United States Patent [19]

Hale

[11] **3,774,358**

[45] **Nov. 27, 1973**

[54] **STRUCTURAL MEMBRANE PANEL FORMED FROM SADDLE SHAPED SURFACE**

[76] Inventor: **Jess R. Hale**, 25913 Stanford Street, Hemet, Calif. 92343

[22] Filed: **Sept. 18, 1972**

[21] Appl. No.: **290,101**

Related U.S. Application Data

[63] Continuation of Ser. No. 77,285, Oct. 1, 1970, abandoned.

[52] **U.S. Cl.** **52/81,** 52/630

[51] **Int. Cl.** **E04b 1/32,** E04b 7/08

[58] **Field of Search** 52/80–82, 630, 452, 454

[56] **References Cited**

UNITED STATES PATENTS

1,872,984	8/1932	Land	52/454
2,545,556	3/1951	Pont	52/81
2,918,023	12/1959	Bettcher	52/81
3,302,359	2/1967	Alleaume	52/630
3,394,506	7/1968	Thompson	52/80
3,439,459	4/1969	Silberkuhl	52/630
3,568,381	3/1971	Hale	52/81

FOREIGN PATENTS OR APPLICATIONS

149,794	5/1937	Germany	52/81
1,230,904	4/1960	France	52/80

Primary Examiner—Henry C. Sutherland

Attorney—Edward A. Sokolski et al.

[57] **ABSTRACT**

A structural membrane panel is formed from an even number of contiguous saddle-shaped surfaces which are bounded by a plane or skew polygon which surrounds a central structural surface which may take the form of a saddle, valley, or a cross-cap. Where a central saddle or valley is utilized, these central elements are bridged to consummate structural integrity.

17 Claims, 28 Drawing Figures

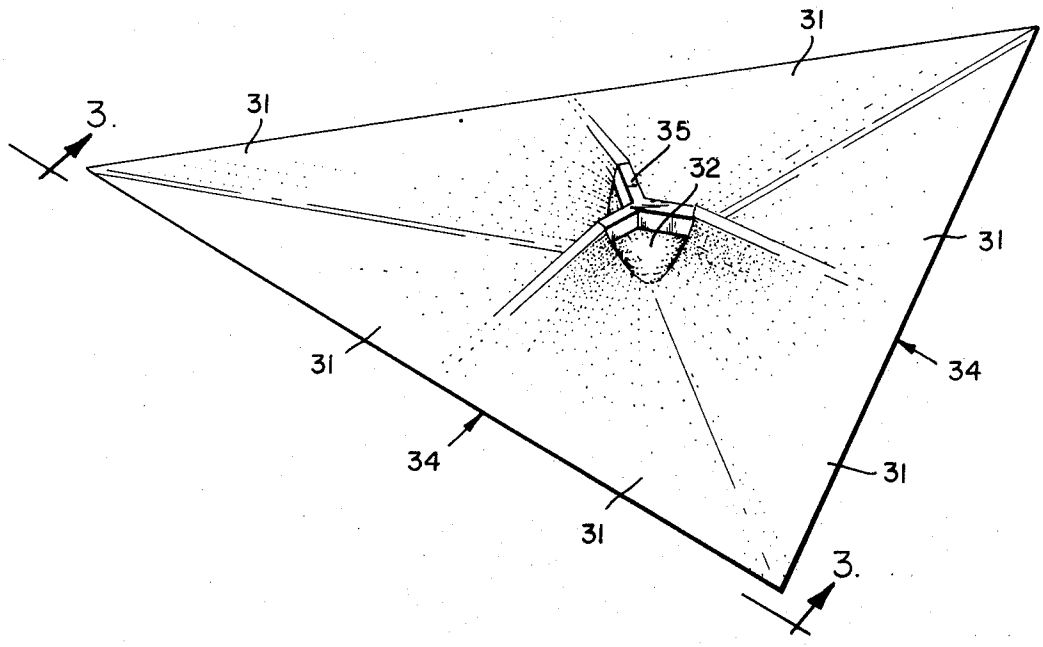


Fig. 1.

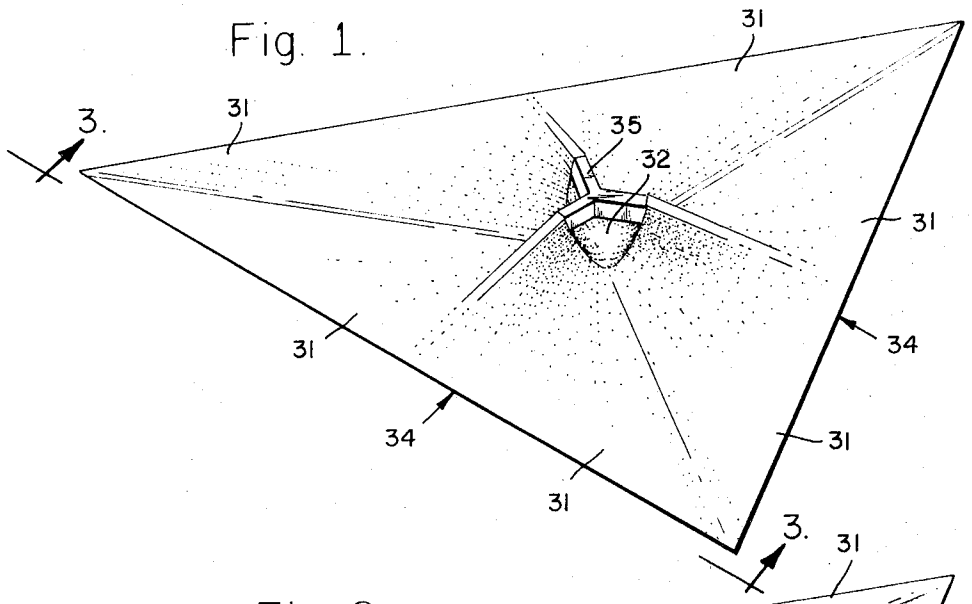
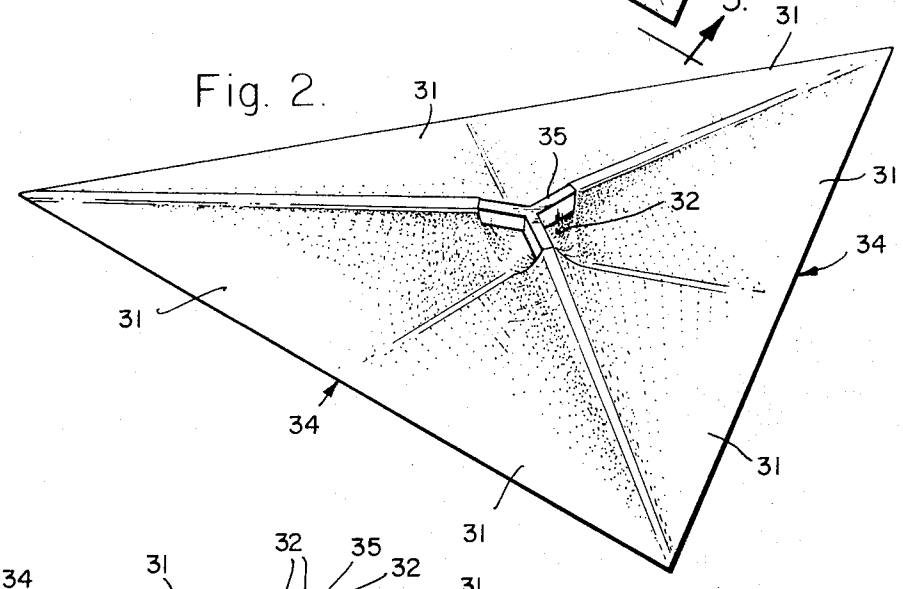


Fig. 2.



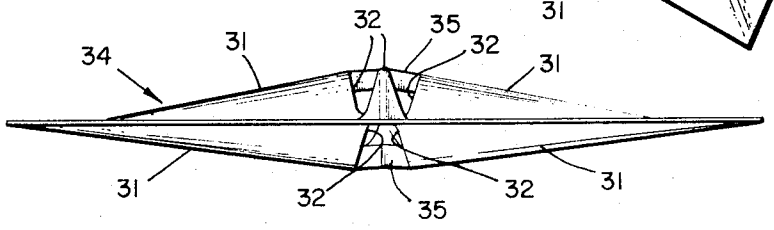


Fig. 3.

Jesse R. Hale,
INVENTOR.
BY.

SOKOLSKI & WOHLGEMUTH,
ATTORNEYS.

Fig. 4.

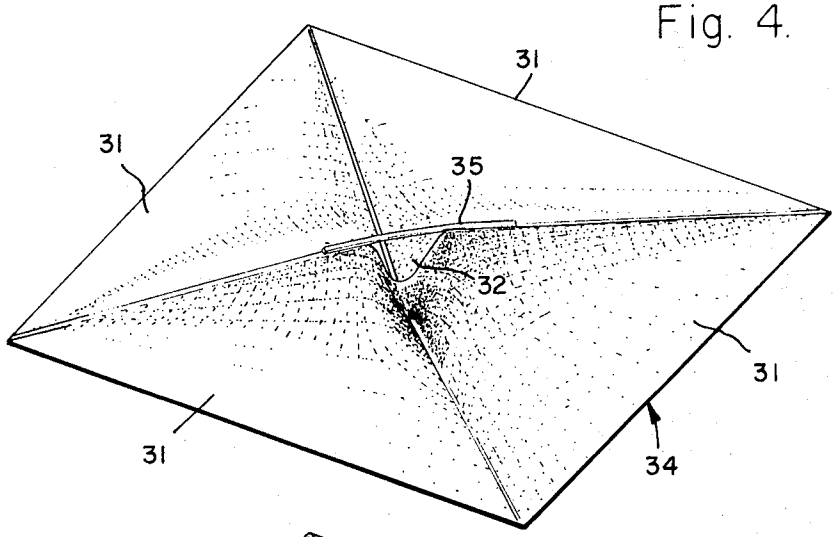


Fig. 5.

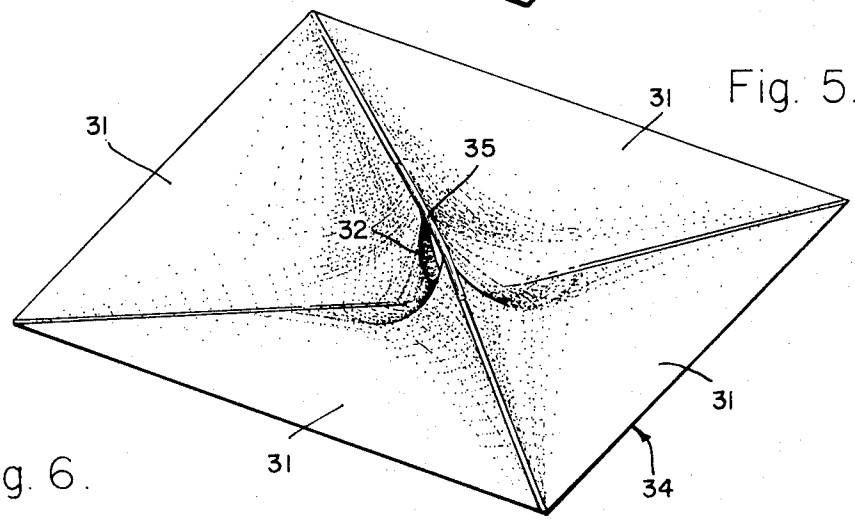


Fig. 6.

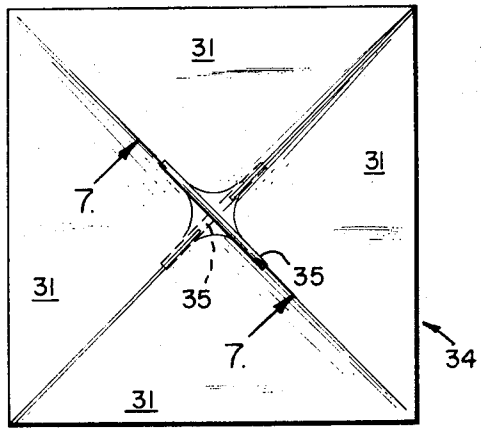


Fig. 7.

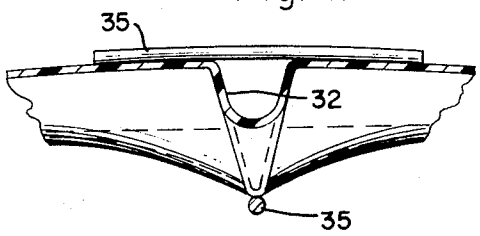


Fig. 8.

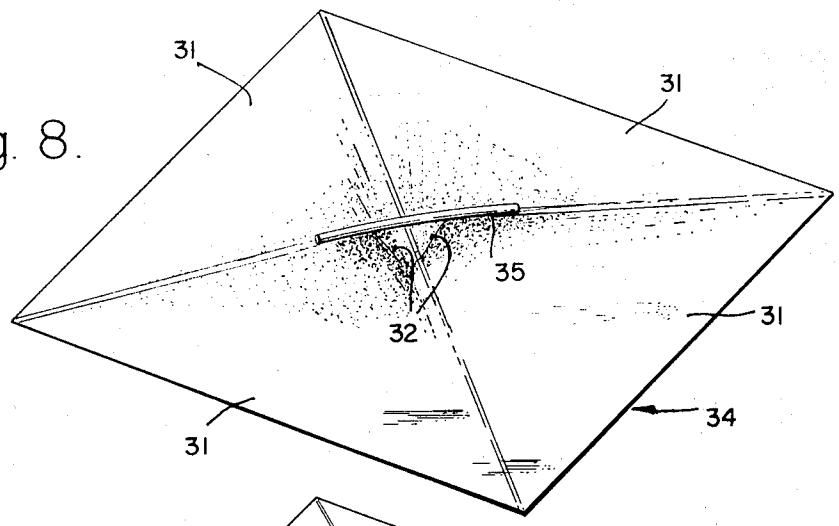


Fig. 9.

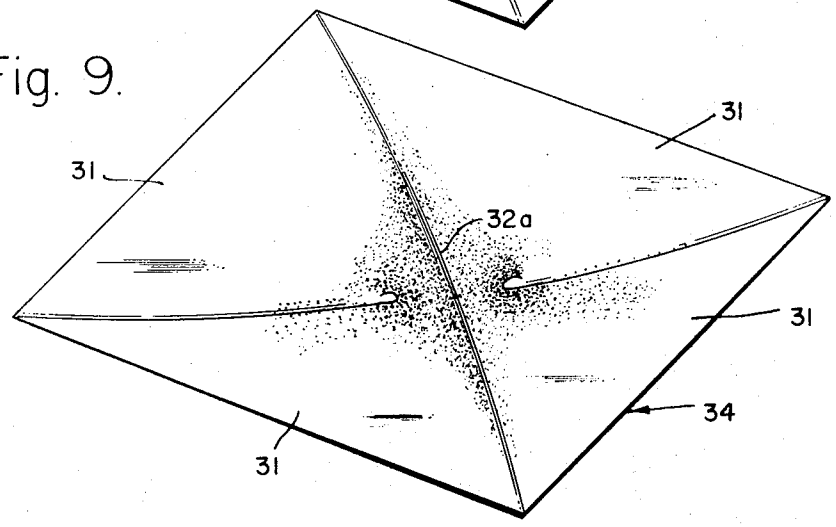
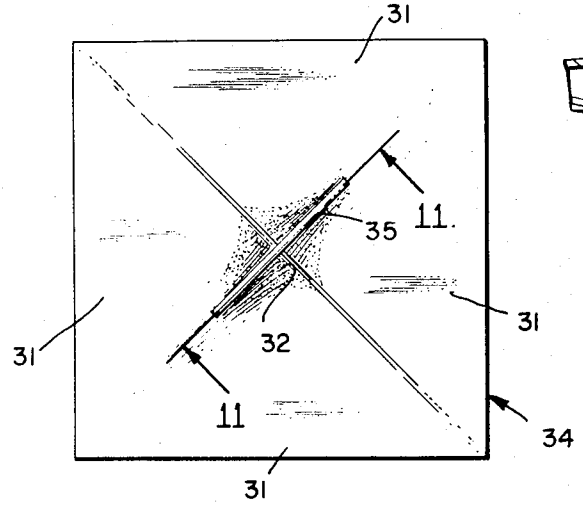


Fig. 10.



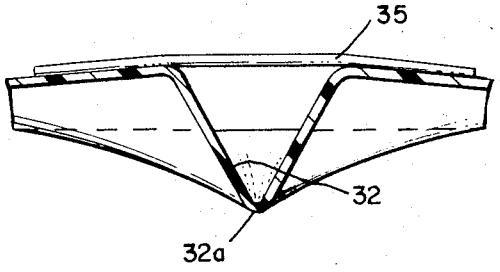


Fig. 11.

Fig. 12.

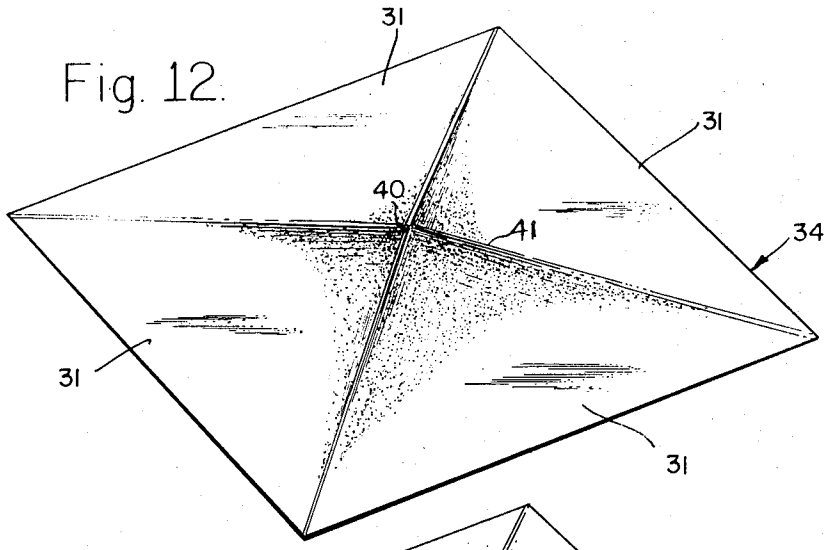


Fig. 13.

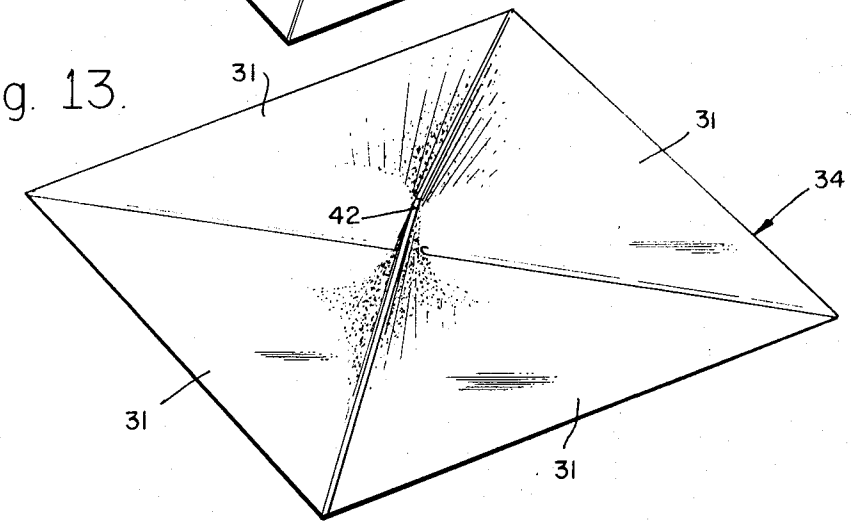
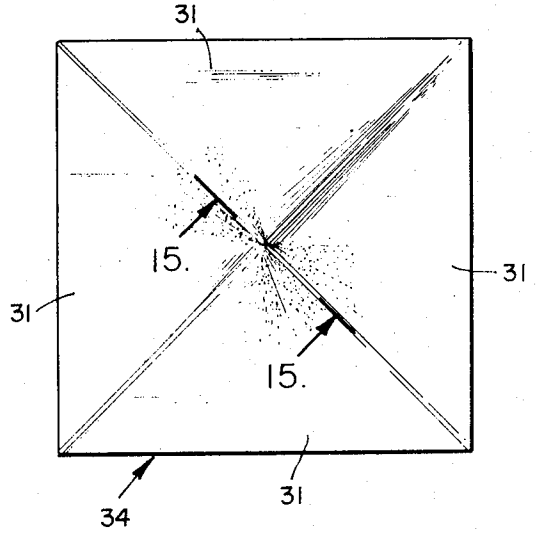


Fig. 14.



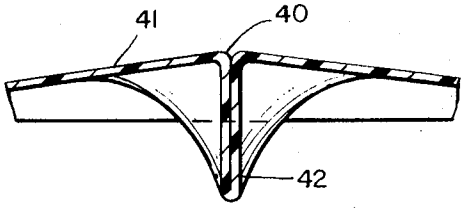


Fig. 15.

Fig. 16.

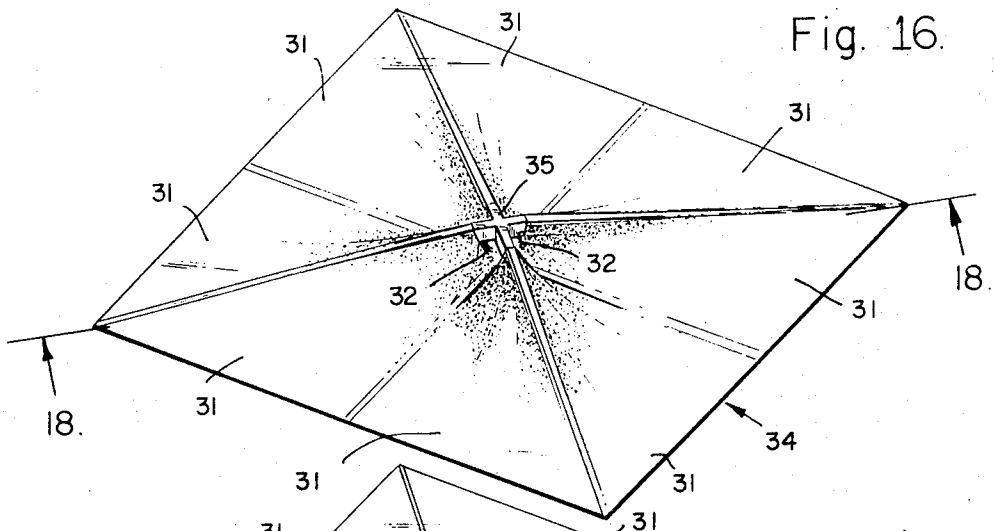


Fig. 17.

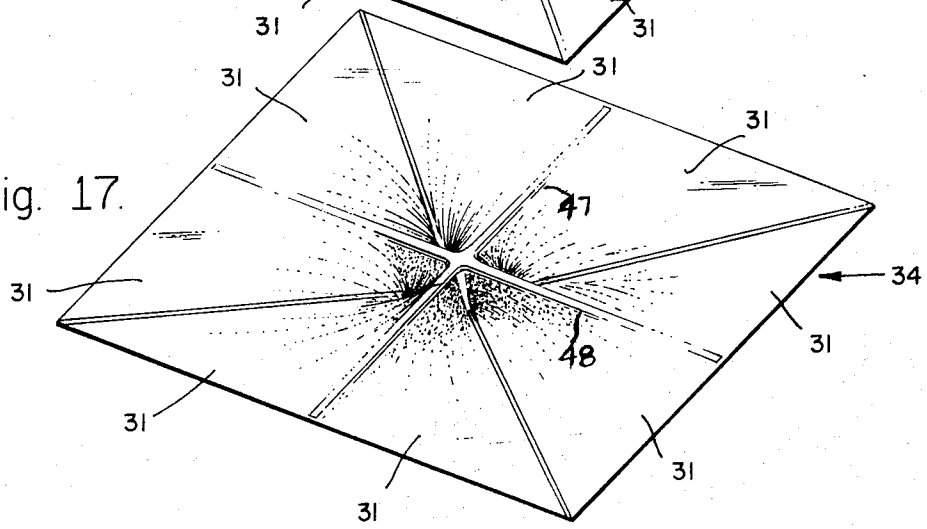


Fig. 18.

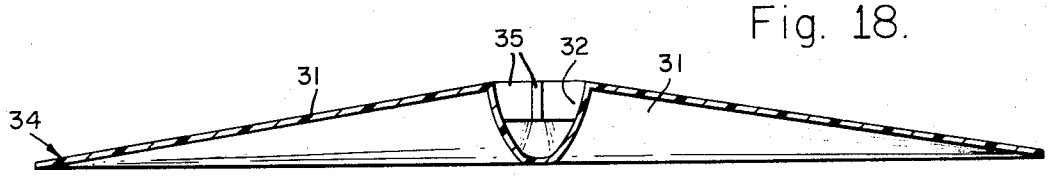


Fig. 19.

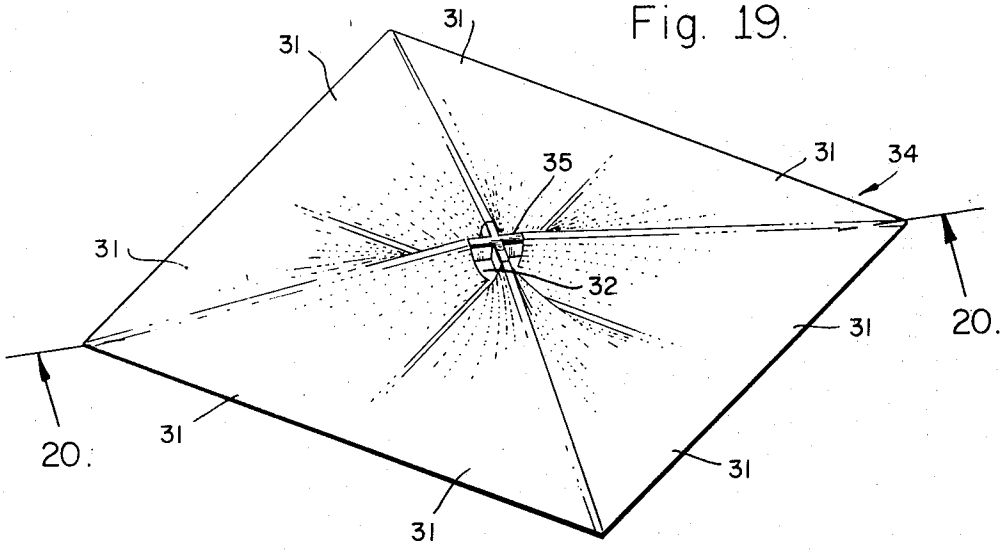


Fig. 20.

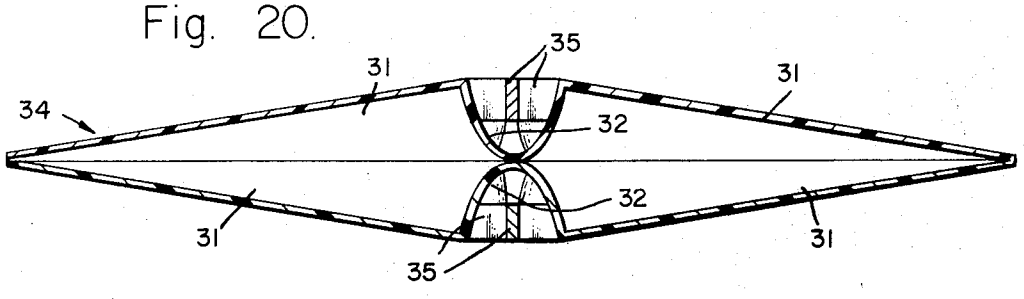


Fig. 21.

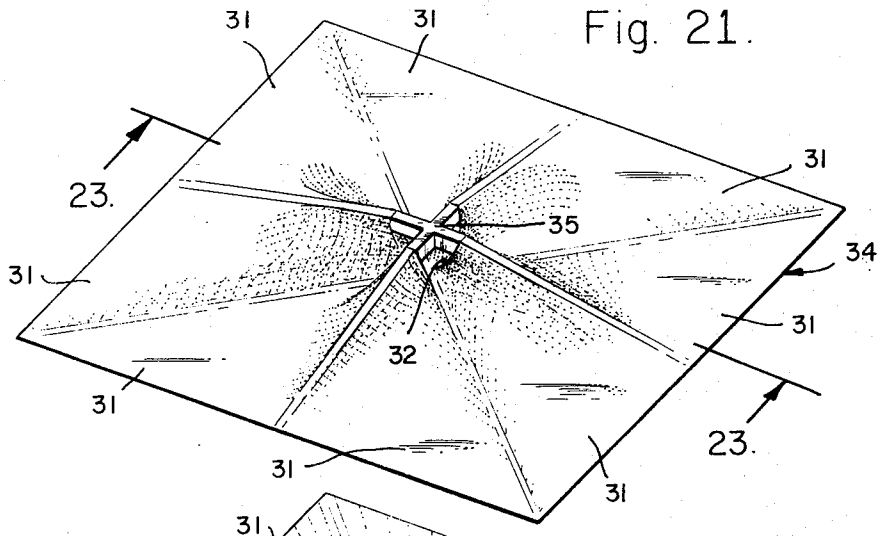


Fig. 22.

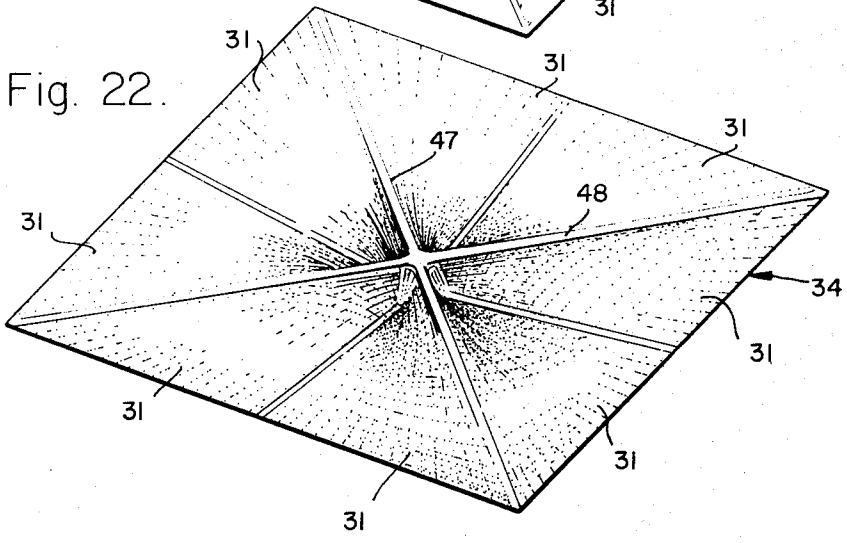


Fig. 23.

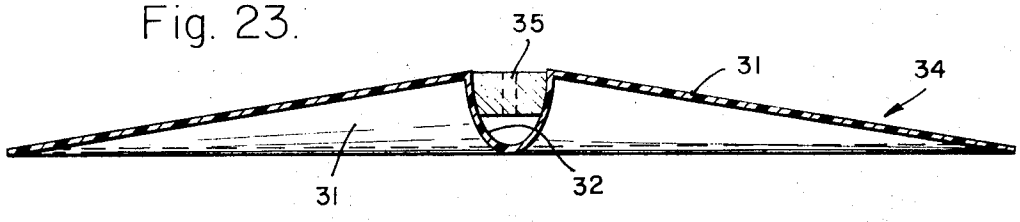


Fig. 24.

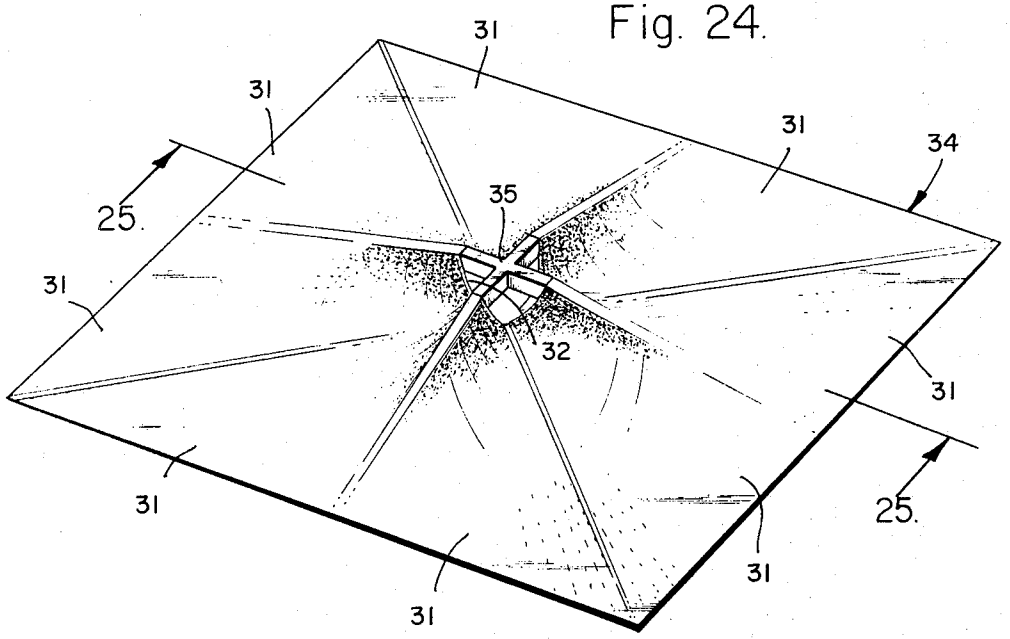
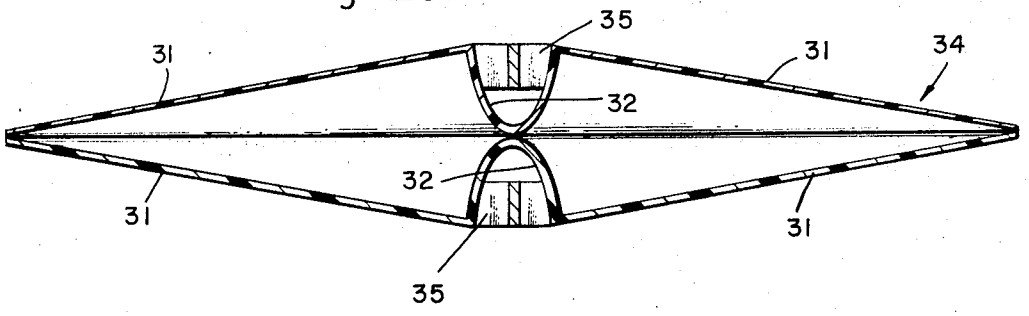


Fig. 25.



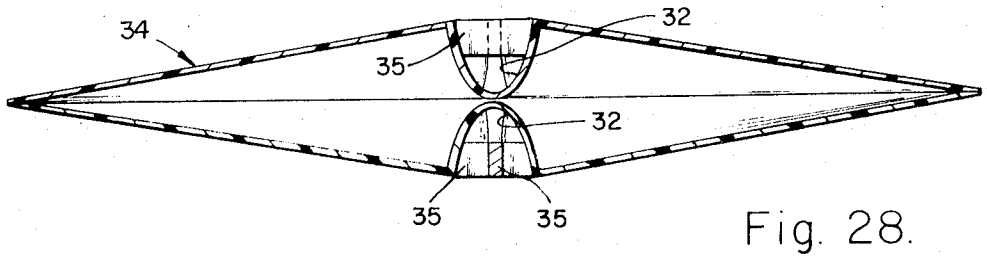


Fig. 28.

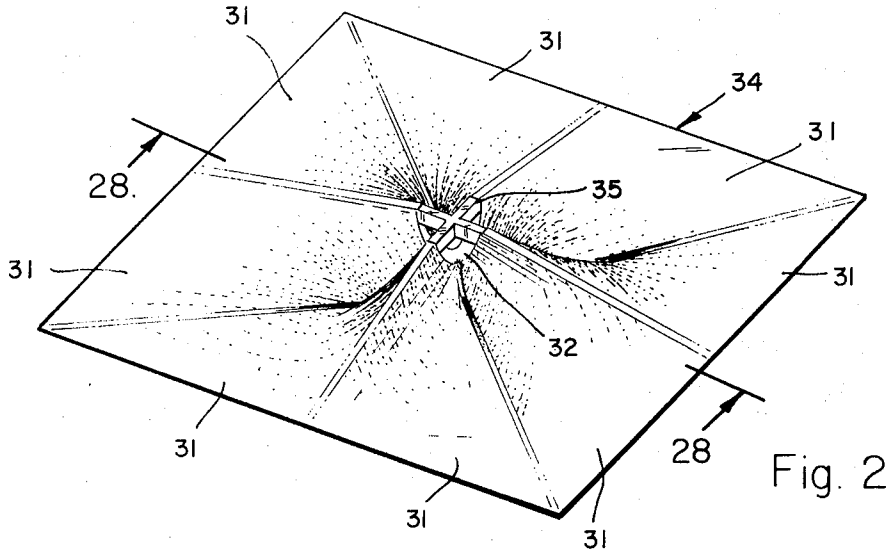


Fig. 26.

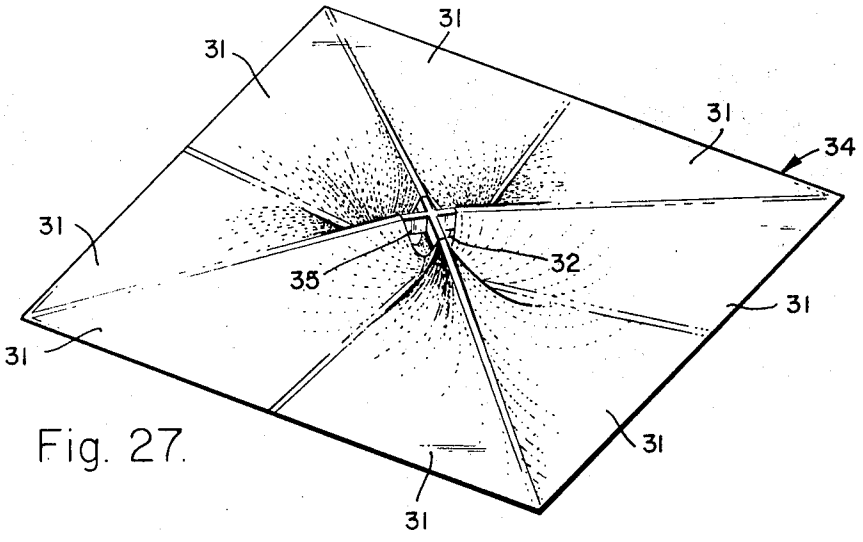


Fig. 27.

STRUCTURAL MEMBRANE PANEL FORMED FROM SADDLE SHAPED SURFACE

This application is a continuation of my now abandoned application Ser. No. 77,285, filed Oct. 1, 1970.

This invention relates to structural membrane panels and more particularly to such panels formed from a plurality of saddle-shaped surfaces bounded by a plane or skew polygon.

Membrane panels have been widely utilized to form such structural members as ceilings, walls and roofs to afford lightweight structural units that can be readily handled and which lend themselves to fabrication out of such materials as plastic, sheet metal and cast materials. Such membrane panel structures have been utilized not only for their structural characteristics but also with aesthetic considerations in mind. Many of such structures, while aesthetically pleasing, lack the structural characteristics to be desired. Others involve comparatively high fabrication costs which limits their marketability.

The structural panels of this invention not only provide structural members having high aesthetic values, but also high strength to weight ratios with excellent rigidity. Further, the panels of this invention exhibit excellent acoustical insulation characteristics having high resonant frequencies and low energy transmission. In addition, the membrane panels of this invention offer economies in fabrication and cost of materials.

It is therefore the principal object of this invention to provide improved structural membrane panels having excellent structural characteristics and aesthetic appeal which lend themselves to economical fabrication.

Other objects of this invention will become apparent as the description proceeds in connection with the accompanying drawings, of which:

FIG. **1** is a perspective view of one embodiment of the device of the invention;

FIG. **2** is a view of the embodiment of FIG. **1** taken from the opposite side thereof;

FIG. **3** is an end view of the embodiment of FIG. **1** taken along the plane indicated by **3—3** in FIG. **1**;

FIG. **4** is a perspective view of a second embodiment of the device of the invention;

FIG. **5** is a perspective view of the embodiment of FIG. **4** taken from the opposite side thereof;

FIG. **6** is a top plan view of the embodiment of FIG. **4**;

FIG. **7** is a cross-sectional view taken along the plane indicated by **7—7** of FIG. **6**;

FIG. **8** is a perspective view of a third embodiment of the device of the invention;

FIG. **9** is a perspective view of the embodiment of FIG. **8** taken from the opposite side thereof;

FIG. **10** is a top plan view of the embodiment of FIG. **8**;

FIG. **11** is a cross-sectional view taken along the plane indicated by **11—11** in FIG. **10**;

FIG. **12** is a perspective view of a fourth embodiment of the device of the invention;

FIG. **13** is a perspective view of the embodiment of FIG. **12** taken from the opposite side thereof;

FIG. **14** is a top plan view of the embodiment of FIG. **12**;

FIG. **15** is a cross-sectional view taken along the plane indicated by **15—15** in FIG. **14**;

FIG. **16** is a perspective view of a fifth embodiment of the device of the invention;

FIG. **17** is a perspective view of the embodiment of FIG. **16** taken from the opposite side thereof;

FIG. **18** is a cross-sectional view taken along the plane indicated by **18—18** of FIG. **16**;

FIG. **19** is a perspective view of a sixth embodiment of the device of the invention;

FIG. **20** is a cross-sectional view taken along the plane indicated by **20—20** in FIG. **19**;

FIG. **21** is a perspective view of a seventh embodiment of the device of the invention;

FIG. **22** is a perspective view of the embodiment of FIG. **21** taken from the opposite side thereof;

FIG. **23** is a cross-sectional view taken along the plane indicated by **23—23** of FIG. **21**;

FIG. **24** is a perspective view of an eighth embodiment of the device of the invention;

FIG. **25** is a cross-sectional view taken along the plane indicated by **25—25** in FIG. **24**;

FIG. **26** is a perspective view of a ninth embodiment of the device of the invention;

FIG. **27** is a perspective view of the opposite side of the embodiment of FIG. **26**; and

FIG. **28** is a side elevational view of the embodiment of FIG. **26** taken along the plane indicated by **28—28** in FIG. **26.**

Briefly described, the structural panels of this invention comprise an even number of contiguous saddle-shaped surfaces which are bounded by edges which form a plane or skew polygon. These saddle-shaped surfaces surround a centrally located structural element which joins the other surfaces together and which may comprise a saddle, a valley or gorge, or a cross-cap. Where a central saddle or a vally or gorge is utilized, bridging members are utilized to tie the vertices of the central structure together. The terms "saddle" and "saddle-shaped" as used herein define a surface which is anticlastic at any point thereon, i.e., has opposite curvatures at any surface point, being convex in one set of directions and concave in a second set of directions from any such point. The term "membrane" as used herein defines a structure in which the major lines of stress fall within the surface of the geometry. The saddle surfaces can be double curved (non-rulable), minimal, or ruled surfaces. Three particular saddle-shaped surfaces which are preferred are the right helicoid, which is rulable, the minimal surface, and the double ruled quadric surface which may comprise a hyperbolic paraboloid or a part of a hyperboloid of one sheet. As already noted, in certain embodiments of the invention, the central saddle of the primitive form is modified to form a valley or gorge in which case only one bridge element is required. In other embodiments, the central saddle is replaced with cross-caps or a tetrahedron.

It is to be noted that a panel constructed with either a central saddle or valley can be nested when stacked for reduced volume in shipping. The structural bridging in this instance would be accomplished at the time of installation or use. The particular surface geometry utilized is dependent upon the specific application requirements. The structural panels can be assembled in multiples in various configurations to provide a great variety of end structures.

Referring now to FIGS. **1–3**, a first embodiment of the membrane panel structure of the invention is illustrated. The panel is fabricatd from a single sheet of plastic, metal or other suitable material by forming the

sheet so that it has six similar contiguous outer saddle surfaces **31** on one side as shown in FIG. **1**, and six similar contiguous saddle surfaces **31** on the opposite side as shown in FIG. **2**, the opposite surfaces of course being in a 180° relationship to each other geometrically. The outer edges of saddle surfaces **31** form a triangular perimeter **34**. Saddle surfaces **31** surround a central saddle surface **32** which is in the form of a monkey saddle and which centrally joins the outer saddles together. The three vertices of the monkey saddles **32** are joined together by rigid bridging members **35** which are fixedly attached to these vertices by cementing or other suitable means, or which may be integrally molded with the panel. As already noted, this panel can be readily fabricated by conventional forming techniques, such as thermoforming, molding, casting, etc. This panel can be made of a relatively thin sheet of plastic or metal to provide a lightweight structure having high rigidity.

Referring now to FIGS. **4–7**, a second panel structure of the invention is illustrated. This embodiment, as the first, may be formed from a single sheet of material and has opposite similar sides which are in rotated relative relationship. In this instance, there are four saddle surfaces **31**, the edges of which form a square perimeter **34**. Saddle surfaces **31** surround a central saddle **32**. The saddle on each side of the panel is bridged by linear bridging member **35** which may be a bar which is fixedly attached to the vertices of saddle **32**.

Referring now to FIGS. **8–11**, another embodiment of the device of the invention is illustrated. This embodiment is similar to that of FIGS. **4–6** in that it includes four saddle surfaces **31**, the edges of which form a square perimeter **34**. However, rather than having a central saddle to join the other saddle surfaces together, this is replaced by valley or gorge **32**. Thus, a linear bridging member **35** is required to achieve structural integrity on only one side of the panel (that shown in FIG. **8**). On the opposite side of the panel as shown in FIG. **9**, the saddle surfaces **31** are structurally tied together by the ridge **32*a*** formed by the bottom portion of the valley on the opposite side of the panel. Ridge **32*a*** thus forms a continuous ridge with the ridges formed where the saddle surfaces **31** meet, this ridge extending diagonally across the square panel.

Referring now to FIGS. **12–15**, a further embodiment of the structural panel of the invention is illustrated. This embodiment is similar to that illustrated in FIGS. **8–11**, except that the valley **32** is pinched together to form a cross-cap **40** and the linear bridging member is eliminated in view of the fact that the cross-cap performs the structural function of the bridge. This embodiment, as for the embodiment just described, comprises four saddle surfaces **31**, the edges of which form a square perimeter **34**. As can best be seen in FIGS. **12** and **15**, the top surface has a continuous diagonal ridge **41** extending thereacross, this ridge including cross-cap **40**. As can be seen in FIG. **13**, the bottom surface has a diagonal ridge **42** running thereacross, forming an X with the ridge on the top surface, thus affording rigidity to the structure.

Referring now to FIGS. **16–18**, still another embodiment of the membrane panel of the invention is illustrated. In this embodiment there are eight saddle-shaped surfaces **31**, the edges of which form a square perimeter **34**. The saddle-shaped surfaces **31** surround central valleys **32** which join the outer saddle surfaces together. The vertices of the valleys are tied together by a bridging member **35** having a pair of cross bridge elements, as shown in FIG. **16**, to complete the structure. The side of the panel opposite to that shown in FIG. **16** is illustrated in FIG. **17** and as it can be seen has two continuous ridges **47** and **48**, each of which extends between the centers of a pair of opposite edges of the panel. These ridges which cross each other at the center of the panel lie in a common plane with each other and all of the panel edges.

Referring now to FIGS. **19** and **20**, another embodiment of the panel structure of the invention is illustrated. This embodiment is synthesized from two panels of the embodiment just described in connection with FIGS. **16–18**, with a pair of such panels being joined together in mirror-image relationship along the surfaces thereof illustrated in FIG. **17**. Thus, in this embodiment, the edges of the two panel elements forming perimeter **34** are in abutment as well as ridges **47** and **48**, which lie in the same plane as these edges.

Referring now to FIGS. **21–23**, still another embodiment of the structural panel of the invention is illustrated. This embodiment is similar to that described in connection with FIGS. **16–18** and in fact is this structure as geometrically rotated 45°. Thus, in the embodiment of FIGS. **21–23**, there are eight saddle surfaces **31** having a square perimeter **34** with central valleys **32**, the vertices of which are bridged by bridging member **35**. In this instance however, the vertices of the valleys and the bridging elements of the bridging member are aligned with points halfway between the corners of the panel rather than lying in diagonals of the panel, as in the previous embodiment. Thus, the surface of the panel illustrated in FIG. **22** (opposite to that shown in FIG. **21**) has a pair of ridges **47** and **48** which are coplanar with the edges of the panel and each other and form diagonals of the panel.

Referring now to FIGS. **24** and **25**, a further embodiment of the panel structure of the invention is illustrated. This embodiment is synthesized by joining two of the panels of the embodiment of FIGS. **21–23** together along the edges and diagonals of the surfaces of FIG. **22** in the same manner as the embodiment of FIGS. **19** and **20** is formed from that of FIGS. **16-18**.

Referring now to FIGS. **26–28**, still another embodiment of the invention is illustrated. This embodiment includes eight saddle-shaped contiguous surfaces **31**, bounded by a square perimeter **34** and which surround a central saddle **32**, the vertices of which are bridged by bridging member **35**. This embodiment is somewhat similar to that of FIGS. **4–7** in that the opposite surfaces thereof are similar, but in this embodiment there are two saddle-shaped surfaces to each edge of the polygon boundary as compared with one for each edge of the earlier described embodiment. In this embodiment, as can be seen in FIG. **27**, the opposite surfaces of the panel are similar and both have the same number of outer saddle-shaped surfaces **31** which surround a central saddle with bridging elements **35** connecting the vertices of the central saddle. These two surfaces, however, are geometrically rotated with respect to each other by 45°.

Thus, the panel structures of this invention can be simply and economically fabricated from sheets of material to provide structural units having excellent structural characteristics as well as aesthetic merit. The structure lends itself to fabrication from thermoform-

ing plastics, fiber glass, reinforced, plastic, metal and cast material, depending on the particular application requirements.

I claim:

1. A membrane panel structure comprising:
an even number of contiguous saddle-shaped surfaces, said surfaces being anticlastic at any point thereon, having concave curvature in a first set of directions and convex curvature in a second set of directions from any such point, the outer edges of said surfaces forming the perimeter of said structure which is polygonal,
a central structural element surrounded by said saddle-shaped surfaces, said central structural element joining the central portions of said saddle-shaped surfaces together to form a structural bridge therebetween.

2. The membrane panel structure of claim 1 where said central structure comprises a saddle-shaped surface and a bridge element rigidly bridging the vertices of said central saddle-shaped surface.

3. The membrane panel structure of claim 1 wherein said central structure comprises a valley and a bridge element bridging the vertices of said valley.

4. The membrane panel structure of claim 1 wherein said central structure comprises a cross-cap.

5. The membrane panel structure of claim 2 wherein there are four outer saddle-shaped surfaces and a fifth central saddle-shaped surface forming each of the opposite sides of said membrane panel, the central surface on one of said sides being oriented normal to the central sur-face on the opposite side, said bridging elements comprising elongated bar members bridging each of said central saddle-shaped surfaces.

6. The membrane panel structure of claim 1 wherein the outer edges of said surfaces are co-planar.

7. A membrane panel structure comprising:
an even number of contiguous outer saddle-shaped surfaces, said surfaces being anticlastic at any point thereon, being convex in a first set of directions and concave in a second set of directions from any such point, the outer edges of said surfaces forming the perimeter of said structure and being polygonal,
a central saddle-shaped surface surrounded by said outer surfaces and joining the central portions of said outer surfaces together, and
bridge means for bridging the vertices of said central saddle surface to rigidly tie said vertices together.

8. The structure of claim 7 wherein the number of said outer saddle-shaped surfaces is six for each of the sides of said panel structure, the polygonal perimeter of said structure being triangular.

9. The panel structure of claim 8 wherein said central saddle-shaped surface is in the form of a monkey saddle having three vertices, said three vertices being joined together by said bridging means.

10. The membrane panel structure of claim 7 wherein the number of said outer saddle surfaces is four for each of the opposite sides of said structure, there being a central saddle for each of said sides, said central saddles each having two vertices, bridging means comprising a linear bar member interconnecting said vertices, the vertices and the bar member on one of the sides of said panel structure being oriented orthogonally to those on the opposite side thereof.

11. The structure of claim 7 wherein there are eight outer saddle-shaped surfaces on each of the sides of said panel structures, the outer edges of said outer surfaces forming a square, a central saddle-shaped surface on each of the panel structure sides, each of said central surfaces having two pairs of mutually orthogonal vertices, the saddle-shaped surfaces on the opposite sides of said panel structure being geometrically rotated 45 degrees with respect to each other.

12. A membrane panel structure comprising:
an even number of contiguous outer saddle-shaped surfaces, said surfaces being anticlastic at any point thereon, having concave curvature in a first set of directions and convex curvature in a second set of directions from any such point, the outer edges of said surfaces forming the perimeter of said structure and being polygonal,
a central valley-shaped surface surrounded by said outer surfaces and joining the central portions of said outer surfaces together, and
bridge means for bridging the vertices of said central valley-shaped surface to rigidly tie said vertices together.

13. The membrane panel structure of claim 12 wherein there are eight outer saddle-shaped surfaces, the outer edges of said surfaces forming a square, one of the sides of said structure including said central valley-shaped surface, the other of the sides of said structure having a pair of mutually orthogonal ridge portions formed therein, said ridge portions extending between the opposite edges of said structure and running through the center thereof, said ridge portions further being coplanar and in the same plane as the edges of said structure.

14. The structure of claim 13 wherein said coplanar ridge portions extend between opposite corners of the square formed by said structure to form diagonals thereof.

15. The structure of claim 13 wherein said ridge portions extend between points at the center of opposite edges of said membrane panel.

16. The structure of claim 14 and further including a second similar membrane panel structure joined to the first membrane panel structure along the ridge portions and the edges thereof to form an integral structure.

17. The structure of claim 15 and further including a second membrane panel structure similar to said first mentioned membrane panel structure, said two membrane panel structures being joined together along the ridge portions and the edges thereof to form an integral structure.

* * * * *