Nov. 29, 1960 W. T. MONGAN ET AL 2,961,802

STRESSED STRUCTURAL UNIT

Filed Feb. 18, 1957 5 Sheets-Sheet 1

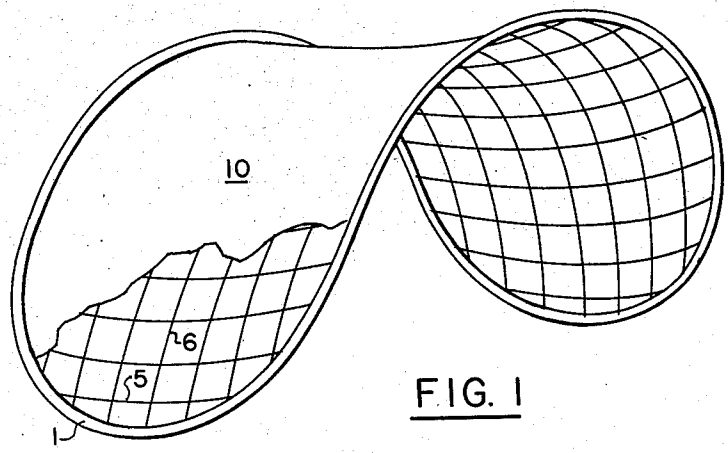

FIG. 1

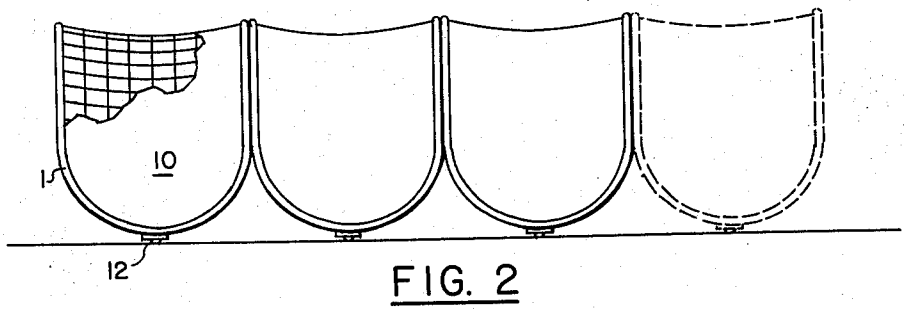

FIG. 2

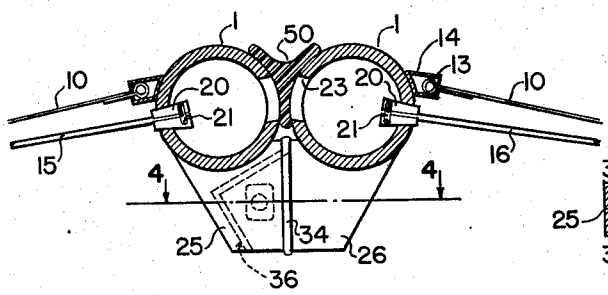

FIG. 3

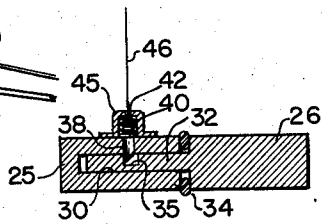

FIG. 4

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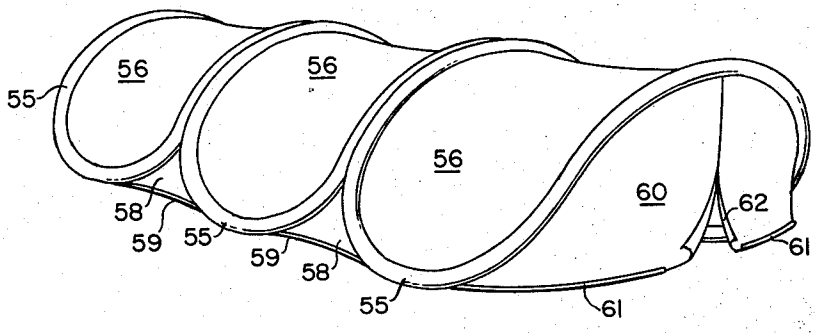

FIG. 5

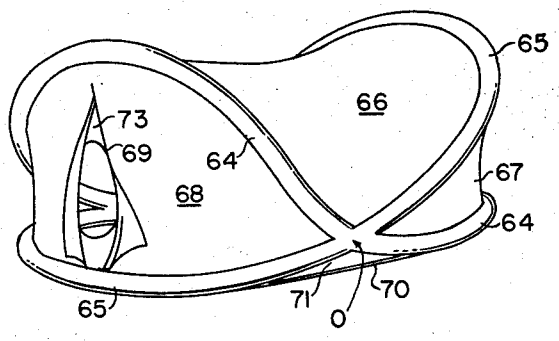

FIG. 6

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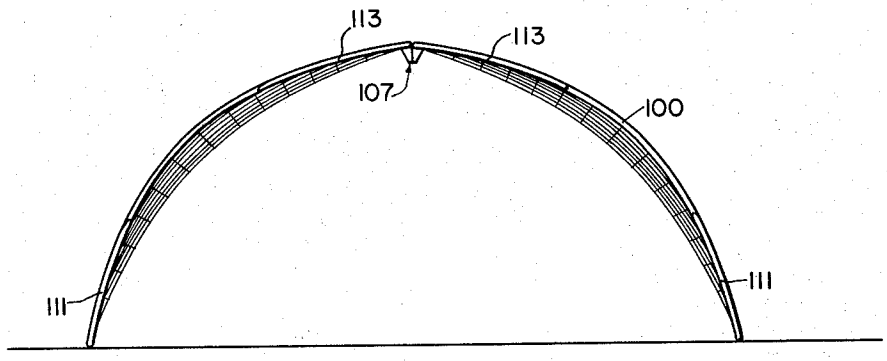

FIG. 7

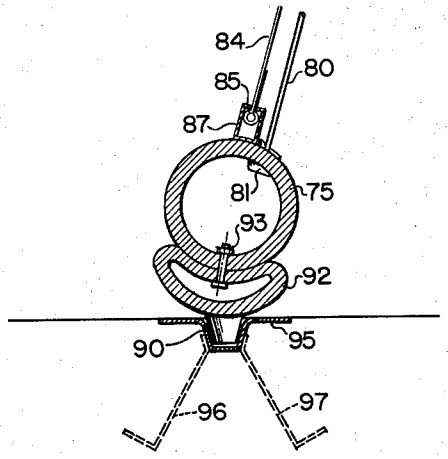

FIG. 8

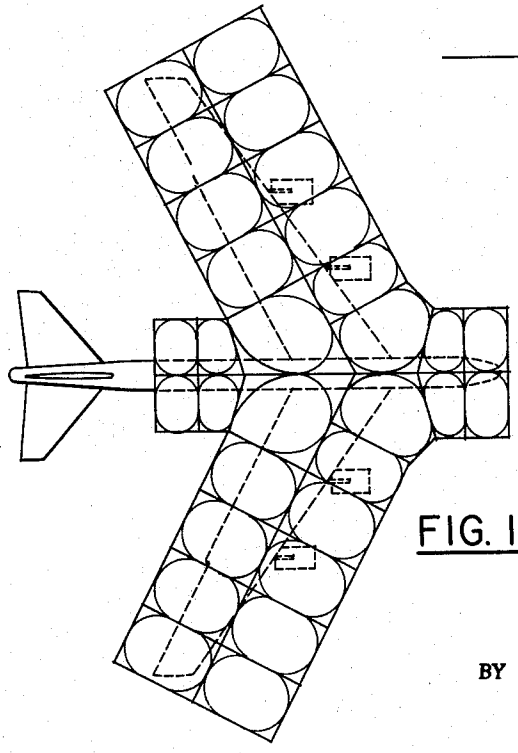

FIG. 14

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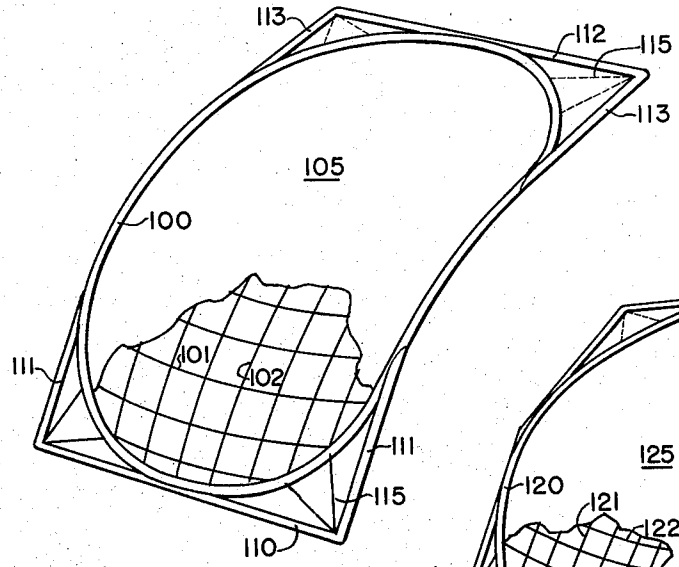

FIG. 9

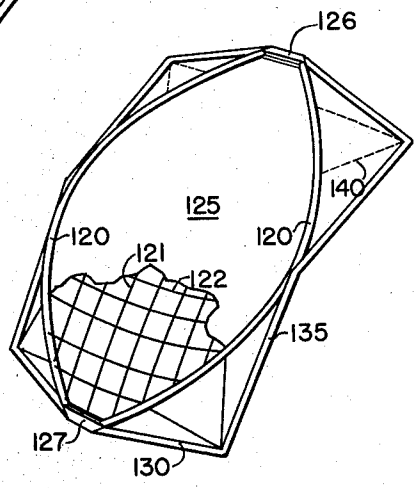

FIG. 10

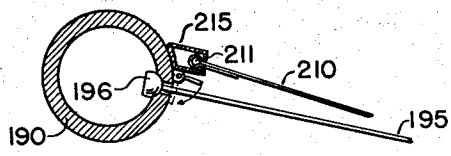

FIG. 15

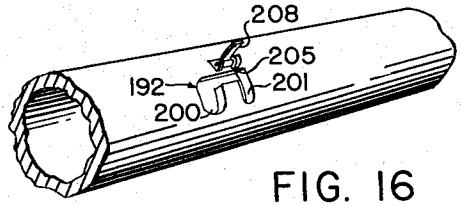

FIG. 16

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Filed Feb. 18, 1957 5 Sheets-Sheet 5

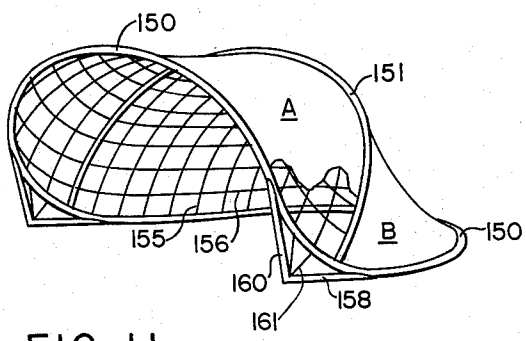

FIG. 11

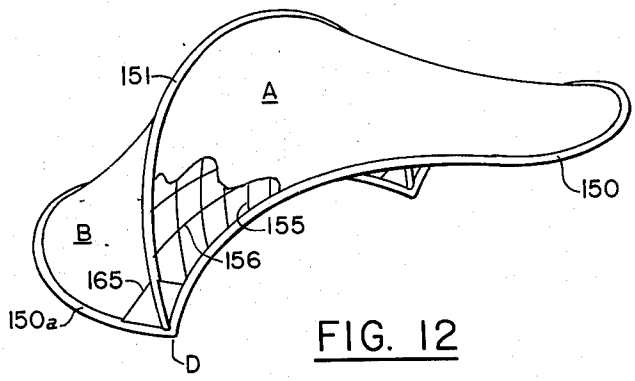

FIG. 12

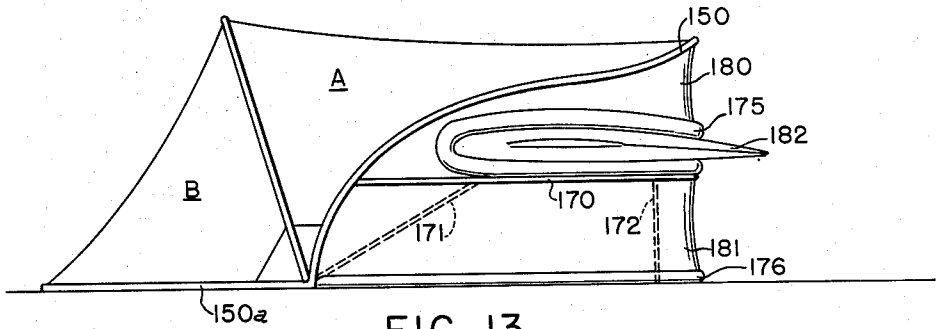

FIG. 13

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United States Patent Office 2,961,802 Patented Nov. 29, 1960

2,961,802

STRESSED STRUCTURAL UNIT

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Filed Feb. 18, 1957, Ser. No. 640,972

6 Claims. (Cl. 50—52)

This invention relates to an improvement in architectural systems and, more particularly, to an improved type of self-contained, internally stressed, structural unit. The invention might also be considered an improvement over the invention of one of the co-inventors herein, described and claimed in application Serial No. 616,228, now Patent No. 2,928,360, filed October 16, 1956, the latter also having reference to stressed architectural units which are self-contained within a peripheral member that is maintained under forces of either tension or compression.

As an expression of the preferred thinking as to the theory underlying the forces of stress involved in the instant invention, it is pointed out that the structure, when completed and placed under these forces of tension and compression, will afford a building unit that presents, in both elevation and section, contiguous parabolic, or near parabolic, curvatures. In this sense, the structure is anticlastic in nature or, in accordance with the popular definition of this term, is one that presents opposite curvatures at a given point, that is, curved convexly along a longitudinal planar section and concavely along the section which is perpendicular to that longitudinal section. As stated, the curves to be found at these points or sections are parabolic or approximately parabolic in configuration.

The invention involves a novel combination of coacting parts to be found in these several elements: the system is confined within a peripheral member, formed as a continuous structural entity; this peripheral member exists in a state of stress due to its bending and compression in the formation of the unit, and the constant exertion of thrust of that member resists the bending, gravity and compression reactions as well as inward acting tension forces exerted by the membrane element. Such peripheral member, consistent with the general reference above, presents contiguous parabolic or ellipsoidal curvatures in plan and parabolic curvatures in elevation.

Secondly, the referred to membrane which exists within and is continuously supported by the peripheral member and stressed by same, as well as by dead loads, is developed in such manner as to place all of its points at or near corresponding points of an imaginary warped plane, thus yielding the minimum possible area within the referred to, deflected, peripheral member.

The membrane restrains the inherent outward thrust or tendency to expand of the peripheral element and may be developed by a system of wires, tapes or cables in tension, each separate series of which is crossed in a direction normal or approximately normal to a second series of wires, etc. All such tapes or elements, representing the basic latticelike framework of the structure, terminate at or near the peripheral member and thus individually restrain the outward thrust of such peripheral element. In lieu of cables or metal tapes and the like, the parabolic or near parabolic curves referred to may be generated by stretched fabrics or by connected

flexible panels which perform in the same manner and which may be so tensioned or shaped as to develop the curvatures referred to above when joined to the peripheral member.

In addition to the two basic elements of the structure, i.e., the peripheral member and its restraining membrane, of whatever form, we may also employ other preferred secondary structures which are here termed, respectively, stabilizing frames and ridge frames. The so-called stabilizing frame may be, in addition, a stressed framework, existing externally of, but in functional association with, the peripheral member and also stressed or placed under tension by a system of attachment to the periphery of the unit. These frames can be of different configurations and are primarily utilized to so alter the shape of the periphery of the main framework as to enable a series of the latter to be interfitted or joined into a larger, self-supporting structure of any desired size. The referred to ridge frame is also a secondary member or group of members which provides a continuous and relatively straight ridge line; in a sense and as will be explained, it comprises a portion of the stabilizing frame and performs the same function of the latter—enables joining of several of the basic elements to provide larger structures of varied and different shapes.

It is thus to be understood that the system of this invention and the unit produced thereby resides primarily in affixing a network of tapes or like elements comprising what is here referred to as a membrane to a resilient, spring-loaded peripheral element, the latter being placed under flexural stress so that it constantly exerts a substantial outward force or thrust. The tapes, braces, continuous membranes or equivalent means which join opposed portions of the periphery are so crossed with respect to each other as to exert relative compressive forces against each other at their crossing points; by this system of development, a series of successive parabolic or near parabolic curves is formed in not only the periphery of the structure but, as well, throughout its intermediate area. Such tensionally stressed formations are thus anticlastic in nature or, in the more popular definition, saddle-shaped in configuration.

The primary difference between a structural system and unit of this invention and well-known architectural frameworks resides in the presence of forces of tension and/or compression which exist throughout the unit as a whole, thus rendering it self-sufficient and stable. It is this factor which materially contributes to the phenomenal strength exhibited by the structure in comparison to architectural structures known to the art, the strength of which must always be calculated with reference to the dead loads within the system. Since this unit is primarily concerned with the tensional forces that come into play during formation of the periphery and the area confined thereby, the system is based upon a theory inapposite to usual engineering formations such as the cantilever, dome, roof trusses, etc., all of the latter being predicated upon the principle of compression of the individual elements thereof.

Thus, in known architectural devices which are utilized as the basic supporting frames for building structures generally, this reliance upon forces of compression imposes definite limitations upon the maximum load bearing capacity obtained thereby, whereas through our invention the amount of obtainable load per weight of unit ratio is far in excess of that heretofore obtainable.

Accordingly, it is a primary object of this invention to provide a structural unit that is self-contained and self-supporting due to its reliance, exclusive of external forces, upon the restraint of a peripheral member which constantly exerts outward thrust, by a membrane of whatever form, the membrane being so tensioned and the periph-

eral element so flexed as to form configurations approaching the parabolic in both plan and section.

A further object of the invention is the provision of a building structure which may be fabricated of almost all known structural materials, e.g., it can be made of synthetic plastics, metals or other obvious materials.

Another object of the invention is the provision of a basic structural unit that, by the addition of stabilizing and ridge frameworks, can be widely varied over its original form so as to permit independent units of same to be joined or used collectively in such manner as to assume any shape conducive to the sheltering or covering of personnel, equipment or aircraft.

An additional objective of the invention is the provision of a structural unit that in and of itself is independently rigid and sturdy and, hence, may exist as a self-supporting framework independent of any exterior bracing or supporting members.

Another objective of the invention is to provide a structural unit that is not only aesthetically pleasing in appearance but also, having in mind the size or volume requirements of any given project, additionally finds use when joined in multiple for projects of considerable magnitude, yet retains those features conducive to ease of erection and dismantling.

Another object of the invention is the provision of a structural unit which, because it can be varied in size and shape in almost innumerable ways, is particularly adapted for group use, especially when such units are of the smaller type such as tent or canopy types; in this aspect, the invention is peculiarly adapted to use by the armed forces for housing of either personnel or fighting equipment.

Reference will now be made to the drawings wherein a more specific description of the invention will be found and wherein:

Figure 1 is a perspective view, partially broken away, showing a form of the basic unit of the invention;

Figure 2 is an elevation view, having one unit partially broken away, demonstrating the manner of interconnecting together a series of the structures shown in Figure 1;

Figure 3 is a detailed view illustrating one form of mechanism for maintaining two or more of the individual structures of Figures 1, 9 and 10 together at their juncture points as well as illustrating one means of securing the tapes and covering to the peripheral member;

Figure 4 is a section view taken on the line 4—4 of Figure 3;

Figure 5 is a perspective view of an alternate embodiment of the invention illustrating the use thereof as a housing unit and showing the entrance way thereof;

Figure 6 is a further alternate embodiment of the invention showing the use thereof as a housing structure with two of the basic frame units positioned in crossed relationship;

Figure 7 is an elevation view of an alternate embodiment of the invention wherein two units are joined together to form a sheltering or covering structure;

Figure 8 is a detailed view of a means for mounting or positioning a given structural unit, such as the joined units of Figure 7, upon a ground or base point;

Figure 9 is a perspective view of a single unit of the invention employed with stabilizing and ridge frames;

Figure 10 is a perspective view similar to Figure 9 showing an alternate construction of the peripheral member and optional and stabilizing ridge frames;

Figure 11 is a perspective view of an alternate embodiment of the invention, partially broken away, illustrating the use thereof as a sheltering or covering structure;

Figure 12 is a perspective view of an alternate embodiment of the invention similar to Figure 11 but having a discontinuous or noncontinuous peripheral member which, however, acts in the same way as the peripheral member in Figure 11;

Figure 13 is an elevation view of Figure 12, illustrating the use thereof as a covering or shelter of a wing mounted engine or propulsion unit of an aircraft;

Figure 14 is a plan view of a number of the basic units of Figure 9 and/or Figure 10 and particularly of irregularly warped variations of same or combinations of the principal or unique configurations embodied in Figure 9 and Figure 10;

Figure 15 is a detailed view showing an alternate manner of interconnecting the crossing, tensional tapes to the peripheral element; and

Figure 16 is a detailed perspective view further illustrating the features of the interconnecting means shown in Figure 15.

A more particular description of the invention will now be given, having reference to the foregoing figures. In Figure 1, the most basic and simplified embodiment of the invention is shown. In this figure, it is seen that the stressed structural unit does take the form of a saddle-shaped configuration, or one which, in section, both longitudinally or laterally, represents a series of contiguous, joining curvatures, all of which are parabolic or near parabolic in shape. The curved area is bounded by a resilient, stressed peripheral member, here designated at **1**. This member, like the other parts of the basic unit, may be made of alternate materials, such as metal, plastics and various types of synthetics, etc. In any event, the peripheral element is so fabricated as to have an inherent spring-like quality or tendency to exert thrust outwardly. When made of metal, for example, conditions may require this member to be prebent to an approximation of its final shape; otherwise, stresses built up within the same may be so great as to exceed the tensile strength of the element and cause its fracture. At any rate, the amount of prebending or the desirability of prebending of the peripheral member is a factor that can be readily determined by engineers skilled in the art who, with the disclosure of this invention before them, can readily compute the strength or condition of the material used and the necessity of prebending it to the desired shape in order that it exerts a sufficient amount of outward thrust but is not restrained in such excessive amount as to cause its fracture. If made of plastic materials, the peripheral member can take the form of tubing which may be filled with air under pressure and the consequent effect of this pneumatic arrangement is to cause the same type of outward thrust to be exerted when the tube is pressurized a predetermined amount.

The peripheral member **1** is, in the course of its evolution to the final shape, subjected to stresses built-up within the area it defines by, in one form of the invention, a series of tapes or elements **5** which extend across the width of the unit; these are crossed by another series of tapes or wires **6** which are positioned in a direction normal or at right angles to the tapes **5**. When tension is placed upon tapes **5**, the lateral curves existing between the sides of the unit is formed and, when tension is placed upon the corresponding tapes **6**, similar longitudinal parabolic or near parabolic curves are obtained. In actual practice, the tapes **5** may be initially positioned and, with positioning of the tapes **6** and increase of tension upon both series of members, the unit is gradually drawn to the position of the ultimate structure shown in Figure 1. At the point of crossing, the two series of tapes exert forces of compression against each other, this causing the saddle-shaped configuration to become rigid and permanent.

As will be seen and with respect to any of the modifications of this basic structure, a covering **10** may be placed over the lattice or framework created by the crossing tapes, and such covering can be affixed in a manner to be described.

The basic unit of Figure 1 can be employed in a number of variable ways as a building unit or housing structure. An illustration of one of its possible uses is found in Figure 2 where four of the separate units of Figure 1

are shown in adjacent relationship, the approximately parallel sides of the adjacent peripheral elements **1** coming together in closed relationship. The units may be affixed together in this position by means to be described and, as shown in Figure 2, when so affixed, the whole series, as an integral unit, may be moved from place to place if mounted upon wheeled means **12** as therein indicated.

One possible method and means of securing several units together at the contacting edges of the peripheral member is shown in Figures 3 and 4. Here, such member may be made of either plastic or metal or other materials of sufficient strength for the purposes herein outlined. These figures also illustrate a means of securing the tape members to the periphery of the unit as well as a mode of securing the covering **10** thereto.

Two tapes, here designated **15** and **16**, are joined to the peripheral element by way of wedge-shaped or conical means, consisting of, in each instance, two matching segments **20** representing, in cross section, semi-circular portions or halves of the respective wedges or cones. These semi-circular portions **20** are detachably secured together on each side by a pivoted plate or retaining latch **21**. The wedges are designed to be placed in corresponding apertures in the peripheral elements **1**, the side walls of such apertures approximating the exterior contour of each wedge. The wires or tapes **15** and **16** are held in place by first inserting them between the halves of the respective wedges **20** with such being positioned interiorly of the peripheral element. Upon tensioning or stressing the tapes or wires, the wedge-shaped halves are drawn together to bear against the tapes with the result that the greater the tension, the greater he force exered by the wedges to hold the tapes in place. As facilitating the assembly of this holding means, apertures **23** may be made in the opposite side of the peripheral elements in order that the wedges and tapes can be reached from that side and placed in their respective positions prior to pulling them taut to the desired extent.

Any convenient method may be used for attaching the covering material **10** but, as shown in Figure 3, such cover **10** may be made with a beaded edge such as indicated at **13**, shown as being part of the material (here preferably of the plastic type) turned back against itself and secured together. This edge is fitted within a suitable slot in a housing **14**, curved at its opposite end to approximate the contour of the peripheral member. The housing **14** is then welded or, if plastic is used as the basic construction material, molded to the exterior of the peripheral elements in a manner which will be well understood by those skilled in the art.

When a number of units are used together, as exhibited in Figure 2, it is desirable that means be employed which will maintain these elements in this related, adjacent position and to this end, the peripheral elements at spaced points may be provided with interlocking devices, forcing the adjacent contours of the structural units together. As here shown, one of the adjacent peripheral members **1** is provided with a series of flanges **25**, each of which is slotted as at **30**. The other adjacent peripheral element is also provided with a complementary flange **26** that is fitted with a reduced portion, flange or tenon **32** adapted to interfit with the slot **30**. A bushing or gasket **34** is preferably placed between the shoulders of the element **26** and its counterpart **25** to prevent wear and render the joint so made moisture impervious. Thus a form of tenon joint is provided and the interconnection maintained by a pin **38**, slidably mounted in a suitable aperture in one side of the member **25**. The pin is adapted to reciprocate in this opening so that it engages a bore **35** in the tenon or flange of the member **26**. When in the position shown in Figure 4, it is obvious that the pin **38** will maintain these two flanges **25** and **26** in sealed position. The pin **38** is fitted with a flange **40** against which a helical spring **42** constantly bears in order that the pin normally tends to be thrust into the bore **35**. At its opposite end, the spring **42** bears against a housing **45** secured by any common method to the element **25**. The pin **38** is withdrawn from its locked position as shown in Figure 4 by a cord or wire **46** permitting withdrawal of it, against the spring tension, out of the depression **35**. The approximate configuration of the slotted member **25** and its complementary joining member **26** is generally indicated at **36**. Where the respective edges of each part are right-angularly disposed to each other, the top edge is slanted upwardly. This configuration facilitates seating of the tenon portion **32** within the slot **30**, though the surmounting tapes or covering members at their point of juncture be angularly inclined to each other or substantially in the same plane. By such means the series of units is readily interconnected and, as quickly, disassembled for shipment or for ease of movement from one place to another.

A further exemplification or varied use of the basic unit of this invention is found in Figure 5 where, again, several of the structures of the general contour exhibited in Figure 1 are joined together at the contacting portions of the peripheral member. This may be accomplished by some form of zipper assembly or by known types of snap fasteners. In this form of the invention, however, its practical utility as a tent, readily assembled, is illustrated. Here, the several peripheral elements **55** are joined as indicated and surmounted by the several covers **56**, which serve as the tensioned membrane element of the structure. The covers also form a more complete enclosure by the addition of the wedge-shaped portions of the material generally indicated at **58**. An additional supporting medium in the sense of an additional retaining member **59** may be used. The latter can also be fabricated with materials subjected to a predetermined amount of stress and such coverings **58** can likewise surmount the usual crossed tapes which, in turn, are located between each of the elements **55**. As illustrative of the simplicity of the employment of the unit in this form, it is seen that the front and rear may include closure curtains **60** which are not structural or in tension. These are bounded by hems **61** which may be weighted or simply secured to the ground. At the central portion of this covering **60**, an opening **62** may be provided without impairment of the system of stress that is common to the entire structure and such openings may be provided with zipper, snap-fastener or like closing devices.

Another embodiment of the invention is found in Figure 6; this is representative of the use of two inflated peripheral members **64** and **65** similar to **55** in Figure 5 which, when joined together at O in an intersecting fashion, interact in combination with the tensionally stressed membrane elements (or covering elements) **66**, **67** and **68** to form a structure or shelter which takes the configuration illustrated. In this formation, the membrane covering **66** which joins the upper segments of **64** and **65**, exerts a restraining force against the outward thrust of the peripheral elements (**64** and **65**), drawing the intersection points O together. In this respect, the upper segments of **64** and **65** form a discontinuous, peripheral member which acts in the same manner as **55** in Figure 5 above (or in the same manner as the continuous peripheral member **55**).

The lower or bottom segments of **64** and **65** exert a downward thrust restrained by membrane elements **67** and **68**. This restraint positions or holds the bottom segments of **64** and **65** such that they form a base for the structure which is in contact with the surface (the ground) upon which the structure is set.

The membrane elements **67** and **68** may act in the same restraining manner as **66** in that they restrain the outward thrust of the discontinuous peripheral element formed by upper segment of **64** and the lower segment of **65** (restrained by **68**) in front, and the discontinuous

peripheral element formed by the upper section of **65** and the lower section of **64** (restrained by **67**) in back, thus drawing the intersection points O together. Again, the closure piece, or fillet **71**, serves to completely close the structure when the element **70** is in contact with the surface on which the structure is resting. The lower segments of **64** and **65**, as well as element **70**, should be in contact with the ground; that is the lower segments of **64** and **65** in conjunction with element **70** form, in plan, an elliptical bottom or, perimeter continuously in contact wtih the ground. Element **70** may be a tubular inflated piece or simply a hem for fillet **71**.

In structures of the type just described, suitable for the housing of but few personnel, it is convenient to provide an opening of slit type, such as indicated at **69**, and consisting of side flaps which, when positioned edge to edge, form a closure. Since the structure, as e.g., shown in Figures 5 and 6, is one existing under tension largely throughout the entire area, I have found it advisable to provide a reinforced opening **73** which permits the membrane element **68** to act as a continuous stressed piece, functioning in the same manner as the element **67**. In other words, with the reinforced opening **73** behind the slit **69**, this entire portion **68** of this side of the unit can remain in stressed condition despite the entrance way formed by such slit **69**.

It is to be appreciated that when the invention takes the forms exhibited in Figures 5 and 6, the use of common forms of plastic or synthetics may be desirable; this is because if the entire unit is made of such materials with the peripheral elements consisting of plastic tubing that is readily inflatable, inflation thereof immediately causes the system to assume its state of stress; dismantling of such a unit is accomplished simply by release of pressure within the peripheral elements. Such unit can then be collapsed and folded into unusually small spaces for transportation purposes.

The basic form of the unit, in itself, of continuous curved formation, may be further modified to provide certain straight line, or nearly straight line, edges that facilitate the interconnection of adjacent units or make possible overall planar configurations of varying design to suit variations encountered in different types of sheltering or covering constructions. Such possible alterations in the basic design to provide these so-called straight line terminal edges are found represented in Figures 9 and 10. In the first of these, the basic unit, following the disclosure of Figure 1, remains substantially the same. It comprises the stressed peripheral element, here indicated at **100**, the two series of crossed tapes **101** and **102** and the overall covering **105** extending throughout the area of the periphery. The additional straight line elements **110** and **111** we prefer to term the base or stabilizing frame (Figure 9). The pairs of bordering straight edges **112** and **113**, respectively, may be considered as the ridge frames, both pairs of elements in this figure being parallel with respect to each other. The ridge framework as herein described may itself be under forces of compression and/or tension and derives additional strength through intermediate tension members such as those indicated at **115** running between the respective corners of the ridge frame and the adjacent points along the peripheral member.

Figure 7 is representative of the use of two of the units of Figure 9, just described. Here, these units are each positioned with one straight line edge or, as described above, the brace frame member **110** resting on the ground surface, and the opposite straight ridge frames **112** are contacted and secured by a means, generally indicated at **107**, to form a shelter in the nature of an arch. This combination is adapted for use in structures of considerable size as, e.g., aircraft hangars. It is thus seen that the use of the described ridge frames and base or stabilizing frames, as complementary to the basic and stressed periphery, permits these units to be used in various ways, dependent upon the type of covering or shelter which is most suitable for the particular project at hand.

In shelters of this magnitude, it is desirable to provide a means for securing them to the ground or a base. Such a means is shown in Figure 8 where the peripheral member **75** is indicated as being at its lowest ground-contacting position. The usual tapes **80** are secured to the peripheral members by a ball and socket arrangement **81** or means similar to that shown in Figure 15. Likewise, the skin **84**, with its usual bead **85**, is affixed in position by a housing **87** that holds the beading in stressed condition in the position shown in this figure. These ground contacting portions of the peripheral elements are adapted to rest upon base points **90** which contain upper surfaces to match the base **110**, here shown as a member **92** comprising a deformed or flattened section thereof. Such base points are pocketed within a plate **95** or series of plates **95** that match the outer configuration of the ground points **90**. In turn, these points, through the use of angular legs **96** and **97**, which are preferably imbedded in concrete, are permanently maintained in position. At the option of the user and depending upon the permanency of the installation desired, the member **92** may be interconnected with the several peripheral elements by means of the usual bolt or pin connection **93**.

In Figure 10, a somewhat similar construction as that of Figure 9 is shown; here, however, the periphery **120** is indicated as forming other than a graduated, continuous curve. Here, the frame members **120** are in effect two opposed stressed members which are joined at their respective ends by interconnecting blocks **126** and **127** to which they are secured in any suitable fashion. Despite the fact that the alternate of Figure 10 represents a frame terminating somewhat at a point, it forms a member which acts the same as the continuous peripheral element **100** of Figure 9. It would still feature the parabolic or near parabolic curves due to the forces of tension asserted by the series of crossing tapes **121** and **122**, respectively, over which the usual covering **125** may be superimposed. In the embodiment of Figure 10, the ridge and base frames are made-up of the end members **130** and side members **135**. Both end and side members are somewhat angularly inclined to each other at their mid-points, thus creating a peaked effect at these points. This is illustrative of the possible variations which may be employed and which conceivably may call for roof effects of this peaked nature. In such cases, the various peaks will interfit to form a continuous peaked structure, more usual in appearance to common forms of shelter units. Here, again, the ridge frame consisting of these various straight elements **130** and **135** may also exist under forces of compression and/or tension by reason of the several tension members **140** which are disposed under stress between the four corners of the ridge frame to adjacent and approximately opposite points upon the peripheral member.

These additional stabilizing frames, just described, provide lateral stability for the type of unit here under consideration during erection or placement of the same. In addition, such stabilizing frames and ridge elements provide for attachment of any type of flexible covering at the base corners of the individual shelter units.

The desirability of utilizing the so-called ridge frames in conjunction with the basic, anticlastic design is further illustrated in Figure 14, more or less diagrammatically showing a hanger for an airplane (indicated in dotted line) where a number of the units are employed. Here, in order to match the configuration of the surface sought to be covered, it is seen that various sizes and irregularly warped variations of the basic unit are employed. Also, the matching edges of several of them are different than the edges of those which together form merely rectangular configurations. These various and different combinations of the same basic unit, developed by alteration of the configuration thereof and alteration of the ridge frames,

enable alternate ground plans or areas to be covered in a continuous and uniform fashion.

It is also to be noted that such ridge frames at their contacting edges can be joined together in the same manner by means of the interconnection previously described with reference to Figures 3 and 4.

This invention is particularly adaptable to prefabrication of its elements. For example, the referred to tapes may be prefabricated into a net which, when the tape ends are connected to the peripheral member, form the structural units consisting of elements **100**, **101** and **102**. In disassembly of the peripheral member **100**, the same may be broken down into segments of convenient length which can be assembled to form a continuous periphery. Appropriate segments may be prebent, if required. With respect to the stabilizing or base frames and the ridge frames, such stabilizing frame elements **110** and **111** may be broken down into segments of convenient size and, when assembled, bolted or connected to the peripheral member. The same is true of ridge frame elements **112** and **113**. In like manner, the elements of the structure illustrated in Figure 10 may be prefabricated.

It is possible to angularly dispose, with respect to the vertical, two or more contiguous, saddle-shaped structures of the invention; also, it is practical to change the surface contour of a given stressed unit so as to provide an angularity ideal for use as individual personnel shelters.

In the fabrication of such alternate forms of the invention, a so-called bow member is utilized in conjunction with the peripheral member; this bow member offers an additional outward or deviating thrust which deforms the surface developed by the membrane, increasing its area and the volume or space included by the structure. Such bow members are deflected in whole or in part by action of the membrane (the crossing tapes) and/or the deflected and restrained peripheral member. The bow element may be partially prebent before taking the ultimate shape shown herein and as described above. Thus, the bow elements are also in a state of stress due to this bending and compression and, hence, exert outward thrust caused by such stress; in the same respects as above, such outward thrust tends to resist the bending of gravity and compression reactions due to the dead load of such substances as compose the membrane itself.

Such a unit employing the bow member, as just described, as shown in Figures 11, 12 and 13 where it is seen that the basic framework of the structure of Figure 1 has been altered to provide this right-angular configuration. Referring to Figure 11, the stressed periphery **150** is here shown as truly representing a smooth curve throughout. Approximately midway at its ends, however, a further stressed element or bow member **151** has been inserted into the latticework of the several tapes. The principle of strength and self dependence is still present—the crossing tapes **155** and **156**, respectively, by assertion of tension upon the peripheral element 150 or the cross member **151**, produces this self-contained system. Such framework is surmounted in usual fashion with contiguous coverings, here marked A and B, respectively, and similarly so designated in Figures 12 and 13. To render this type of unit more conducive to practical usage, the smooth curve of the peripheral element **150** is provided with opposed angles consisting of members **158** and **160**, each of which join the periphery in the manner shown and which are positioned, with respect to each other, at approximate right angles. Such angles or additional framing are further rigidly affixed to the periphery of the unit by further tension tapes **161**. These angles provide additional ground support for the unit so that it rests upon a given surface in the position shown in Figure 11 with a convenient open entrance way.

Instead of employing a unit with a continuous curved periphery, the same may be broken or angled, as at D, Figure 12, without deterioration of the functional stresses existent in the system. In this figure, it is seen that the periphery might be considered in two portions—portion **150**, terminating at the point D, and periphery **150***a*, curved to meet at that same point D. The usual tapes **155** and **156** over which the coverings A and B are placed, perform the same function of tension against the outward thrust of the elements **150**, **150***a* and **151**; hence, the structural unit retains its same anticlastic or near parabolic configuration in both section and plan (having reference to either periphery **150** or periphery **150***a*).

Figure 13 illustrates the practical utility of a housing unit such as shown in Figure 12. Here, such unit is modified only by the provision of an intermediate member **170**, the plan projection of this member being semicircular or parabolic, suitably braced by elements **171** and **172**. The function of this member is to hold in place an inflatable tubular sealing element **175** (the inflated element providing a weather seal). The top portion of the inflatable tubular member may be weighted or braced to hold it against the top surface of the wing. Closure curtain **180** is attached to peripheral element **150**, intermediate member **170**, and inflatable element **175**. Closure curtain **181** is attached at the top to element **170**, at the side to peripheral member **150**, and its base is held in proximity to the ground by a hem **176**, which may be weighted and/or attached to the ground. In the modification of Figure 13, the opening in the form of a slot, created by the inflatable tubular element **175**, is of a shape to approximate the shape of the wing **182** of an airplane. It is thus seen that using these units, wing mounted engines or propulsion units can be serviced in a weather-proof environment, the units providing only the limited covering or shelter required for this task. Through suitable modification of these shelter units, they may also be utilized as covering elements for the nose sections of aircraft.

Reference has been made, in the foregoing description of Figures 3 and 4, to one type of means of interconnecting the numerous tapes or wires from point to point on the periphery of a given unit. Another such means, as the one to be described, is also simplified, and provides a quick and time-saving method of interconnection. This is particularly true of the mechanism shown in Figures 15 and 16 which is adaptable to prefabrication or with the peripheral elements properly apertured and the locking means already placed in position prior to the erection of a given unit.

Here, the peripheral element is designated at **190** and takes the form of a tubular member fabricated of either plastic or metal. At predetermined points along such element, a slot or opening, generally indicated at **192** and consisting of a peculiar U-shaped configuration, is adapted to enable locking of the individual tapes **195** in place, each of the latter terminating in a button or bead **196** which bears against the inner side of the referred to slotted opening.

The opening is cut with a longitudinal slot **205** and right-angularly at each end of the latter are formed two additional slots **200** and **201**. The opening or slot **200** is of such size to enable passage of the bead **196** therethrough, whereas the slot **201** need be only of that size to accommodate the tape **195**. In placing each of the tapes in a fixed relationship with the periphery **190**, the bead **196** is first passed through the opening **200** and then the tape moved into the slot **201**; this being of lesser size, the bead rests against such slot and is retained by the inner surface of the peripheral member. In order to maintain each of the tapes in this position and prevent movement back to the larger opening **200**, a spring clip **208** may be provided. This is a pivoted plate shown in the open position in Figure 15. When it is rotated downwardly or as indicated in Figure 14, it crosses the interconnection between the two slots **200** and **201**, thereby

preventing movement of the bead to the larger opening where it would be released.

As in the other cases, the lattice formed by the various crossing tapes is preferably covered by an additional membrane **210**, similarly fitted with a peripheral bead **211** that is retained in the same type of housing **215**, the latter being attached to the peripheral members **190** in any known manner.

Much of the foregoing description has been made with reference to fabrication of that system of this invention which involves the use of crossing tapes or the like, employed to create the stress upon the peripheral member. However, it is to be understood that this system of wires, tapes or cables in tension may be substituted by a sheet of suitable material as the membrane filling the area within the peripheral element. Such sheet may be formed with a tubular plastic boundary that acts as the peripheral member under stress when inflated. Plastic sheets such as Mylar are of sufficient tensile strength to provide a restraint or exert those forces of tension which are equivalent to those created by the described system of tapes. In placing stress upon such a plastic film or covering in the same directions as the tension is placed upon the several crossing tapes, a like result is obtained—the membrane element assumes a shape that will be anticlastic in nature. The amount of tension to be put upon such a solid sheet, performing as the membrane, or the amount of tension to be put upon the tapes or cables themselves if these are used, will be apparent to skilled engineers in this art, once the desideratum is pointed out to them, as herein, of the desirability of maintaining longitudinal and lateral curvatures which are parabolic or near parabolic in configuration.

The foregoing invention represents a structural system which, because it is prestressed to a predetermined configuration and maintained under stress in a state of tension and/or compression, is not only permanently stable but is also self-contained and self-supporting, being fully independent of extraneous supporting media. Furthermore, the simplified method of fabrication, which includes either the use of synthetic films or the positioning and setting of the involved tape system, permits a wide variety of uses of the invention and peculiarly adapts it for use as a tent or canopy shelter that can be readily assembled by one individual. The use of multiple units of the basic scheme of the invention permits innumerable combinations which may culminate in housing structures of considerable magnitude. Even in the latter instance, however, this same facet of ease of assembly and disassembly substantially reduces the inherent problems of mass transportation of units of this type. Furthermore, since the materials out of which the basic units may be fabricated are practicaly limitless, this type of architectural structure represents a minimum in cost of production. These advantages are consistent and obtainable with the other inherent advantage of such units—the considerable strength thereof, in contrast to known structural systems. This inherent quality of strength evolves from the theory and practice herein described and claimed to the effect that if a crossed periphery is subjected to such stresses as to form a plane anticlastic in nature, both longitudinally and laterally, the resulting formation will exhibit unusual self-supporting and independent qualities, i.e., independent of any extraneous supporting means.

While the invention is shown in but several preferred embodiments, it is to be understood that the scope thereof is inclusive of other modifications and changes and is not to be limited except as set forth in the claims appended hereto.

We claim:

1. In a structural unit, a spring-loaded peripheral element of resilient material defining a closed area, said element being adapted to exert thrust outwardly in a direction away from the center of said area, means to place said element under stress, said means comprising a membrane interconnecting opposed sides of said periphery, said membrane extending throughout said area and placing said peripheral element under restraint, said element defining successive high and low points and comprising an anticlastic formation having approximately parabolic curvatures in one direction and having additional approximately parabolic curvatures in a direction approximately normal to said one direction, and bow means attached to and extending across said periphery to deflect the defined area thereof, said bow means being of elastic, outwardly thrusting material, said bow means being restrained by said membrane, whereby the shape of said area is deformed.

2. In an architectural unit for building structures, a closed, curve, continuous peripheral element, said element being of inherent elasticity and exerting outward thrust and being prebended in the direction of interiorly directed tensional forces to prevent rupture on the application of such forces, means to place said element under tensional stress, said means comprising two series of tension members, one of said series interconnecting opposite side of said element from end to end thereof, the other series of said members inter-connecting the other, opposed sides of said element in a direction approximately normal to said first series, one of said series exerting pressure against the other of said series throughout the area defined by said element, said element comprising a shape anticlastic in nature throughout the said area, and a covering means superimposed over both of said series of members and affixed to said element, said element being structurally self-supporting and independent of any exterior, supporting means.

3. In a structural unit, a plurality of continuous, spring-loaded peripheral elements of resilient material, said elements exerting outward thrust throughout, means to place each of said elements under stress in a direction opposite the direction of said thrust, said means comprising a membrane interconnecting opposed sides of each of said peripheral elements, said membrane placing said peripheral elements under restrictive tension, said elements defining a configuration of successive high and low points, said configuration having curves of approximately parabolic configuration in both longitudinal and lateral section, and interlocking tongue and groove means attaching the adjacent of said elements together at a portion of the peripheries thereof whereby an extended housing shelter is formed.

4. In a structural unit, a continuous, spring-loaded peripheral element of resilient material, said element exerting outward thrust throughout, means to place said element under stress in a direction opposite the direction of said thrust, said means comprising a membrane interconnecting opposed sides of said peripheral element, said membrane placing said peripheral element under restrictive tension, said element defining successive high and low points and having curves of approximately parabolic configuration in both longitudinal and lateral section, and bow means attached to and extending across said periphery to deflect the defined area thereof, said bow means being of elastic, outwardly thrusting material, said bow means being restrained by said membrane, whereby the shape of said area is deformed.

5. In a structural unit, a continuous, spring-loaded peripheral element of resilient material, said element being provided with straight line edges attached thereto and positioned exteriorly thereof, said element exerting outward thrust throughout, means to place said element under stress in a direction opposite the direction of said thrust, said means comprising a membrane interconnecting opposed sides of said peripheral element, said membrane placing said peripheral element under restrictive tension, said element defining successive high and low points and comprising curves of approximately parabolic configuration in both longitudinal and lateral section, each of said straight line edges comprising a ridge frame and

a stabilizing frame, said ridge frame and stabilizing frame being positioned upon opposed sides of said element with the opposed of said straight line edges thereof being disposed in parallel relationship.

6. In a structural unit, two spring-loaded peripheral elements of resilient material, each of said elements exerting outward thrust throughout, said elements intersecting each other at a point between the respective ends thereof, and means to place said elements under stress in a direction opposite the direction of said thrust, said means comprising a membrane interconnecting the opposed sides of said elements positioned on one side of said point, said membrane placing said elements under restrictive tension, said elements above said point comprising a configuration having curves of approximately parabolic configuration in both longitudinal and lateral section, said elements comprising a shelter unit having an approximately elliptical base contact shape on the side of said point opposite said one side.

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