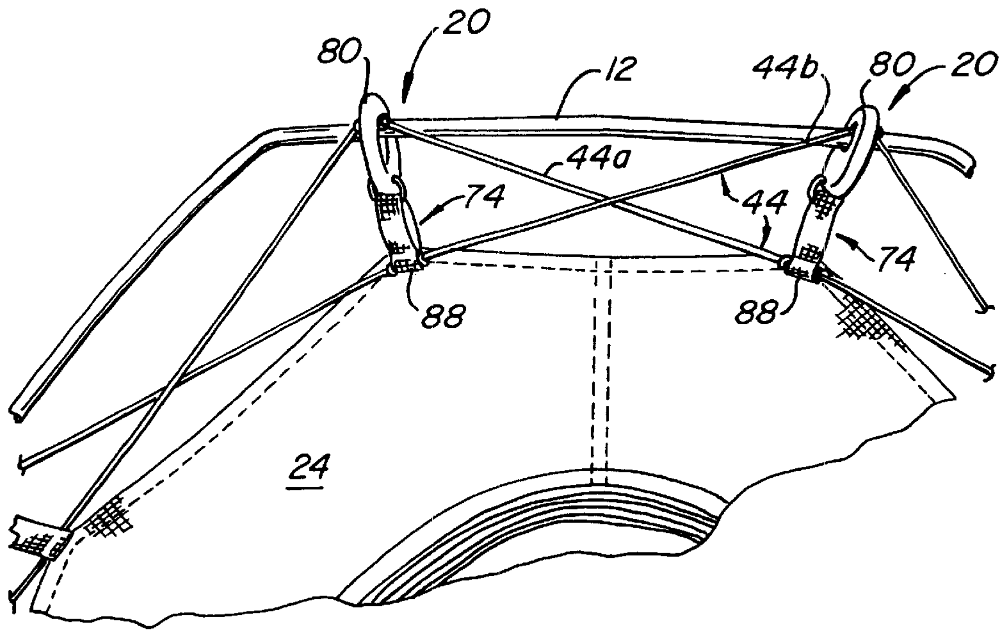


FIG. 3.

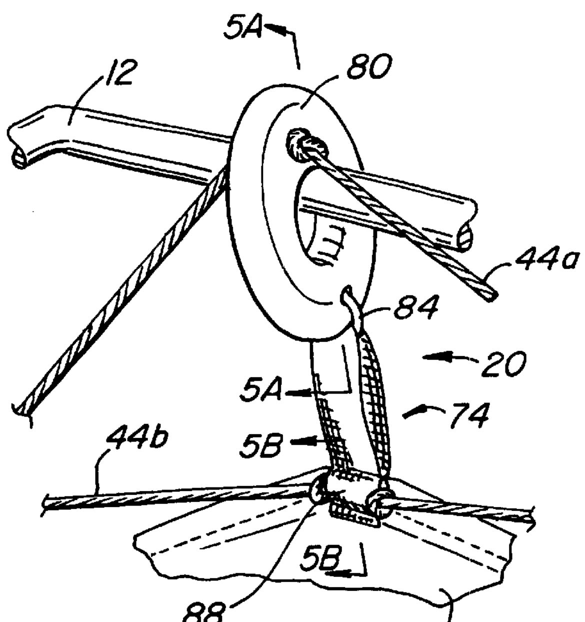


FIG. 4.

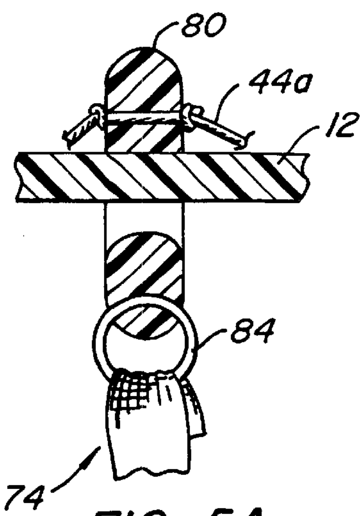


FIG. 5A.

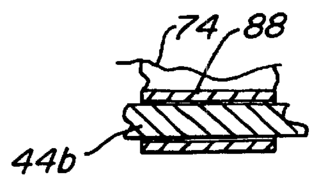


FIG. 5B.

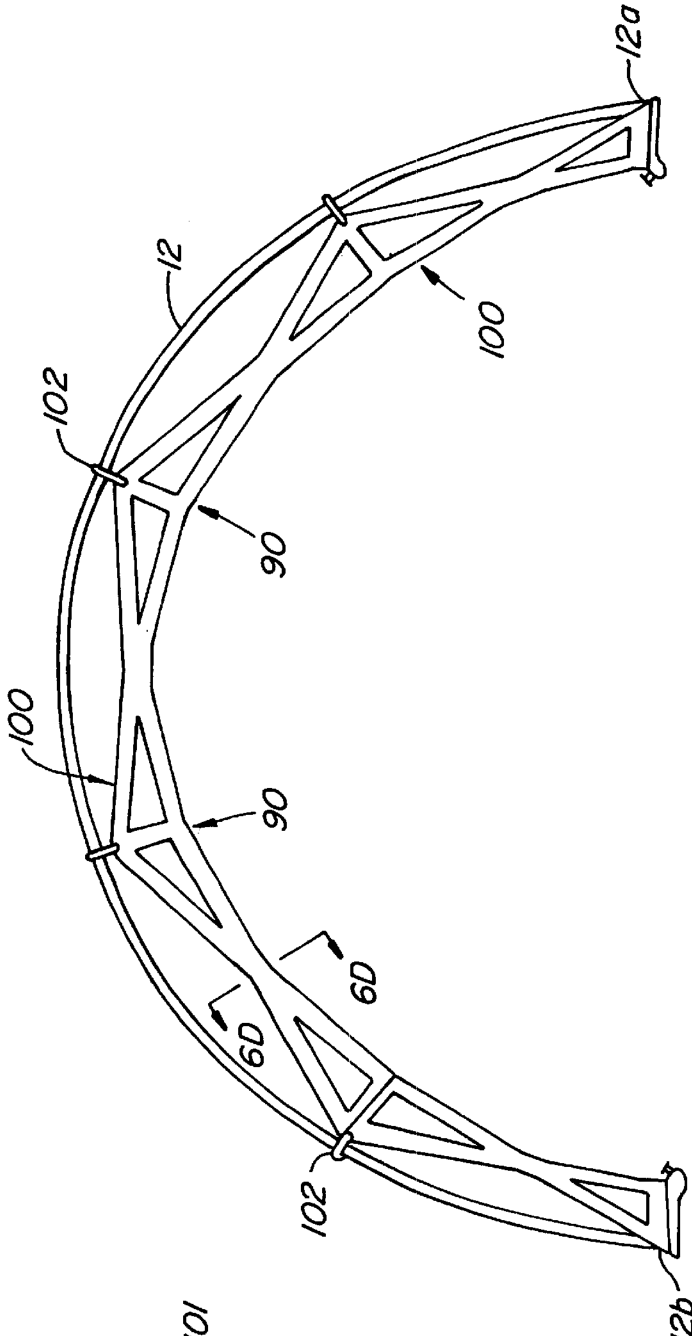


FIG. 6C.

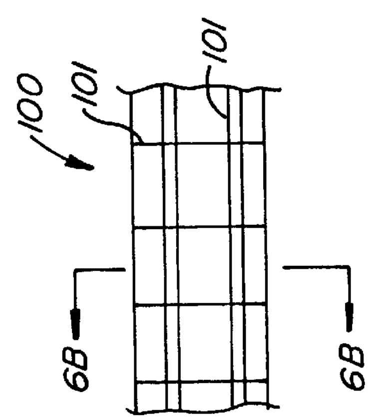


FIG. 6A.

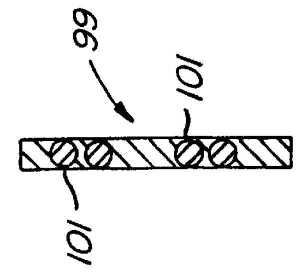


FIG. 6B.

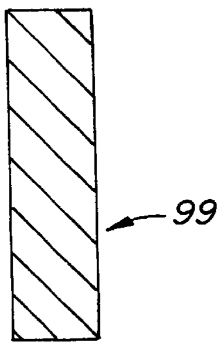


FIG. 6D.

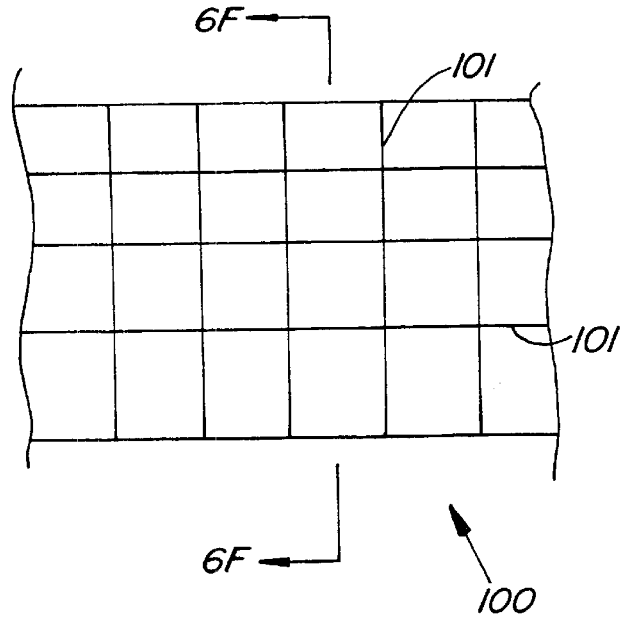


FIG. 6E.

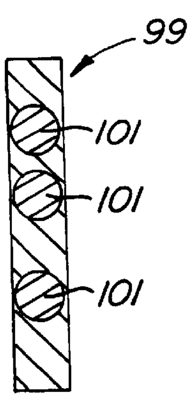


FIG. 6F.

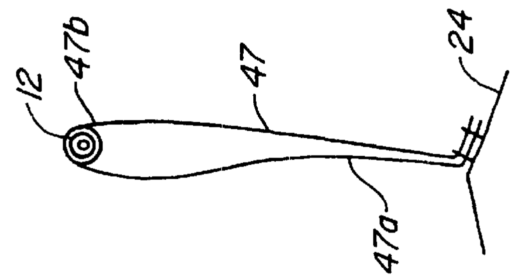


FIG. 7B.

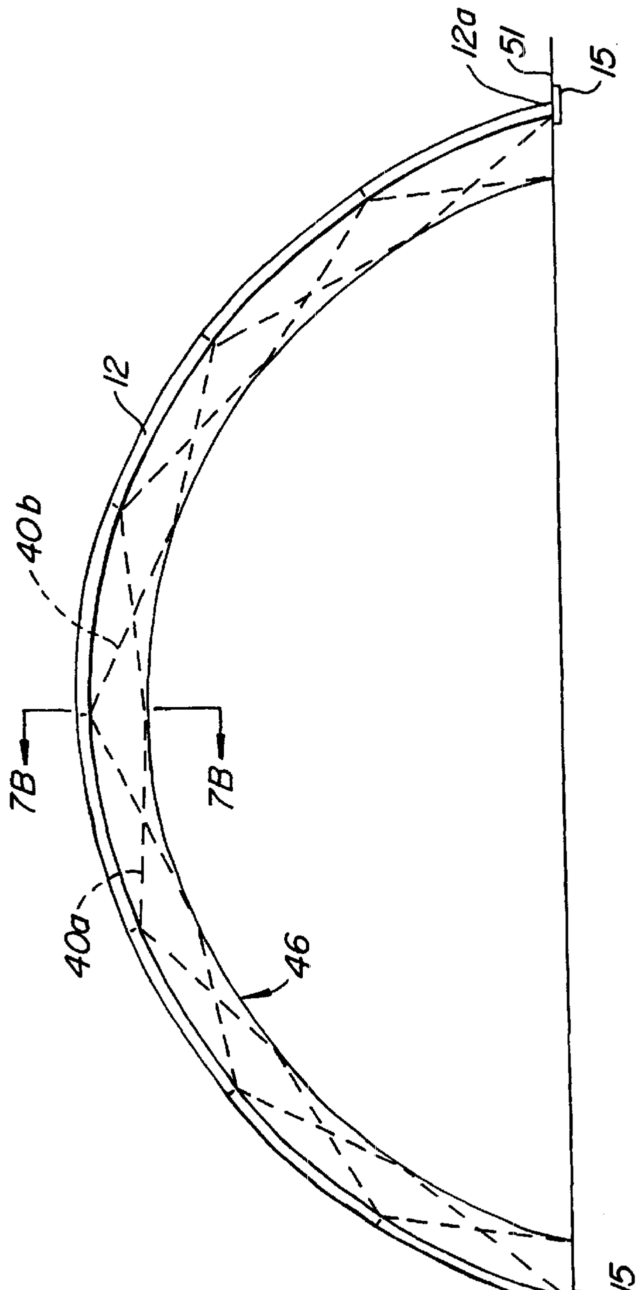
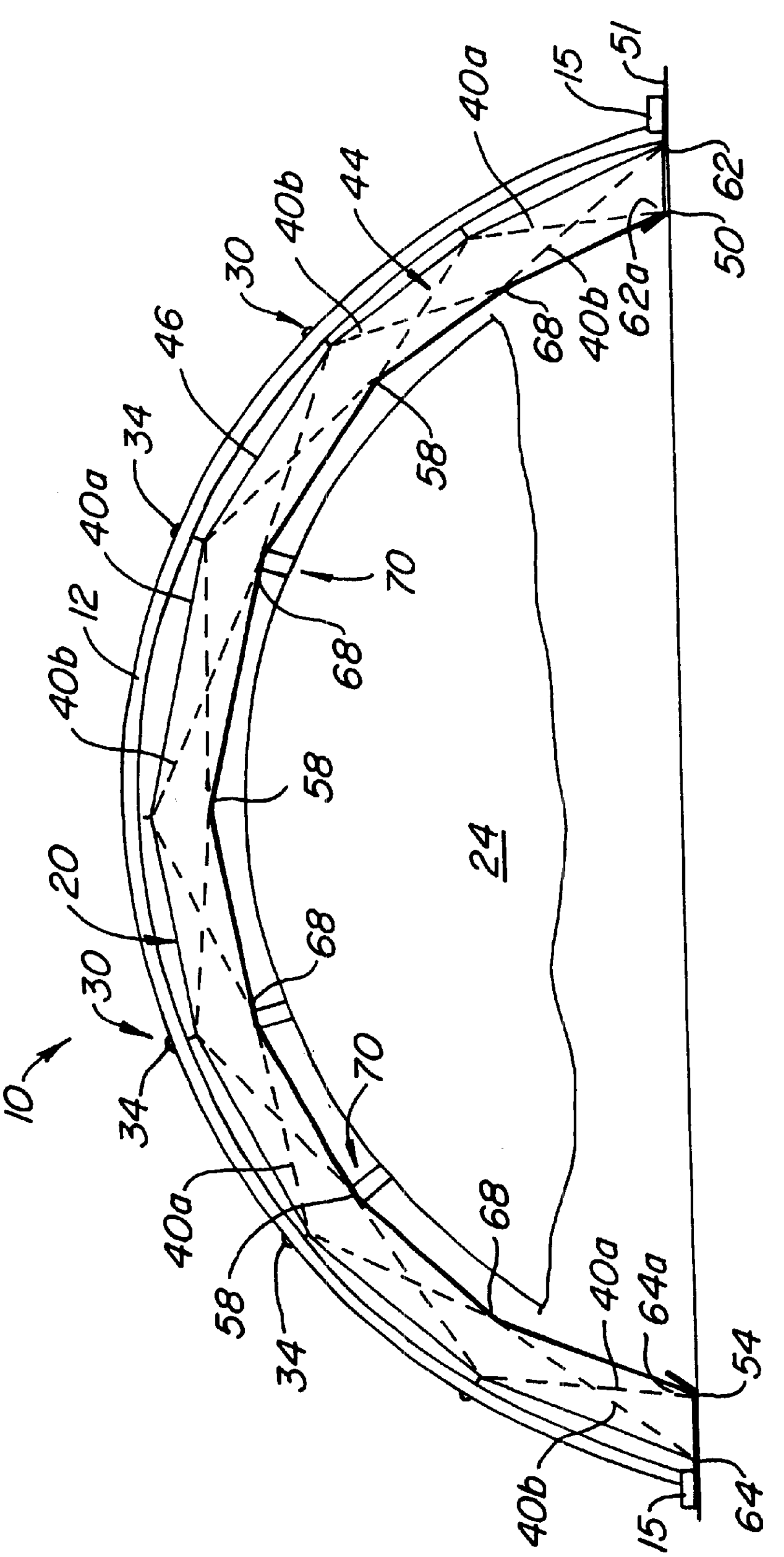


FIG. 7A.



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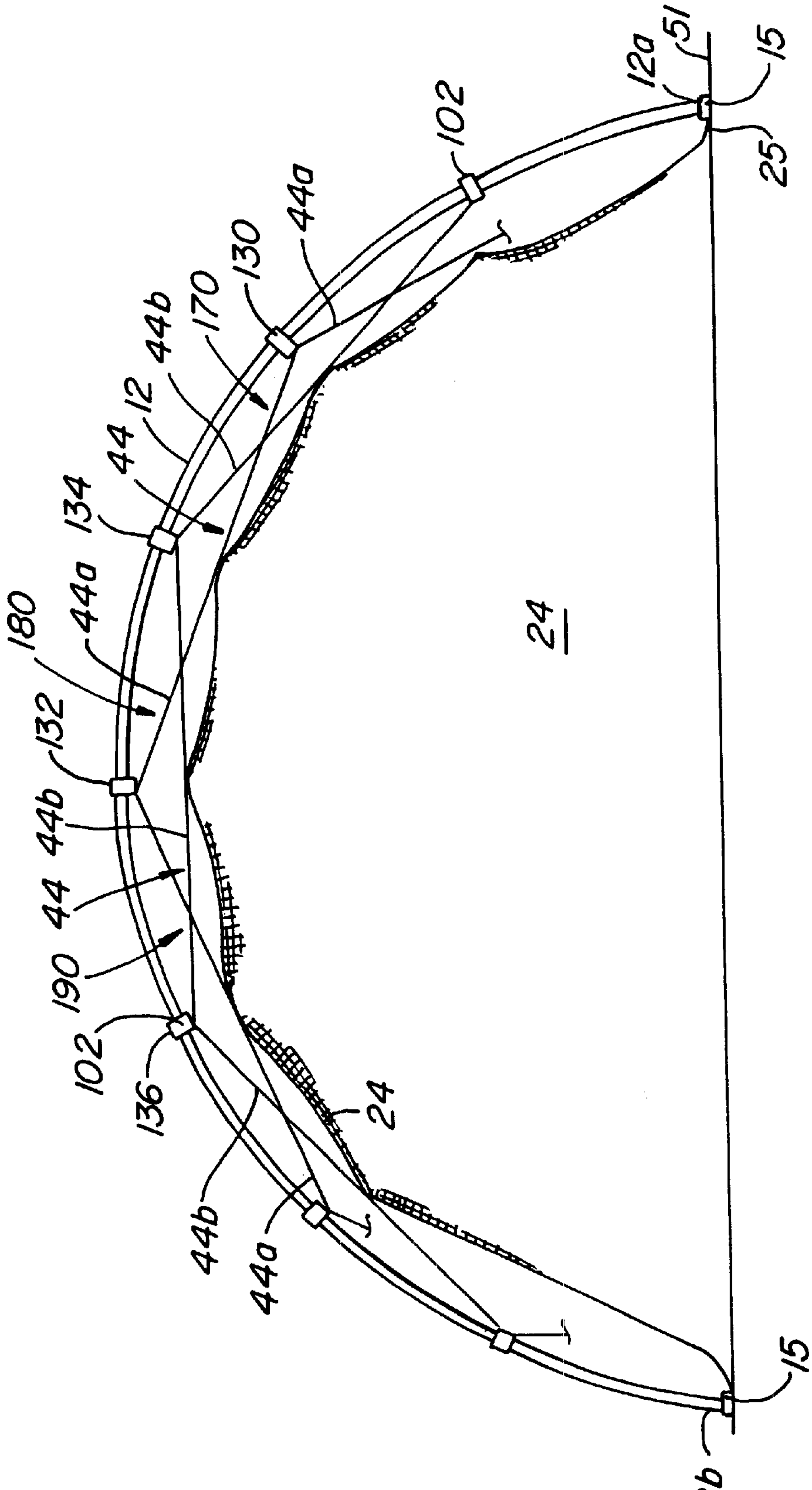
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FIG. 9A.

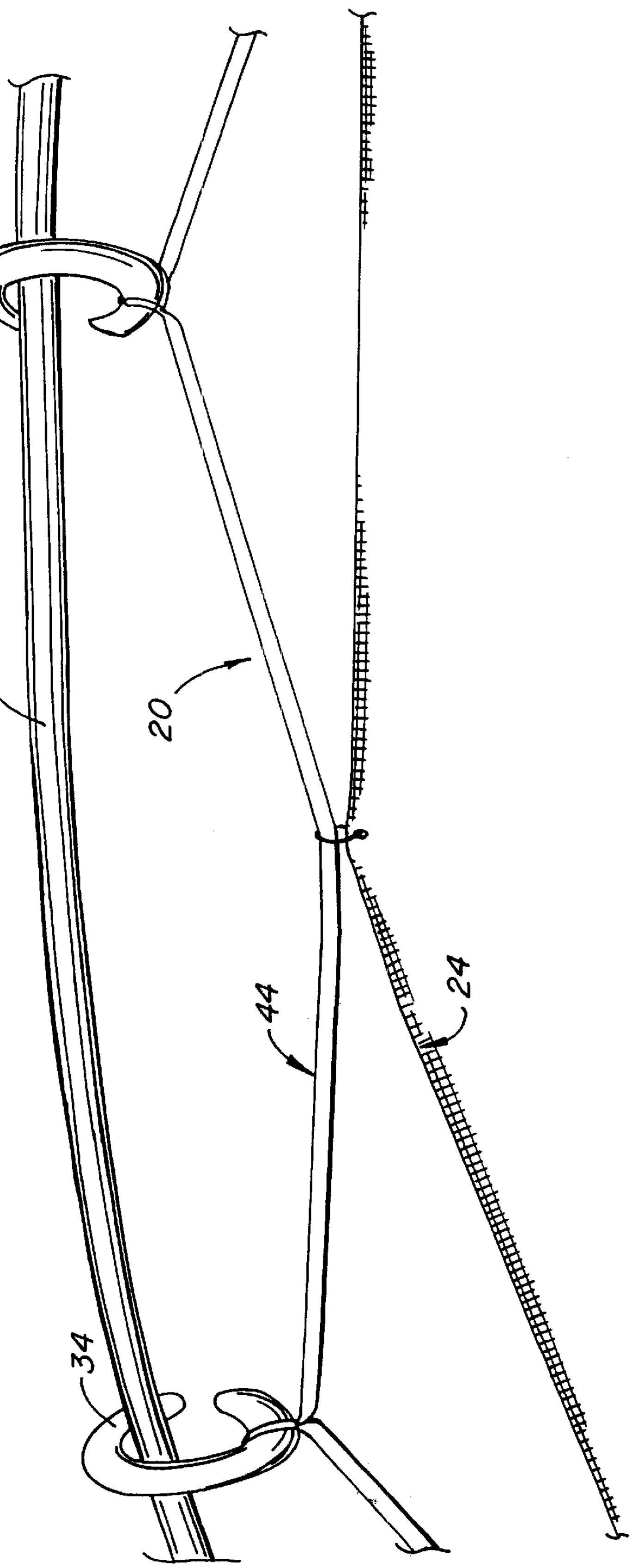


FIG. 9B.

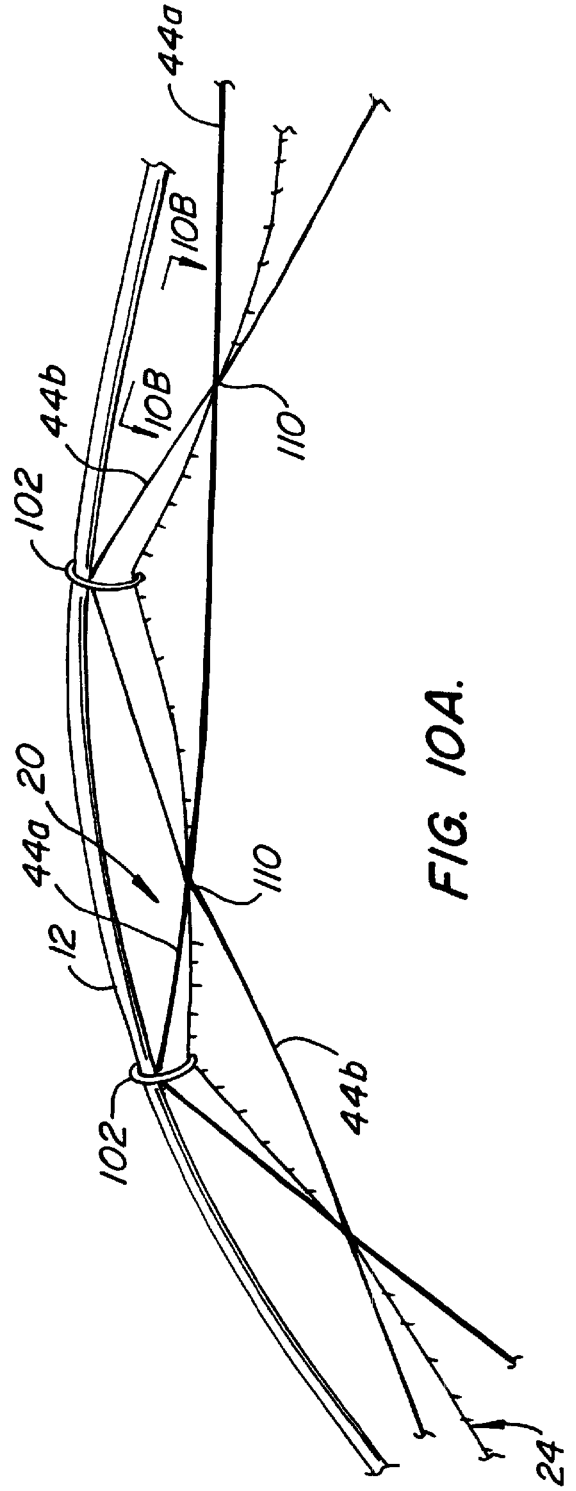


FIG. 10A.

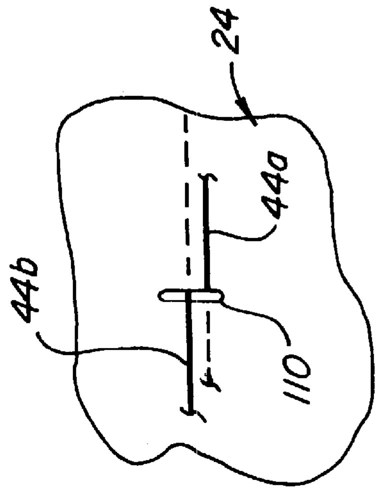


FIG. 10B.

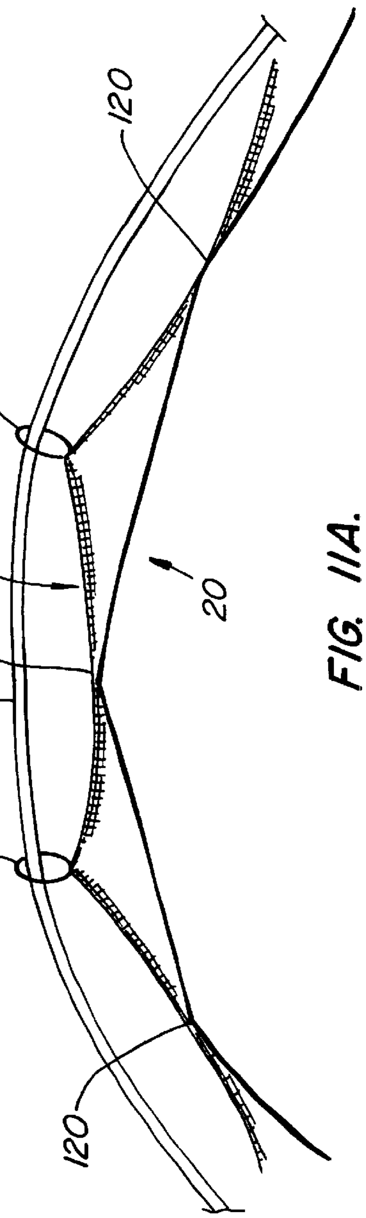


FIG. 11A.

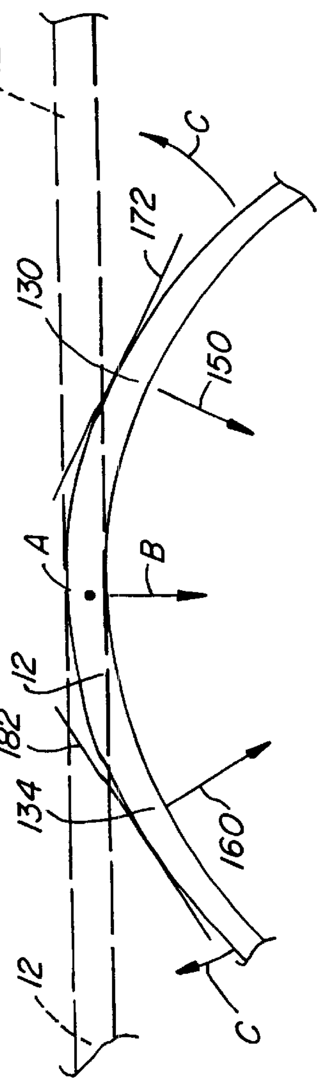


FIG. 12.

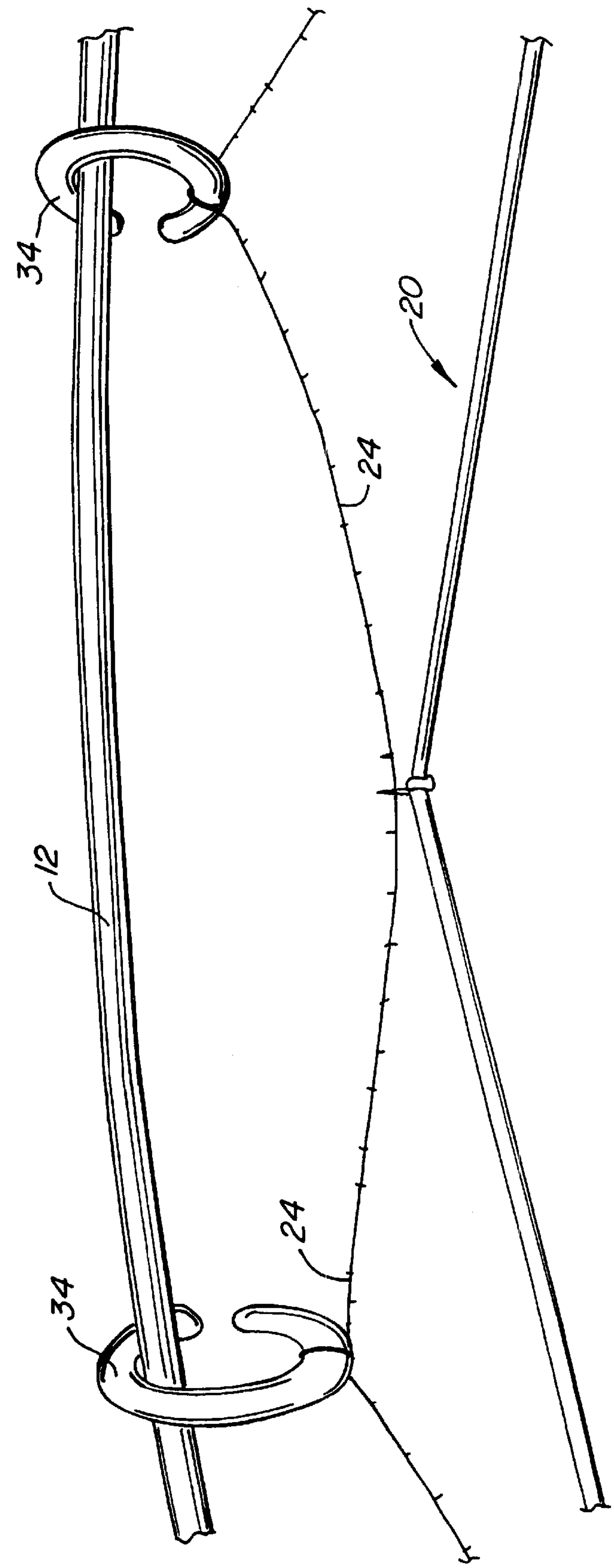


FIG. 11B.

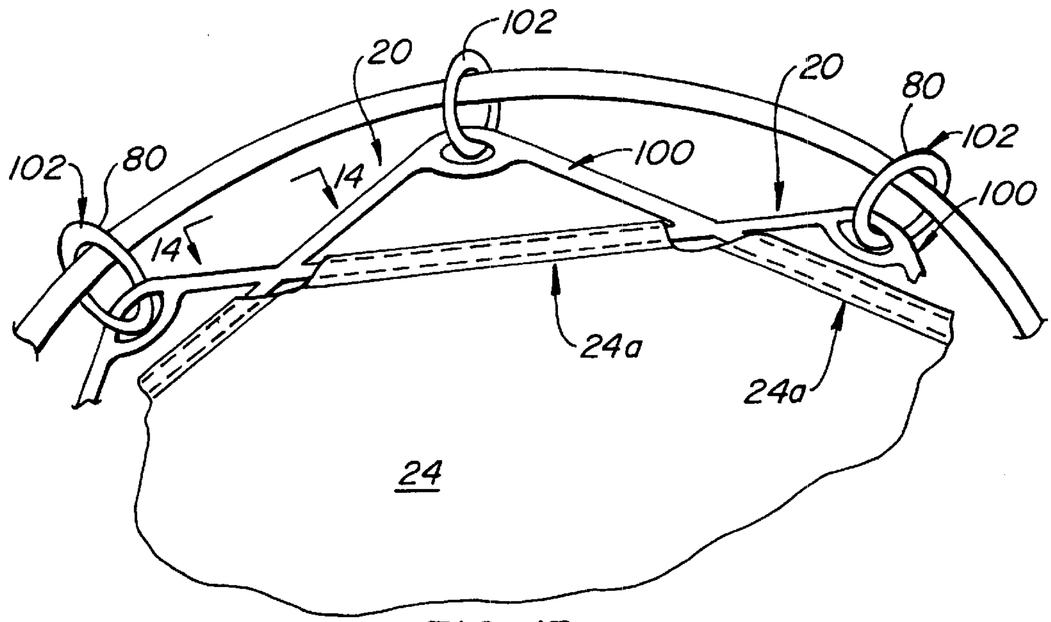
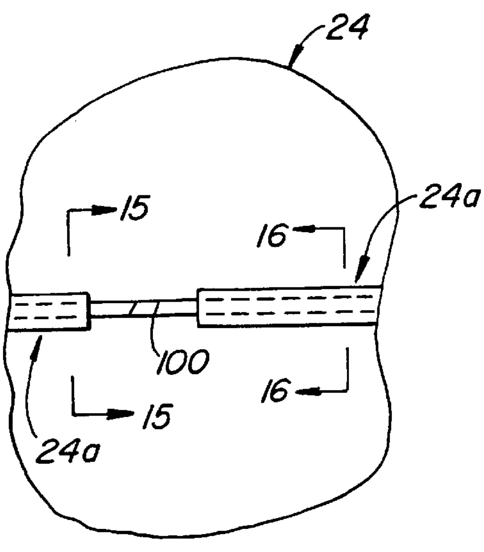


FIG. 13.



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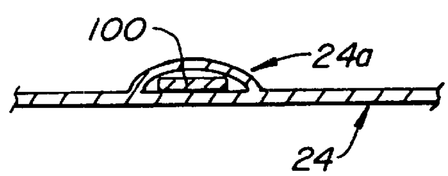

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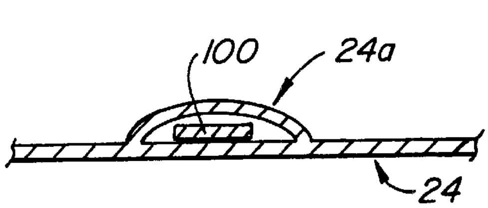


FIG. 16.

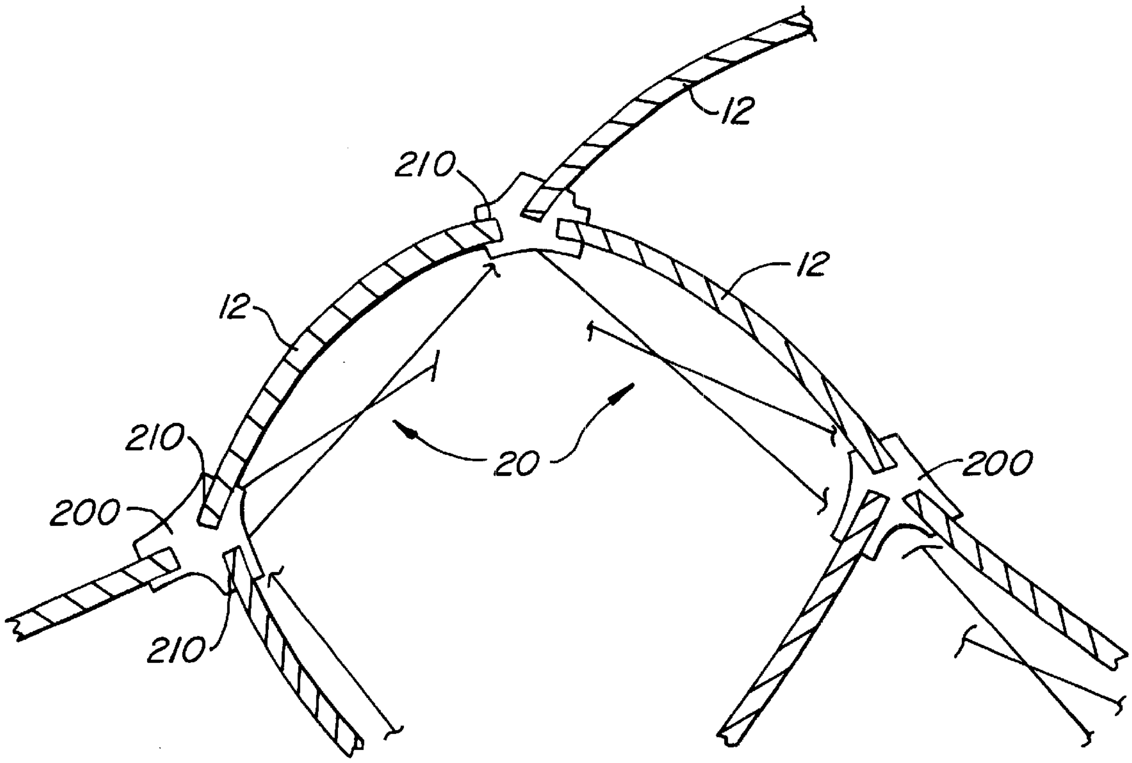


FIG. 17.

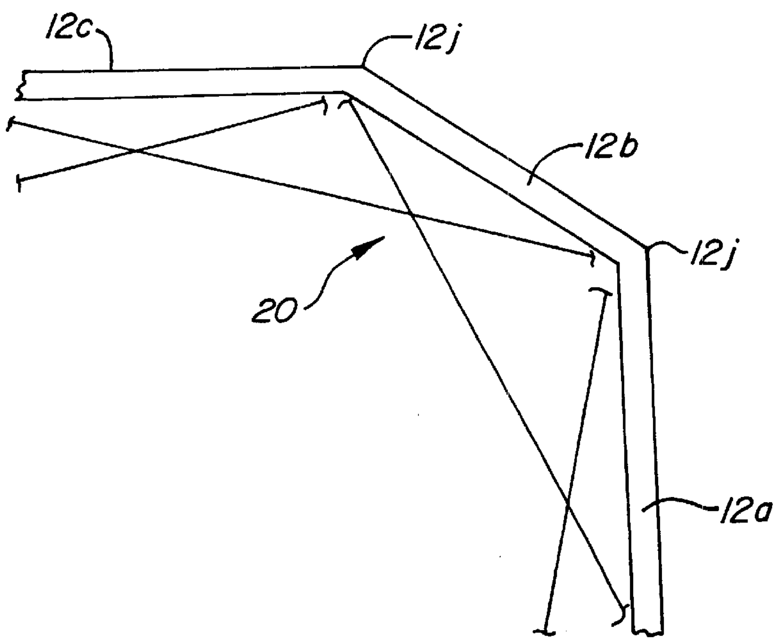


FIG. 18.

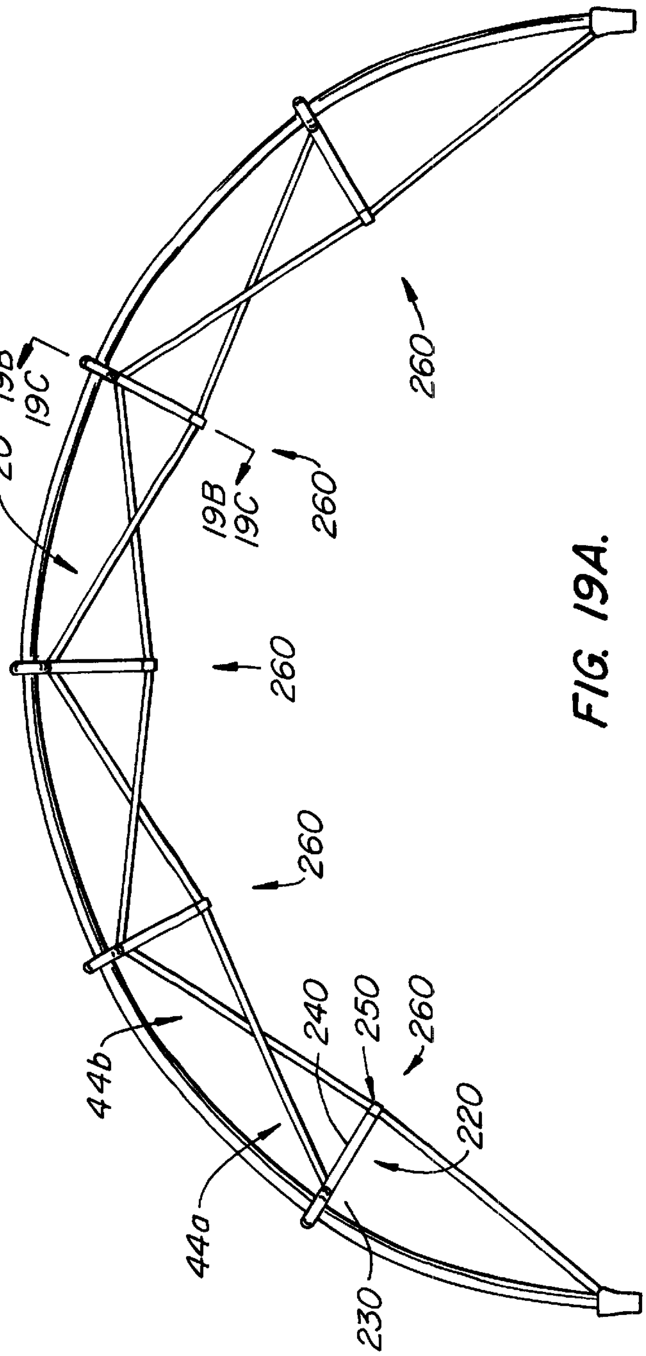


FIG. 19A.

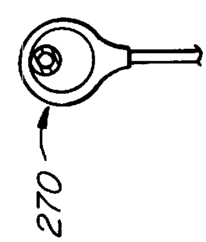


FIG. 19B.

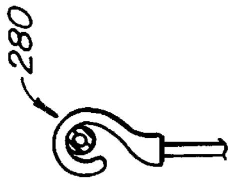


FIG. 19C.

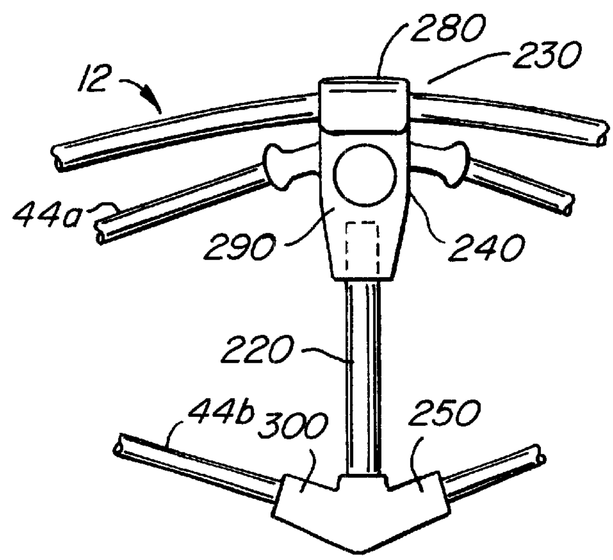


FIG. 20A.

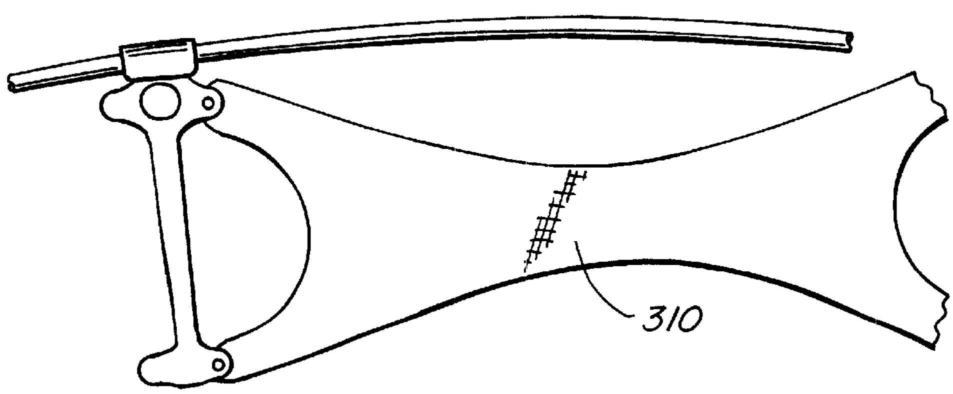
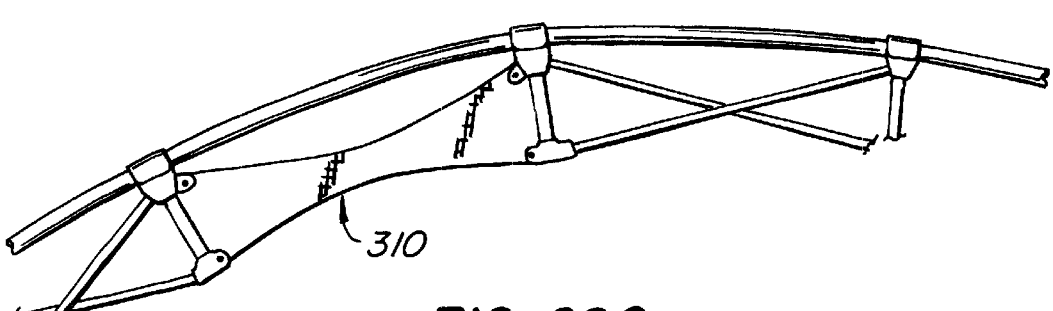


FIG. 20B.



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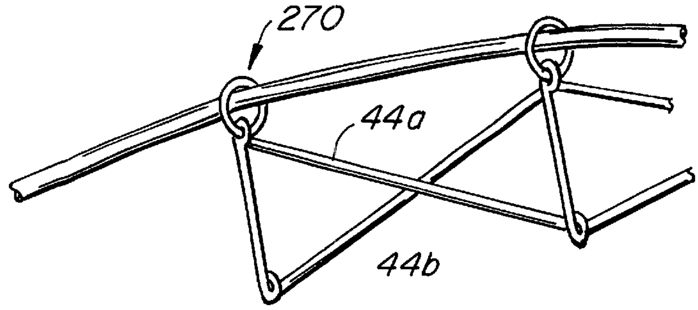

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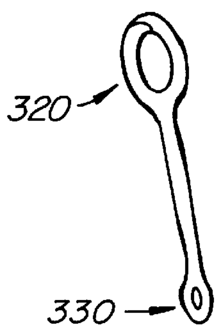

FIG. 20E.

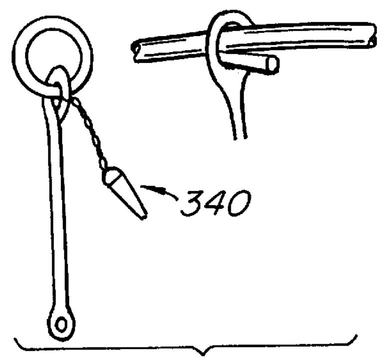

FIG. 20F.

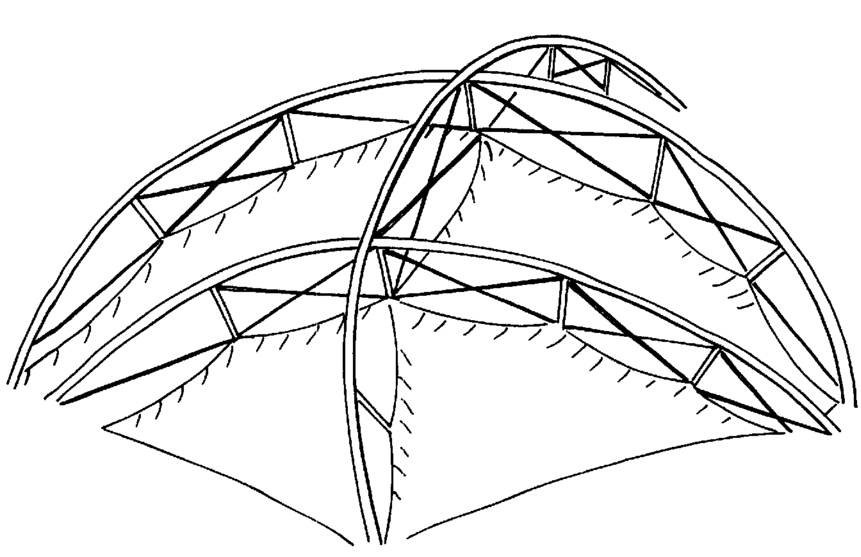

FIG. 21A.

FLEXIBLE STRUCTURE AND METHOD

RELATED APPLICATION(S)

This is a continuation-in-part of application Ser. No. 09/079,246 filed May 14, 1998 now U.S. Pat. No. 6,145,527.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to flexible structures having a broad range of utility. More specifically, the present invention relates to a flexible structure, which may find application as a tent or shelter, among other things, being of a type having at least one pole or rod maintained under tension in a selected shape, and a flexible member associated therewith, the structure exhibiting improved strength and rigidity in response to external loading forces, such as wind, rain, etc.

2. Description of the Prior Art

Convex multi-poled tent structures are described in U.S. Pat. Nos. 3,986,519, 4,099,533, 4,265,260, and 4,414,993, all of which are commonly assigned to the assignee of the present invention, and all of which are incorporated herein by reference as if repeated verbatim. U.S. Pat. Nos. 3,986,519 and 4,099,533 both disclose dome-like structures composed of a plurality of pole or rod elements maintained under tension in a generally arcuate shape, and an underlying membrane. Each structure includes at least two intersecting sets of such pole or rod elements. The rod or pole elements are held in fixed relationship at intersections by fittings secured to the underlying flexible membrane or sheath. The underlying membrane or sheath acts as a tension member to maintain the poles under tension. This structure, which employs the underlying membrane to tension the poles, lacks the added rigidity and strength of the structure of the present invention, which employs tension elements.

U.S. Pat. Nos. 4,265,260 and 4,414,993 disclose a flexible vault structure which similarly includes a plurality of deformable resilient poles that are held under tension in generally arcuate shape by an underlying fabric member. U.S. Pat. No. 4,265,260 discloses the use of fabric sleeves in addition to fittings for coupling the poles to the underlying fabric member. This structure similarly lacks the added rigidity and strength of the structure of the present invention, which includes additional tension elements.

Some multi-poled tent structures in the past have used internal guylines or similar structures located inside the enclosed space defined by the membrane in an effort to impart additional rigidity and strength to the structure. The guylines have generally extended between poles that define the structure and have consisted at most of two intersecting lines. Thus not only have the guylines failed to impart additional strength and rigidity to each pole, they have also interfered with the use of the enclosed space.

What is needed therefor and what has been invented is a flexible structure that exhibits improved rigidity and strength over prior art structures, and that overcomes the foregoing deficiencies associated with the prior art. More particularly, what is needed and what has been invented is a flexible structure comprising at least one deformable resilient pole with a tension web assembly coupled thereto in order to maintain the pole in a selected, e.g., a generally arcuate, shape under tension. The tension web assembly maintains the pole in its desired shape under tension and provides improved rigidity and strength when the structure is subjected to external load forces such as snow, wind, rain, etc. An underlying membrane may be coupled to the tension web

assembly to provide a highly stable, rigid, and strong shelter structure, for example a tent.

Also provided is a method for making such a structure, including a method for maintaining one or more of a plurality of deformable resilient poles in a selected, e.g. generally arcuate, shape under tension such that the structure exhibits improved strength and rigidity in response to external forces.

SUMMARY OF THE INVENTION

The present invention broadly accomplishes the desired objects by providing a flexible structure comprising at least one deformable resilient pole, and at least one tension web assembly having one or more strut members and coupled to the pole to maintain it under tension in a selected, e.g., generally arcuate, shape. Preferably, the web assembly extends from a first point on the pole to a second point on the pole. More preferably, the distance from the first point to the second point is more than about 50% of the length of a tensioned, arcuately-shaped pole. Even more preferably, at least one web assembly generally extends from one end of the pole to another end of the pole.

Preferably, the flexible structure includes a plurality of tensioned generally arcuately-shaped poles and a plurality of tension webs coupled to the poles by means of hooks, sleeves or other means, such that each pole has at least one tension web associated therewith. The poles may, but not need be, arranged in a crossing pattern having a plurality of intersections, depending on the desired shape of the structure. The web assembly preferably comprises a relatively rigid material, e.g., a material comprising a plurality of tensile fibers oriented to resist undesired deformation of the poles, when subjected to external load forces.

A flexible member may be coupled to and supported by the web assembly to define a sheltered space. The flexible member is preferably a flexible membrane, such as tent fabric.

BRIEF DESCRIPTION OF THE DRAWINGS

Exemplary embodiments of the present invention summarized above are shown in the accompanying drawings wherein:

FIG. **1** is a perspective view illustrating one presently preferred embodiment of a flexible structure comprising a plurality of deformable resilient pole elements held under tension in a generally arcuate configuration by a first preferred form of tension web assembly coupled thereto;

FIG. **2** is a partial side elevational view illustrating another presently preferred embodiment comprising at least one deformable resilient pole element maintained under tension in a selected shape by a second preferred form of tension web assembly, which is coupled thereto and to a flexible membrane, to define a sheltered space;

FIG. **3** is a partial side elevational view illustrating yet another presently preferred embodiment of a flexible structure, similar to that of FIG. **2**, comprising another preferred form of tension web assembly coupled to a deformable resilient pole to maintain the pole under tension in a selected shape, and coupled to a flexible member to define a sheltered space;

FIG. **4** is an enlarged perspective view of a preferred form of ring member shown in FIG. **3** for coupling a tension web assembly to a deformable resilient pole and to an underlying flexible member;

FIG. **5A** is a vertical sectional view taken in the direction of the arrows and along the plane of line **5A—5A** in FIG. **4**;

FIG. 5B is a vertical sectional view taken in the direction of the arrows and along the plane of line 5B—5B in FIG. 4;

FIG. 6A is a top plan view illustrating a presently preferred embodiment of a portion of a fibrous band for forming a tension web assembly;

FIG. 6B is an enlarged vertical sectional view taken in the direction of the arrows and along the plane of line 6B—6B in FIG. 6A., Illustrating the orientation of a plurality of tensile fibers within the band;

FIG. 6C is a front elevational view illustrating another presently preferred embodiment comprising at least one deformable resilient pole maintained in a generally arcuate shape under tension by another preferred form of tension web assembly defined by a plurality of geometrically interconnected bands extending substantially from one end of the pole to another;

FIG. 6D is an enlarged vertical sectional view taken in the direction of the arrows and along the plane of line 6D—6D in FIG. 6C;

FIG. 6E is a top plan view of another preferred embodiment of a band suitable for forming a tension web assembly;

FIG. 6F is an enlarged vertical sectional view taken in the direction of the arrows and along the plane of line 6F—6F in FIG. 6E;

FIG. 7A is a front elevational view of a flexible structure comprising yet another presently preferred embodiment wherein at least one deformable resilient pole element is disposed within a sleeve and is maintained in a generally arcuate shape under tension by another presently preferred form of tension web assembly coupled thereto;

FIG. 7B is a vertical sectional view taken in the direction of the arrows and along the plane of line 7B—7B in FIG. 7A;

FIG. 8 is a front elevational view of a flexible structure comprising yet another presently preferred embodiment, wherein at least one deformable resilient pole element is maintained in a generally arcuate shape under tension by yet another preferred form of tension web assembly, comprising a low stretch, sheet-like web coupled to the pole at regular intervals, and coupled to an underlying flexible member to define a sheltered space;

FIG. 9A is a front elevational view of a flexible structure comprising yet another presently preferred embodiment, wherein at least one deformable resilient pole element is maintained in a generally arcuate shape under tension by a tension web assembly comprising a plurality of tension members (i.e., cords, wires, or the like) each coupled to the pole at a plurality of locations, and further coupled to an underlying flexible member to define a sheltered space;

FIG. 9B is a partial side elevational view of a flexible structure comprising yet another presently preferred embodiment, wherein at least one deformable resilient pole element is maintained in a generally arcuate shape under tension by a tension web assembly comprising a low stretch element coupled to the pole by hooks and a low stretch member integrally formed with an underlying flexible member defining a sheltered space;

FIG. 10A is a partial side elevational view of a flexible structure comprising yet another presently preferred embodiment, wherein at least one deformable resilient pole element is maintained in a generally arcuate shape under tension by yet another presently preferred form of tension web assembly, which passes through openings in and supports an underlying flexible member defining a sheltered space.

FIG. 10B is a horizontal view taken in direction of the arrows and along the plane of line 10B—10B in FIG. 10A;

FIG. 11A is a partial side elevational view of a flexible structure comprising yet another presently preferred embodiment, wherein at least one deformable resilient pole element is maintained in a generally arcuate shape under tension by another preferred form of tension web assembly comprising a low stretch element formed within an underlying flexible member that defines a sheltered space, and a low stretch member integrally formed with the flexible member.

FIG. 11B is an enlarged partial side elevational view of the embodiment depicted in FIG. 11A;

FIG. 12 is a schematic view illustrating a deformable resilient pole of the type used in the present invention maintained in a generally arcuate shape under tension, and showing the tension forces thereon in relation to potential coupling points of a tension web assembly of the invention;

FIG. 13 is a partial side elevational view of a flexible structure comprising yet another presently preferred embodiment, wherein at least one deformable resilient pole element is maintained in a generally arcuate shape under tension by yet another presently preferred form of tension web assembly, comprising a plurality of tension cords coupled to the pole via rings and to an underlying flexible member that defines a sheltered space by passing through peripheral seam pockets therein;

FIG. 14 is a horizontal view taken in the direction of the arrows and along the plane of line 14—14 in FIG. 13;

FIG. 15 is a vertical sectional view taken in the direction of the arrows and along the plane of line 15—15 in FIG. 14;

FIG. 16 is a vertical sectional view taken in the direction of the arrows and along the plane of line 16—16 in FIG. 14;

FIG. 17 is a perspective view of a flexible structure comprising yet another presently preferred embodiment, wherein a plurality of deformable resilient pole segments coupled to each other through hubs are maintained in respective selected shapes under tension by another presently preferred form of tension web assembly, partially shown, which is engaged to and between respective hubs;

FIG. 18 is a partial side elevational view of a flexible structure comprising still another preferred embodiment, wherein a plurality of deformable resilient pole segments are integrally coupled to each other at angular junctions to define pole elements, wherein the pole segments are angularly disposed with respect to each other, and further wherein another preferred form of tension web assembly, which is partially shown, engages the pole segments in relation to the angular junctions to maintain the poles in selected shapes under tension;

FIG. 19A is a front elevational view illustrating another presently preferred embodiment, wherein the web assembly includes a plurality of strut members;

FIG. 19B is a vertical sectional view taken in the direction of the arrows and along the plane of line 19B—19B in FIG. 19A;

FIG. 19C is a vertical sectional view taken in the direction of the arrows and along the plane of line 19C—19C in FIG. 19A;

FIG. 20A is an enlarged elevational view of a preferred form of strut member with a preferred form of tension web as shown in FIG. 19A;

FIG. 20B is an enlarged elevational view of a preferred form of strut member as shown in FIG. 19A, with another preferred form of tension web shown;

FIG. **20**C is an enlarged elevational view illustrating another presently preferred embodiment of a tension web with strut members and employing alternating types of tension members;

FIG. **20**D is an enlarged elevational view depicting a preferred form of strut member;

FIG. **20**E is an enlarged elevational view of another preferred form of strut member;

FIG. **20**F is an enlarged elevational view of yet another preferred form of strut member; and

FIG. **21**A is a perspective view showing another presently preferred embodiment of a flexible structure similar to that depicted in FIG. **1** wherein the tension web assembly incorporates a plurality of strut members.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Presently preferred embodiments of the invention will now be described in detail with reference to the drawings, wherein similar parts are identified by like reference numerals.

The invention is preferably embodied in a flexible structure, generally illustrated as **10**. The flexible structure **10** of the present invention may be used for any suitable purpose, such as a shelter, storage space, dwelling, tent, kite, or the like. A particularly useful application is as a tent and the structures described herein may be referred to from time to time as tents. However, such references are merely exemplary and are not intended to be limiting.

Depending upon the desired shape, volume and usage of the flexible structure **10**, the structure may include one or more pole or rod elements **12**. For example, an elongated "hoop" style tent structure can be fabricated using a single pole element **12**. Alternatively, more complex "dome" type structures will generally employ a plurality of pole elements **12**. In its broadest aspect, the scope of the present invention is not dependent on the number of pole elements **12** employed. Thus, the flexible structure **10** may include a plurality of pole elements **12**, which may be arranged in any suitable fashion, such as to produce a "vault" shaped or a generally dome-shaped structure, as shown in FIG. **1**. Each of the poles **12** is elongated and has termini or terminal ends **12***a* and **12***b*. The poles may be continuous or may be formed in segments. For example, each pole may have multiple segments with cooperating fittings and be held together by well known shock cord techniques.

The poles **12** may be arranged in a variety of configurations. The terminal ends **12***a* and **12***b* of the tensioned poles **12** will generally terminate in a common plane and may be distributed around the common plane if desired to produce a plurality of pole crossings as best shown in FIG. **1**. The terminal ends **12***a* and **12***b* (see FIGS. **7** and **8**) may be supported by a pad **15**, or the like, to prevent the terminal ends **12***a* and **12***b* from entering a support base or ground **51** when the flexible structure **10** is functioning as a dwelling, such as a tent. When the plurality of poles **12** are arranged to produce the generally dome-shaped structure of FIG. **1**, the poles **12** may be disposed in a crossing fashion at a plurality of intersections **16**. Alternatively, as shown in FIG. **17**, a plurality of tensioned poles **12** may be intercoupled through hubs **200**. Each such hub **200** preferably includes openings **210** for receiving ends of two or more tensioned poles **12**, depending on the desired shape of the structure. Also alternatively, as shown in FIG. **18** a plurality of pole segments **12***a*, **12***b*, **12***c*, etc. may be integrally bound or coupled to each other at angular junctions **12***j* to produce a quasi-arcuately-shaped pole **12** wherein the pole segments **12***a*, **12***b*, **12***c*, etc. are angularly disposed with respect to each other.

The flexible pole elements **12** may be any of the well known pole types typically used in known tent structures. These include single and multi-piece poles made of aluminum, fiberglass, graphite, or other suitable materials which are deformable and resilient.

A key aspect of the flexible structure **10** of the present invention is the provision of a tension web assembly **20**. The tension web assembly **20** may take various forms as will be described in detail hereinafter. The tension web assembly **20** is preferably coupled to one or more pole elements **12** by any of a variety of means, as will also be described in detail hereinafter. The tension web assembly **20** preferably functions to maintain a pole element or elements to which it is coupled in a selected shape under tension. For example, as shown in FIG. **1**, tension web **20** is coupled to pole elements **12** and maintains them under tension in a generally arcuate shape. Of course, those skilled in the art will realize that other pole shapes are also possible, depending upon the material and lengths of the poles, the relative length of the tension web, and other factors. For example, various arcuate configurations having different radiis are possible. Other configurations, for example as shown in FIGS. **2**–**4**, **17**, and **18** are also possible.

Depending on the desired use of the flexible structure **10**, the tension web **20** may have secured or coupled thereto a flexible member **24**, which may be conventional flexible tent material for example, as shown in FIGS. **1**–**4**, **8**, **9**A, **9**B, **10**A, **11**A, **11**B, **13** and **20**. Alternatively or additionally, although not shown, a covering could be placed over the structure. The flexible member **24** may be secured or coupled to the tension web **20** in numerous different ways, some of which are described in further detail hereinafter. The flexible member **24** will preferably define a sheltered space for any desired use. "Sheltered" as used herein does not necessarily mean the space must be completely enclosed or even that it must provide complete shelter from external elements. However, the sheltered space should at least be usable for the intended purpose of the structure.

The flexible member **24** includes marginal edges **25** (see FIG. **1**) that typically will be co-planar with the terminal ends **12***a* and **12***b* of poles **12**. The flexible member **24** may or may not include an integral portion or be coupled to a portion in the plane of the poles, e.g., the floor plane. The flexible member **24** may be any suitable membrane, skin, film, fabric or the like, such as a plastic sheet material of polyethylene, polypropylene, vinyl and the like, or a woven fabric such as cotton, nylon, or polyester, or any other material, including a material having the characteristics of being stretchable in multiple directions. When the flexible structure **10** is functioning as a tent, the flexible member **24** will preferably be a suitable tent fabric.

Because of its unique construction, wherein a tension web **20** maintains the pole elements **12** under tension in a selected shape, the flexible structure **10** of the present invention exhibits improved strength and rigidity compared to prior flexible structures wherein the flexible membrane **24** itself was wholly or substantially responsible for tensioning the pole elements.

Thus, attention is now turned to a more detailed description of the unique tension web assembly **20** of the invention. The tension web assembly **20** may be embodied in numerous alternate configurations to provide tensioning of the poles and to impart strength and rigidity to the structure. A number of presently preferred embodiments are identified and described herein below.

As best shown in FIG. **1**, each portion of web assembly **20** is preferably aligned with an associated pole **12** and extends from one end (e.g., terminal end **12***a*) of its associated pole **12** to the other (e.g., terminal end **12***b*) While FIG. **1** depicts a portion of the web assembly **20** extending substantially from one end of the pole **12** to the other end of the pole, the spirit and scope of the present invention also includes a tension web assembly **20** extending over less than about 50%, or over more than about 50%, of the value of the entire length extending along and/or spanning the arcuate length of the tensioned pole. In multi-pole configurations, each pole **12** preferably has a portion of the web assembly **20** associated therewith. However, there may be configurations where sufficient strength and rigidity are achieved by coupling the tension web to less than all of the poles, for example to selected poles only.

In preferred embodiments depicted in FIGS. **2** and **8**, the tension web assembly includes at least one hook assembly, generally illustrated as **30**, and preferably a plurality of hook assemblies **30** for coupling the tension web to the tensioned pole **12** at a plurality of spaced locations. In the embodiment of the invention illustrated in FIG. **8**, each hook assembly **30** includes a hook **34** for engagement to the tensioned pole **12**. The hook assembly couples the tension web assembly **20** to the pole **12** and communicates the tension force of the tension web to the pole. In the particular embodiment of FIG. **8**, the tension web comprises one or more contiguous tension members **46** and the hooks attach to an upper edge of **46**, which may be a low stretch plastic or fabric material. In this embodiment the tension vectors that result from coupling the tension member **46** to the pole extend generally along dotted lines **40***a* and **40***b*. Preferably the tension member **46** will be secured to the ground or other fixed surface at opposite ends by stakes **50** and **54** or other suitable means. The width of the tension member **46** will depend on a variety of parameters including the materials selected for the web member and the poles, the degree of rigidity and strength desired, and possibly the size of the sheltered space to be defined by underlying membrane **24**. Alternatively, the tension web may comprise a pair of tension members **44**, such as cords, ropes, or the like, as shown in FIG. **2**, which are identified individually as **44***a* and **44***b*. If separate tension members **44***a* and **44***b* are employed, they may be contained within a tension sleeve (not shown). In the embodiment of FIG. **2**, they are exposed. If separate tension members **44** are employed in the embodiment of FIG. **8**, one tension member preferably extends under tension in a direction generally along dotted line **40***a* from a point **62***a* near one distal end of the pole element **12**, where it is affixed or bound to the sleeve or alternatively to the ground **51**, to a diametrically opposed point **64***a* near the opposite distal end of the pole element **12**, where it is also affixed or bound to the sleeve or to the ground **51**. In extending from point **62***a* to **64***a*, the tension member preferably connects to every other hook **34**. Between points of connection to alternating hooks **34**, the tension member preferably attaches to a sleeve at intermediate points **58**.

The second tension member preferably extends in a manner similar to the first tension member. More specifically, the second tension member extends under tension in a direction generally along dotted line **40***b* from point **62** near one distal end of pole element **12** where it is affixed or bound to a sleeve or to ground **51**, to a point **64** which is diametrically opposed to point **62** near the opposite distal end of pole element **12**, where it is likewise connected to either a sleeve or ground **51**. In extending from point **62** to point **64**, the second tension member preferably connects to every other hook **34** in an alternating arrangement with the first tension member. Between points of connection to alternating hooks, the second tension member preferably connects to a sleeve at intermediate points **68**. As thus arranged, the first and second tension members preferably criss-cross each other between any pair of hooks **34**, just as tension vectors would in the case of a contiguous tension member, thus producing a tension web which maintains pole element **12** in a generally arcuate shape under tension.

In the embodiment of the invention illustrated in FIG. **2**, the tension members **44***a* and **44***b* are similarly preferably arranged in a criss-crossing arrangement and engage alternating hooks **34** coupled to the tensioned pole element **12**. In this particular embodiment, the respective hooks **34** in turn engage connecting members or loops **74**. The tension members **44***a* and **44***b* engage the lower parts of alternating hooks **34** and the lower parts of alternating loops **74**, for example at points **76** and **78**.

It will be apparent to those skilled in the art that while two tension members **44***a* and **44***b* are shown in the exemplary embodiment of FIG. **2**, a single member or more than two members could be used. It will also be apparent that while tension members **44***a* and **44***b* are shown extending substantially from one distal end of pole element **12** to the opposite distal end, one or both members could extend a shorter distance, depending on the desired shape and application, among other things. Additionally, it will be apparent that tension vectors in a contiguous tension member as illustrated in FIG. **8** will provide substantially similar functionality as individual tension members.

In the preferred embodiments shown in FIGS. **2** and **8**, a flexible member **24** may be attached underlying the tension web assembly, if desired, to define a sheltered space. In particular, in the embodiment of FIG. **2**, the flexible member **24** may suitably be attached at a plurality of points **76**, **78**, etc., for example by sewing to the bottom of loops **74**. As shown, a miniature sleeve or loop may be formed thereby for tension member **44***a* or **44***b* to pass through. In the embodiment of FIG. **8**, the flexible member **24** may be attached to tension web **20** by any suitable means including suitable connector straps **70**. Alternatively, the tension web **20** could be connected directly to the flexible member **24**, for example via a stitched seam, or may even be formed integrally therewith.

It will be apparent to those skilled in the art that flexible structure **10**, for example in the form shown in FIGS. **2** and **8**, may or may not include flexible member **24**. Flexible member **24** may be omitted if desired for a particular application because it is not necessary in order to maintain the pole elements **12** under tension as in prior flexible structures. Thus, the exposed pole structure may stand alone, for example as shown in FIG. **1**, or alternatively a suitable covering may be placed over the top of the pole structure.

Referring now to FIGS. **3**–**5**B, another presently preferred embodiment of the tension web assembly **20** will be described. This embodiment is similar to the embodiment of FIG. **2** in that it also employs exposed, criss-crossing tension members **44***a* and **44***b*. However, in place of hooks **34**, rings **80** are employed to couple the tension web to pole element **12** and to optional flexible member **24**. As best shown in FIG. **3**, a plurality of rings **80** are slidably disposed on pole element **12**. Each ring **80** preferably has a lower ring **84** associated therewith for engaging a loop **74** as shown in detail in FIGS. **4** and **5***a*. Each loop **74** is preferably either coupled to or formed with a sleeve **88**. In this embodiment of the invention, tension members **44***a* and **44***b* alternately pass through the upper part of rings **80** and the lower part of loop **74** through sleeves **88**, as best shown in FIGS. **3**, **4** and **5**B. Alternatively, tension members **44***a* or **44***b* could pass through separate holes in the lower portions of rings **80** or even through the same openings as lower rings **84**. This may provide improved structural stability in some configurations. If desired, hooks, knots, or other mechanisms may be used as shown in FIGS. **4** and **5**A, to prevent tension members **44***a* and **44***b* from sliding relative to rings **80** and sleeves **88**.

As with the exemplary embodiment of FIG. **2**, fewer or more tension members may be employed as desired. Moreover, if desired, a flexible member **24** may be coupled to the tension web assembly **20**, for example at sleeves **88**. The flexible member **24** may be coupled to the tension web assembly **20** by any suitable means including stitching or adhesive.

Note that in this particular example, pole **12** is not maintained in an arcuate shape, but is seen to have relatively sharper bends at specific locations. The present invention is not limited by any specific pole shape or configuration.

Yet another preferred embodiment of the invention is shown in FIGS. **7**A and **7**B. This embodiment is similar to the embodiment of FIG. **8** in that the tension web assembly may either define tension vectors extending generally in the direction of dotted lines **40***a* and **40***b* in a contiguous tension member **46**, or include separate crisscrossing tension members extending generally in the direction of dotted lines **40***a* and **40***b*, contained within a tension sleeve **47**. In this embodiment, when a contiguous tension member **46** is employed, the pole element **12** is preferably contained and slides freely within an upper portion of the tension member **46** rather than the tension web being coupled to the pole element **12** by hooks **34** as in FIG. **8**, or by other means, e.g., rings, as in FIG. **3**, etc. Thus in this embodiment, the tension member **46** has a sleeve **47** formed therewith, preferably at the top. The sleeve **47** may be formed in any suitable manner. For example, as shown in FIG. **7**B, the sleeve **47** may be formed by an enclosed loop of fabric or other material sewn or bonded to the top of tension member **46**. Alternatively, the sleeve may be formed integrally with the material forming the tension member **46**, for example by folding over a length of fabric extending above the tension member **46** and sewing or otherwise bonding the free end to the top of the tension member **46** along its length.

In either alternative, the material for the upper sleeve **47***b* should be selected to allow the pole element to slide freely. If separate tension members **44***a* and **44***b* are used, they may be coupled to the pole element **12** or to an upper portion **47***b* of the sleeve **47** in any suitable fashion. In one alternative, each tension member may be provided with a plurality of rings at spaced locations corresponding to desired coupling locations with pole element **12**. The rings can be extended into the upper sleeve portion **47***b* so that pole element **12** can slide through the rings freely. Another alternative is to attach the tension members **44***a* and **44***b* to an upper portion **47***b* of the sleeve **47** at selected locations by stitching, adhesive bonding or any other suitable means.

Persons skilled in the art will realize that either less or more than two tension members may be employed depending on the needs and goals of the particular design. Similarly, other pole shapes and configurations may be employed. Further, the tension web assembly may extend less than substantially all the way between the two distal ends of the tensioned pole element. Also, if desired, a flexible member **24** (not shown in FIG. **7**A) may be attached or coupled to the bottom of the tension member **46** or sleeve **47** at selected locations and by any suitable means to define a sheltered space.

FIGS. **1** and **6**A–**6**F depict yet another presently preferred embodiment of a flexible structure using a tension web assembly **20**. In this embodiment, the tension web assembly **20** comprises a plurality of tension web members **90**. Tension web members **90** may be integrally formed. Alternatively, adjacent tension web members **90** may be interconnected by stitching or other bonding to form tension web assembly **20**. The tension web **20** thus formed may be exposed as shown in FIG. **6**C, or may be enclosed in a sleeve **48** as best shown in FIG. **1**. Whether exposed or enclosed within a sleeve, the tension web assembly **20** (or the sleeve) is preferably coupled to the pole element **12** at a plurality of spaced locations associated with the locations of the tension web members **90**. Coupling may be by any suitable coupler or connector generally illustrated as **98** including rings, hooks, buckles or the like. As further best shown in FIG. **1**, the tension web assembly **20** is generally preferably aligned in a substantially co-planar relationship with associated poles **12**.

Preferably, the tension web members **90** are formed in a geometric shape or configuration selected for strength in maintaining pole elements **12** in their selected shape under tension. In the particular embodiment shown, the web members **90** are formed in a sort of triangular shape and connected end to end. Also in one particular embodiment, best shown in FIG. **6**C, each triangle is "bifurcated" by a vertical strip. While the vertical strip is not strictly necessary, it can be useful in some configurations to provide additional strength and to assist in coupling the tension web **20** to pole element **12** and to an underlying flexible member **24** (if desired). It can also be useful in interconnecting tension web members **90** in three dimensions, as shown in FIG. **1**. The tension web members **90** may be interconnected in any suitable fashion including stitched seams, studs, or rivets, adhesive bonding, or the like. In this particular embodiment, the tension web members **90** comprise interconnected tension web bands **100**. The particular thickness, width and length dimensions of the tension web bands **100** will depend on the particular pole shape and configuration, tension web assembly configuration, pole material, and desired strength and tension parameters. Preferably, each tension web member **90** is coupled to a tensioned pole element, with which it is associated, at a plurality of spaced points by connectors **102**, which may be rings, hooks, sleeves or the like, all as previously described herein, which allow the pole elements **12** to slide relative to the tension web **20**. Thus, for example, the poles **12** of FIG. **1** could be encased in pole sleeves such as shown in FIG. **7**B, and the tension web members **90** or sleeves **48** could be coupled or attached thereto. The particular placement of the connecting rings, hooks etc., will depend on the particular design of the structure **10**, but may be placed so as to couple one or more tension members **90** to one or more pole elements **12**.

Tension web bands **100** (as well as all other variations of the tension web assembly **20** described herein) are preferably formed of a low stretch, strong, high tensile strength material in order to impart strength and rigidity to the structure and to resist deformation of the poles when external forces are applied. Thus, the tension web will preferably be formed of a relatively low stretch, non-fibrous material, such as a molded or extruded plastic. Suitable materials may include polypropylene and high density polyethylene. Alternatively the tension web may be formed of a fibrous material, provided it is one with relatively high tensile strength, especially high directional tensile strength. Suitable materials may include heavy duty nylon, woven polyethylene bands, or woven kevlar or dacron. A composite or laminate material having appropriately oriented tensile strength is also suitable. Such materials may include a polyester sheath or laminate encasing woven kevlar fibers or a high density polyethylene sheath or laminate encasing woven polyethylene or polypropylene bands.

More particularly, tension web bands **100** are suitably formed of a high density, woven, laminated polyethylene material sold under the product name Tuff-Tarp by Lewis Hyrnan & Co., Inc. of Carson, California. A fibrous material suitable for the tension web bands **100** is high tensile strength dacron sold commercially by BSS Corporation of Howl & Bainbridge under the trademark BSS Performance Dacron and having product name "Blade-HT" and "Warp-Oriented."

In the particular case where the tension web is composed of a fibrous material, such as a woven material, it is preferred that the fibers **101**, as shown in FIG. **6**E, be oriented so as to resist deformation of the poles **12** when an external load/force (e.g., wind, snow, etc.) is placed either directly on the poles **12** or indirectly thereon by application to a connected flexible member **24** supported by the pole(s) **12**. Since the web bands (as well as other forms of tension members previously described) will couple to the poles at points forming geometric chords, and will thus tension the poles at least generally along the chords, it is preferred the tensile fibers be oriented such that the material exhibits maximum resistance to stretching in the direction of the chords. Standard woven nylon materials, such as nylon tent fabric, will generally not be suitable unless properly oriented because they tend to be relatively stretchy along the chords (i.e., the bias). Proper orientation of such material can be achieved for example by cutting into strips with the warp oriented generally along the geometric chord. The tensile fibers **101** when properly oriented will act to provide tensile stiffness to counteract the bending movement of the pole(s) **12** when a load/force is placed on the poles or flexible member **24**.

Referring now to FIGS. **10**A, and **10**B, still another presently preferred embodiment of the present invention is illustrated. In this embodiment, the tension web assembly **20** is seen to partly extend through a flexible member **24**, which it supports. More specifically, and as best shown in FIG. **10**A, tension members **44***a* and **44***b* are arranged in alternately criss-cross fashion as previously described. However, in this embodiment, tension members **44***a* and **44***b* also pass through openings **110** in a flexible member **24** (see FIG. **100**). Tension members **44***a* and **44***b* are coupled to pole elements **12** via connectors **102** such as previously described. In addition, connectors **102** also directly engage flexible member **24** at a plurality of spaced apart locations.

FIGS. **11**A and **11**B illustrate a further variation of the embodiment of FIGS. **10**A and **10**B. In this embodiment, a flexible member **24** is directly coupled to connectors **102** at a plurality of spaced locations. In this particular embodiment, the member **24** is preferably constructed of a material tensilely strong enough to function as part of the tension web, at least in the vicinity of the poles. For example, the member **24** could be provided with a low stretch material insert in the vicinity of the pole, or with a heavy, low stretch seam insert. To provide adequate stiffness and strength, a tension web assembly **20** is connected on the inside surface of the flexible member **24** at a plurality of spaced points **120**. Together, the upper part of the web, which is integral with the member **24**, and the lower part of the web assembly **20** possess sufficient tensile strength to maintain poles **12** in their desired shape under tension.

FIGS. **13–16**, illustrate yet another preferred embodiment wherein a tension web assembly **20** includes both an outer web and an inner web, which is formed as part of a flexible member **24**. In this embodiment, flexible member **24** is provided with seams of a low stretch, flexible tension web material **24***a*, or alternatively sleeves or pockets wherein low stretch web bands **100** are sewn-in. This comprises an inner tension web. The outer tension web comprises web bands **100**, which respectively, alternately are attached to connectors **102** or rings **80** in an alternating fashion. The bands **100** of the outer tension web are preferably fused, bar tacked, or otherwise fixedly connected to the seams or bands **100** of the inner web to form the tension web **20**.

Referring now to FIGS. **9**A and **12**, an example of operation of the invention and a method for maintaining at least one pole **12** in a desired shape under tension is described. As shown in FIG. **12**, the deformable, resilient pole element **12** is substantially straight and untensioned initially. Tension members **44***a* and **44***b* are coupled to locations **130**, **132**, **134**, **136** on the pole **12** via connectors **102**. The tension members **44***a* and **44***b* form a plurality of geometric chords relative to the pole between connection points and impress an inward tension force on the pole **12**, thus bending it into a desired shape, in this example generally arcuate, where it is maintained under tension.

The spacing of the coupling locations defines a plurality of zones. Zone **170** is located between locations **130** and **134**. Similarly, zones **180** and **190** are respectively located underneath the arcuate-shaped stressed pole **12** between locations **132** and **134** and locations **132** and **136**. In the particular example shown, the tension members **44***a* and **44***b* crisscross each other in zones **170**, **180** and **190**.

When external forces, for example due to wind, rain, or the weight of an exterior cover e.g., a "fly," are imposed on the structure **10**, the tension forces on the pole **12** at coupling locations **130**, **132**, **134**, and **136** resist deformation of the pole **12**. Vectors **150** and **160** represent tension forces at the respective locations **130** and **134**. Vector **150** represents a tension force that is in a direction which is generally normal or perpendicular with respect to a plane **172** which is tangent to the pole at the location **130**. Similarly, vector **160** represents a tension force in a direction which is also generally normal or perpendicular with respect to a plane **182** that is tangent to the pole at the location **134**. These tension forces act to resist deformation of the pole **12**, for example at point A in the direction of the arrow B in FIG. **12**, in response to application of external forces in that direction. While the foregoing description has used cords or the like as tension members **44***a* and **44***b*, those skilled in the art will appreciate the same operation and effects may be provided by properly selected plastic materials, or by properly selected woven materials, provided the tensile fibers are properly oriented as described previously. For example, the tensile fibers **101** of the web band **100** of the web assembly **20** would function the same as the cords by resisting the deformation of the pole(s) **12** under an external load.

In some applications, it may be desirable or necessary to impart additional stiffness or strength to the flexible structure **10** without altering the shape or profile of the structure. In those instances, it may be desirable to add strut members to the tension web assembly. FIGS. **19–21** illustrate additional preferred embodiments in which the tension web assembly **20** further includes strut members **220**.

Referring to FIG. **19**A, the tension web assembly **20** incorporates at least one strut member **220**, and preferably a plurality of such strut members. The strut members **220** may be incorporated at spaced locations **260** along the tension web to optimize the strength and rigidity of the structure.

Each strut member **220** preferably includes a first external end **230**, an intermediary segment **240**, and a second internal end **250**. The external end **230** may be connected with the pole(s) **12** in a variety of manners, as will be described. The internal end **250** may be connected with the tension web assembly **20** also in a variety of suitable ways.

The strut members **220** are preferably formed of a rigid material in order to impart additional strength and rigidity to the structure and to resist deformation when external forces are applied to the structure. While in preferred embodiments, the strut members **220** are constructed of material such as molded or extruded plastic, lexan, carbon reinforced nylon, aluminum, titanium, steel or wood, those skilled in the art will realize that other suitable materials having similar properties could be used.

As shown in the preferred embodiment of FIG. **19**A, the strut members **220** are preferably oriented substantially perpendicular to the tangent of the pole **12**, and are in substantially co-planar arrangement with the pole. When properly aligned, the strut members **220** will act to provide tensile stiffness to counteract bending movement of the pole(s) **12** when a load or force is placed on the poles or flexible member **24**.

The strut members **220**, in cooperation with the tension web assembly **20**, also serve to dampen or absorb any load or force which is applied to the pole(s) **12**. Thus, similarly to what is shown in FIG. **7**, in the embodiment of FIG. **19**A, when a load or force is applied to the pole(s) **12**, the strut member **220** is displaced from its non-loaded position. As the strut member **220** is forced to move in response to the load, however, its movement is increasingly constrained by counteracting forces generated by the tension members **44***a* and **44***b*, via the tension vectors **40***a* and **40***b*.

It is evident that the length of the strut member **220** is important to its function. The strut member preferably should be long enough so that the angle between the internal end **250** of the strut member **220** and the tension member **44***a* or **44***b* is less than 90 degrees when a load is applied to the structure in order to provide suitable force dampening.

Other preferred embodiments of the invention are shown in FIGS. **19**B and **19**C. In these embodiments, the external end **230** of the strut member **220** is slidably connected with the pole element **12** by either a ring element **270** or a hook element **280**. It will be appreciated by those skilled in the art that the strut member **220** may be fixedly secured to the pole **12**, for example, by sizing the hook **280** to establish a friction fit with the pole **12**. The strut member may also be configured to be either permanently or temporarily secured to the pole.

As best shown in FIGS. **20**A–**20**F, strut members **220** may be incorporated into the tension web assembly **20** in a variety of ways. FIG. **20**A depicts one preferred embodiment of a strut member **220** in cooperative connection with a pole **12** and the tension web assembly **20**. The external end **230** and intermediary segment **240** of the strut member are joined via an external hub **290**. The external end **230** of the strut member is configured with a hook **280**, which is connected with the pole. The external hub is connected with tension member **44***a* in any suitable manner. One example would be inserting an end of the tension member through a hole in the hub and knotting the end of the tension member. Another would be passing the tension member through holes in opposing sides of the hub body. The internal end **250** of the strut is connected with an internal hub **300**. The internal hub is similarly connected with tension member **44***b* in any suitable manner.

FIG. **20**B illustrates another preferred embodiment of a strut member **220** in cooperative connection with a pole **12** and the tension web assembly **20**. In this embodiment, the tension members **44***a* and **44***b* are exemplified as a single tension band **310**. The tension band **310** is connected with both the external and the internal end **250** of the strut member **220** in any suitable manner. As shown, the strut member may be one contiguous structure.

It will be appreciated by persons skilled in the art that the strut member **220** can be separate, or contiguous with, the tension web assembly **20**. FIG. **20**C illustrates a preferred embodiment of a tension web assembly which incorporates strut members and in which alternate forms of tension members (both contiguous and separate) are employed. In this embodiment, the tension band **310** is integrally connected to the strut member along a length of the strut member, whereas the separate tension members are connected in any suitable manner as pointed out previously.

FIG. **20**D depicts yet another presently preferred embodiment of a tension web assembly which incorporates strut members **220**. In this embodiment, the external end **230** of the strut member is configured with a ring **270**, thus allowing the strut member to be slidably connected with the pole. As further shown in FIG. **20**E, the intermediary segment of the strut member is configured with an eyelet **320**, and the internal end of the strut member is configured with an eyelet **330**. The eyelet **320** is connected with the ring **270** and the tension member **44***a*, while the eyelet **330** is connected with the tension member **44***b*. FIG. **20**F illustrates another embodiment of the strut member of FIG. **20**D, wherein the ring **270** may be securely compressed against the pole **12** by inserting a wedge **340** into the ring **270**. In this way, the strut member **220** is fixedly connected with the pole via a friction fit.

FIG. **21**A illustrates a flexible structure **10** having a plurality of poles **12** similarly to the structure shown in FIG. **1** described previously. Associated with each pole is a tension web assembly **20** incorporating a plurality of strut members **220** at spaced locations. While the embodiment shown has a plurality of poles, it is appreciated that the present invention may incorporate one or more poles. Further, while the embodiment shown generally has one tension web member per pole, it will be appreciated that the structure may omit web members from some poles and may omit strut members from some tension members depending on the shape, strength, purpose and other parameters of the desired structure.

While the present invention has been described herein with reference to particular presently preferred embodiments thereof, a variety of modifications, changes, and substitutions are envisioned in the foregoing disclosure, and will be appreciated by those skilled in the art. For example, in some instances certain features of the invention may be employed without a corresponding use of other features without departing from the intended scope and spirit of the invention. Additionally, modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope and spirit thereof. Accordingly, it is intended that the invention not be limited to the particular embodiments disclosed, but that it will include all embodiments and equivalents falling within the scope of the appended claims.

What is claimed is:

1. A flexible structure comprising:

at least one deformable, resilient pole; and

at least one tension web coupled to said pole and maintaining said pole in a selected shape under tension, said tension web including at least one strut member.

2. The flexible structure of claim **1** wherein said tension web is coupled to said pole by said at least one strut member.

3. The flexible structure of claim **1** including a plurality of strut members positioned along said tension web at a plurality of spaced locations.

4. The flexible structure of claim **1** wherein said at least one strut member is aligned substantially perpendicular to the tangent of the pole.

5. The flexible structure of claim **1** wherein said at least one strut member is comprised of a rigid material.

6. The flexible structure of claim **1** wherein said at least one strut member is in substantially co-planar orientation with the pole.

7. The flexible structure of claim **1** wherein said tension web is fixedly coupled with said pole.

8. The flexible structure of claim **1**, including a flexible member coupled to said structure and defining a sheltered space.

9. The flexible structure of claim **1** wherein said tension web comprises a plurality of tension members.

10. A flexible dome structure comprising:

a plurality of deformable, resilient poles arranged in crossing relationship;

a tension web assembly coupled to at least some of said poles and maintaining said poles in a generally arcuate shape under tension, said tension web assembly including at least one strut member.

11. The flexible dome structure of claim **10** including a flexible membrane coupled to said structure defining a sheltered space.

12. The flexible dome structure of claim **10** wherein said tension web assembly comprises a plurality of tension members and wherein a plurality of poles have at least one tension member coupled thereto.

13. The flexible dome structure of claim **12** wherein said tension web assembly includes a plurality of strut members and wherein each said tension member coupled to a pole is coupled to said pole by at least one strut member.

14. The flexible dome structure of claim **12** wherein said tension web assembly includes a plurality of strut members positioned at spaced locations along at least one of said tension members.

15. The flexible dome structure of claim **10** wherein said at least one strut member is a rigid member.

16. The flexible dome structure of claim **10** wherein said at least one strut member is oriented substantially perpendicular to the tangent of at least one of said poles.

17. The flexible dome structure of claim **10** wherein said at least one strut member is oriented substantially co-planar with respect to at least one of said poles.

18. A flexible structure comprising:

a plurality of deformable, resilient poles;

a tension web assembly coupled to at least some of said poles and maintaining said poles in a selected shape under tension, said tension web assembly including at least one strut member.

19. The flexible structure of claim **18** wherein said tension web assembly is configured to oppose bending of the poles in response to an external force applied to the structure.

20. The flexible dome structure of claim **18** wherein said tension web assembly is configured to dampen external force applied to said structure.

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