

April 26, 1960

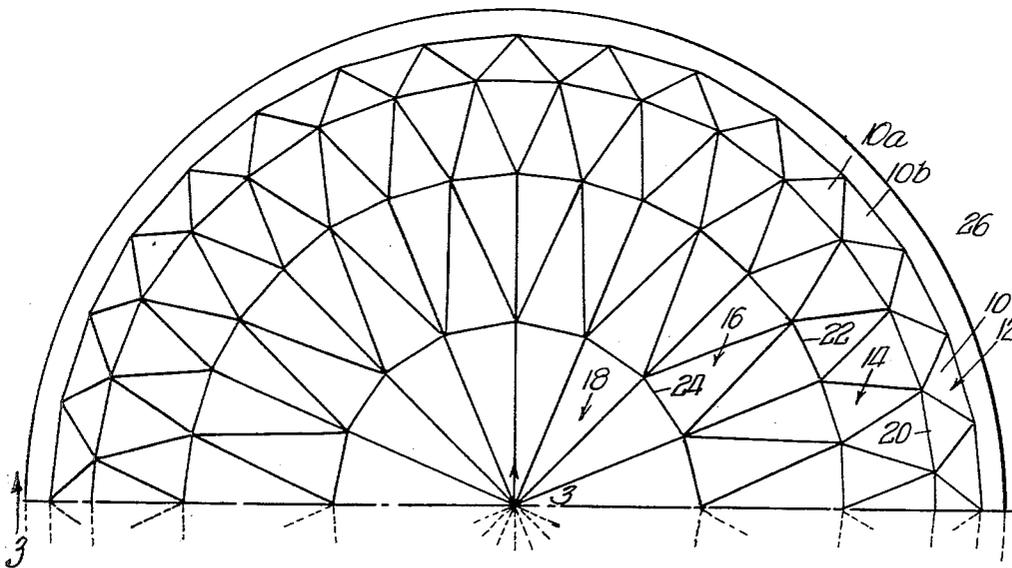
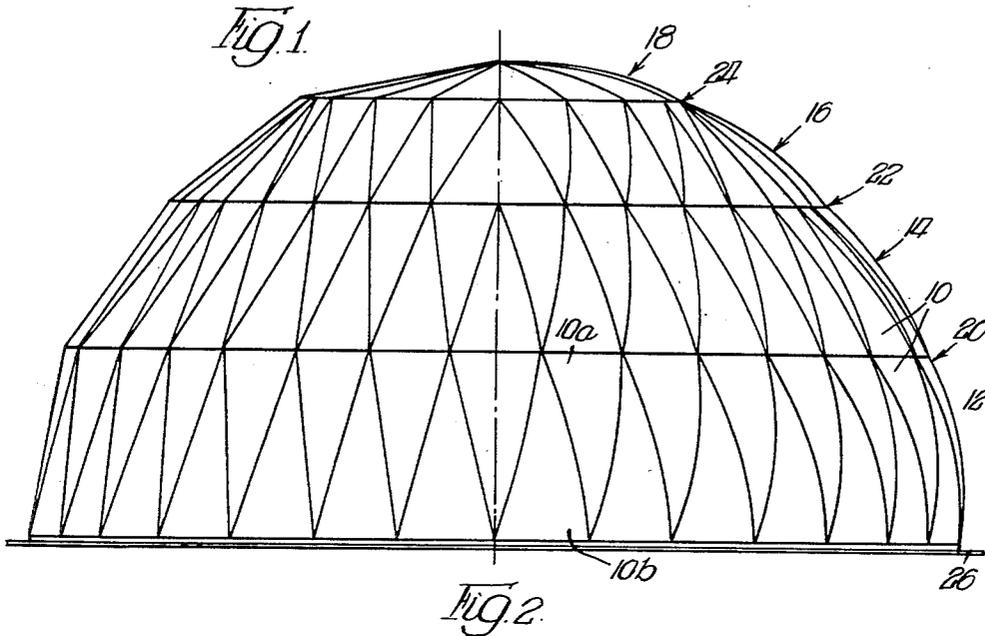
A. M. RICHARDSON ET AL

2,934,075

INFLATABLE STRUCTURE

Filed Aug. 16, 1955

2 Sheets-Sheet 1



INVENTORS.
Ambrose M. Richardson,
George W. McCauley,
By *Wilkinson Huxley Byron & Stone*
attys

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2 Sheets-Sheet 2

Fig. 4

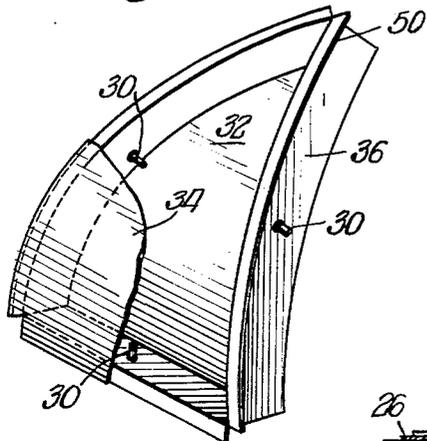


Fig. 3

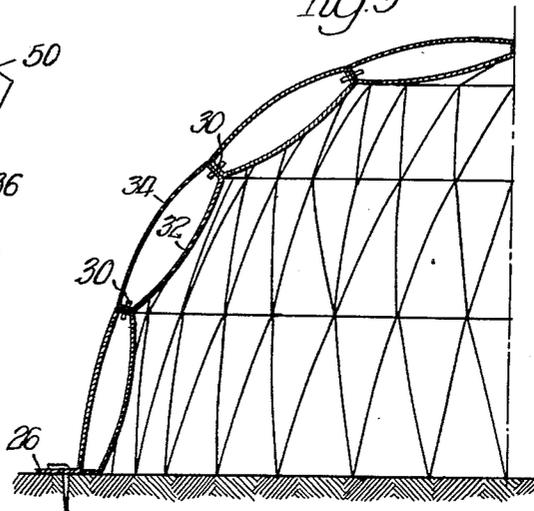


Fig. 5

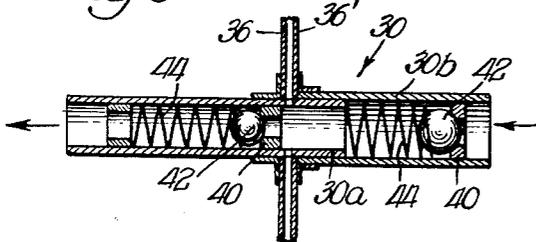


Fig. 6

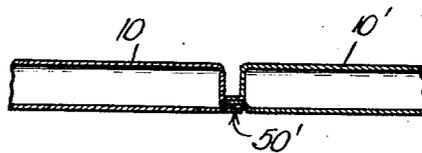
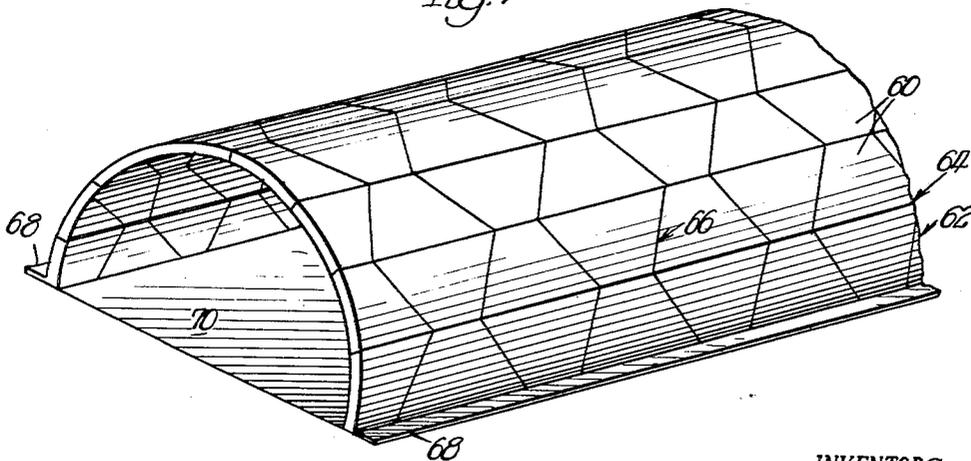


Fig. 7



INVENTORS:
Ambrose M. Richardson,
George W. McCauley,
By Wilkinson Huxley Byron & Stume
attys

1

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INFLATABLE STRUCTURE

Ambrose M. Richardson and George W. McCauley,
Champaign, Ill.

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18 Claims. (Cl. 135—1)

This invention relates to a shelter structure, and more particularly to such a structure that is inflatable, which when inflated comprises in its unitary form both a structural framework and an integument of high strength-to-weight ratio that may be adapted to areas of almost any size. Thus, the shelter can range from a small one-man type of shelter, such as might be used for survival and temporary housing purposes by the Armed Forces, up to proportions of a roof or canopy suitable for covering stadia, towns, or large areas of countryside wherein it is desired to provide and maintain special conditions of climate.

In its broadest aspects, the invention embraces a cellular structure of material which, when deflated, is pliable and capable of being folded to occupy a relatively small space, and which, when inflated, is relatively rigid by virtue of the membrane of which the cells are formed being tensioned by internal fluid pressure, thus causing the seams which occur between adjacent cells to become structural tension members. By making the cells of preferred polygonal shape, these tension members, in relation to one another, are disposed like the elements of a truss system to impart to the structure a strength and rigidity capable of withstanding heavy static loads, as well as dynamic forces, such as those realized from snow and wind.

The advantages of the present invention are best expressed in one of two basic architectural forms, and their modifications. These are the hemispherical dome, and the semicylindrical arch, the latter resembling what is commonly known as the Quonset hut type of structure. Elementally, the cells preferably take the form of polygons having not less than three principal sides, with their included angles being acute angles.

The primary form is, therefore, a triangular cell, which lends itself to the hemispherical dome construction; and the trapezium, which is especially well adapted to the semicylindrical structure, although the invention embraces the use of either for any type of structure that may be adapted from these shapes. Any flexible fabric capable of being hermetically sealed is adapted to the usages of the present invention, but it is preferred that the materials employed be in plentiful supply and of a non-critical nature, and ones that possess an optimum strength-to-weight ratio per unit of area to be enclosed. The development of modern plastics offers many possibilities in this regard, and one of these, available on the commercial market under the brand name "Mylar," is well suited to the purposes of the present invention.

The cell form of the present invention, while not limited to any shape or size within the demands of operativeness, preferably is one of two kinds:

The first of these is made from two pieces of fabric, such as plastic membrane, formed to identical polygonal shape and size, arranged in congruent relation, and hermetically sealed around their edges to form a cell. A plurality of cells formed in this manner are joined by

2

overlapping the edge seams of contiguous cells, preferably in sandwiched relation, by heat sealing methods, although any other method to which the material lends itself is within the purview of the invention. The cells are interconnected by conduits, or preferably a check valve system, so that fluid pressure introduced to one cell is transmitted to adjacent cells, to the end that the internal pressure of all the cells becomes equalized. In this type of construction, the membrane of which the cells are formed is placed under tension by pressure in the order of two pounds above normal atmospheric pressure, and the seams between the cells likewise become tensioned so as to impart strength and rigidity to the whole.

The other type of cell is one which is better adapted to field assemblage and may be of triangular, trapezoidal, or even hexagonal form. Using the triangular form as a typical example, two triangular pieces of membrane are provided, one of which is smaller than the other, and these are joined at their corresponding edges by hermetic flanges of the same material to form a pie-shaped wedge, which, when moderately inflated, constitutes what in solid geometry might be defined as the frustum of a triangular pyramid regarding the outer membrane as the base. For a hemispherical dome, such a cell might be said to resemble a triangular plug removed from a pumpkin, with the wall thickness of the plug being tapered along radii emanating from the center of the pumpkin. Valve members having stems adapted to interconnect between adjacent cells are projected from the central portions of the flanges. Thus, a "pneumatic brick" is provided which can be assembled in the field to form igloo shapes, or in the case of trapezoids, cylindrical shapes, with the size of the completed structure limited only by the size and shape of the individual cells. In this respect, it will be understood that large structural enclosures will demand larger component cells than the smaller enclosures.

The invention admits of the construction of transparent or translucent domes or arches through which sunlight and radiant heat may be transmitted. Also, the degree of translucency or opacity in such constructions may be controlled by a pigment included in the plastic, or by means of "smoke" or other suspended particles of appropriate characteristic introduced in the inflating fluid. Where the exclusion of light is desirable, opaque cells may be employed, and it is possible to omit one or more cells in a group to provide windows and doorways. It is possible further to use a combination of opaque and transparent or translucent cells to provide lights in an otherwise opaque structure.

Referring now more particularly to the drawings, in which like references of character identify like parts throughout:

Figure 1 is a side elevational view of a hemispherical dome constructed upon the principles of the present invention, the left half of the center line of which shows the geometry of the cell construction without regard to deformation from inflation, and the right side of which illustrates the appearance of the structure as it is rendered bulbous by the inflating pressure within the cells;

Figure 2 is a half-plan view of the construction shown in Figure 1, it being understood that the structure there shown is intended to encompass 360°;

Figure 3 is a quarter sectional view taken along line 3—3 of Figure 2;

Figure 4 illustrates a triangular cell having the form of the frustum of a triangular pyramid;

Figure 5 shows one form of check valves connected between contiguous cells;

Figure 6 is a sectional view showing the seam by which adjacent cells are connected; and

Figure 7 is a perspective view of a semicylindrical arch constructed of trapezoidal-shaped or hexagonal-shaped cells.

As shown in Figures 1, 2 and 3, a dome structure is made up of a plurality of triangular cells 10, which are developed in tiers 12, 14, 16 and 18, separated by the parallel latitudinous seams 20, 22 and 24. The cells in each tier are arranged alternately in obverse and inverse relationship in complementary fashion, so that by making the inverted cells 10a of the same height as the obverse cells 10b, but of smaller dimension along the base, an inwardly inclined tier is provided, the upper rim 20 of which is parallel to the base of the tier, but of smaller perimetric extent.

Tier 14, similarly constructed of obverse and inverse triangular cells, the latter of which are smaller at the base than the former, is mated to the tier 12 at the latitudinous seam 20, terminating at its upper extent in a similar seam 22 parallel to the seam 20.

Tier 16, similarly constructed, is joined to the underlying tier 14 at the seam 22, leaving a circular opening that is closed by a plurality of triangular cells which radiate from a common center of the pole. These may effect a complete closure or may be truncated so as to provide a smaller aperture for ventilation or flue purposes at the center of the structure.

A base flange 26 is provided around the base of the construction as an integral part of the lower tier of cells, by means of which the structure may be fastened to the ground by stakes, or mounted upon sills or the eaves of an underlying building, as may be required. In this arrangement, it will be noted that each tier is composed of two sizes of cells, except that the cap-piece 18 is adapted to be made of triangular cells of the same size, and is preferably so constructed.

The diagonal seams of one tier register with those of adjacent tiers and are thus propagated across the entire structure in diagonal relation to the other seams, so as to effect a cross bracing comparable to that obtained in a truss system. The parts so assembled and inflated form an exceedingly strong and rigid body that is not materially weakened or disturbed by the omission of one or more triangular cells at local areas to provide access openings or vents.

As appears in Figure 3, the cells are interconnected by valves 30, which are designed to permit the cells to be inflated from a single valve stem (not shown) provided for this purpose either at the polar cells or at any convenient location at the base of the structure.

As shown in Figure 4, each cell is constructed of an inner web or membrane 32 and an outer web or membrane 34, which are connected by flanges 36 so as to make a hermetic closure penetrated by the valve stems 30 at midpositions of the three flanges.

As appears in Figure 5, flanges 36 and 36' between adjacent cells are connected by telescoping the protruding portion 30a of one valve stem within the internally extending valve stem 30b of the neighboring cell. Each of these cells is provided with a valve seat 40 that is adapted to be maintained in closed position by ball valves 42 in response to the bias of springs 44 contained within the valve stems. Pressure in excess of two pounds is capable of unseating the ball valves 42 so as to permit the transmission of fluid pressure through the valves in the direction of the arrows in Figure 5. Since the cells become adequately inflated at a pressure as low as two pounds above the normal atmospheric pressure, the springs 44 withstand pressures up to two pounds without unseating and so are effective in maintaining the cells in inflated condition even where the pressure is applied at the side of the ball valve tending to unseat the same.

Obviously, pressures in the opposite direction are resisted by the seating of the ball valves upon their seats 40 in each case. By an arrangement of this kind, it is

possible to sustain a puncture in any one cell at any place in the structure without permitting the sustaining pressure to escape from adjacent cells.

By this system, it is also possible to take a number of pneumatic bricks, as appear in Figure 4, and assemble them together by joining the valves in the manner already described to provide an arch construction that may be either hemispherical or semicylindrical. The inflating pressure is usually sufficient to render the joints between the cells assembled in this manner weather-tight without doing more, but if desired a sealing compound may be first applied to the confronting surfaces of the flanges 36, or an overlapping margin 50 (Figure 4) may be provided around the external edge of each cell to cooperate with similar margins on the adjacent cells, which may be sealed together to provide a weather-proof joint. In Figure 6, flanges of this type are shown joined between adjacent cells 10, 10', to form an overlapped seam 50' between them.

In Figure 7 a semicylindrical arch type of construction embodying the present invention is formed out of trapezoidal cells 60, all of which are of the same size, and which are joined together and valved in any of the ways hereinbefore discussed. Triangular cells of the same size may also be adapted to this type of structure.

Alternately, cells of hexagonal shape may be formed by merging any two of the cells 60 at their base lines. In the latter case, trapezoidal shaped cells are needed to fill in the openings left in the lowermost courses between the hexagons. As in the case of the hemisphere already described, the trapezoidal cells are arranged obversely and inversely in alternate relation to each other to provide courses 62, separated by parallel seams 64 which extend along the cylinder in parallel relation to its axis. The edges of the trapezoidal cells are joined to constitute diagonal seams 66 which intersect longitudinal seam 64 to provide a truss structure in tension which resists static and dynamic loads.

At the foot of the arch, flanges 68 are provided for joining with underlying structure or the ground to prevent the arch from spreading and flattening. In the case of a survival shelter, this may be accomplished by joining the feet of the arch to a membrane of fabric 70, which in its cross dimension is equal substantially to the diameter of the arch, and which acts as a chord member in tension to prevent the feet of the arch from spreading apart.

Under certain conditions, the inflating fluid may be a liquid, but the increase in the unit weight of the structure sustained by the use of liquids for such purpose does not justify the substitution.

In small shelters, it is contemplated that the inflating gas may be compressed air or carbon dioxide carried in cartridges for this purpose, which may be attached to the master valve stem of the collapsed shelter and actuated to inflate the same. In the larger structures, a compressed air pump is the most likely means to effect the inflation.

In all of the modifications herein disclosed, it is contemplated that the seams between cells may be made by butting the edge flanges of such cells and applying to one or both faces of the butt-joint an adhesive tape, either of the pressure-sensitive kind or of the type requiring both heat and pressure, to join the edges together and to seal the joint. Such tapes may extend across the structure in unbroken lengths for as long a distance as such seams are continuous and may cross and be joined to similar taps of intersecting seams.

We claim:

1. An inflatable building element that is relatively pliable when deflated and relatively rigid when inflated, comprising a pair of principal walls of identical polygonal shape hermetically joined together in congruent parallel relation to form a fluid tight cell, the included angles of

5

three sides of the polygonal shape of which are acute angles, and means for connecting said element to similar adjacent elements, said means including valving for passing fluid to and from said fluid-tight cell.

2. The element of claim 1, in which the polygonal shape of said cell is triangular.

3. The element of claim 1, in which the polygonal shape of said cell is trapezoidal.

4. The element of claim 1, in which one of the principal walls is smaller than the other principal wall, said walls being hermetically joined at their edges by tapered flanges which impart to the cell the shape of the frustum of a triangular pyramid when inflated.

5. A pneumatic structure composed of a plurality of cells that are flexible when collapsed and substantially rigid when inflated, said cells being joined at their edges to form seams, said seams constituting tension members throughout said structure when said cells are inflated, certain of said seams intersecting other of said seams diagonally to form a truss system throughout said structure.

6. The invention of claim 5, said structure being a hemispherical shell or dome.

7. The invention of claim 6, said cells being triangular and arranged in tiers composed of obvert and invert cells alternately arranged, said invert cells being of less dimension across the base than said obvert cells.

8. The invention of claim 7, the base of the obvert cells in the lowest tier defining the base of the hemisphere, the bases of said invert cells joining with the bases of the obvert cells of the next tier above to define latitudinous seams parallel to said base.

9. The invention of claim 5, said structure being a semi-cylindrical arch.

10. The invention of claim 9, said cells being polygonal in shape, said polygon having a base and two sides arranged at acute angles respecting said base.

11. The invention of claim 10, in which the bases of said cells constitute longitudinally extending seams, said seams defining longitudinal courses of said cells joined together.

12. The invention of claim 10, in which said cells are triangular.

13. The invention of claim 10, in which said cells are trapezoidal.

14. The invention of claim 9, in which said cells are hexagonal.

15. In an inflatable structure, a plurality of polygonal cells joined together to define seams between said cells, said seams constituting a diagonal bracing system for said structure when said cells are inflated, check valves affording intercommunication between said cells to equalize the pressures therein, said valves being effective to retain static pressures within each cell at a definite minimal value above that of the ambient atmosphere, without regard to lower pressure differences among adjacent cells, said

6

valves having means responsive to pressures higher than said definite minimal value, and to dynamic conditions of flow, to transmit fluid pressure to adjacent cells of lower static pressure.

16. An inflatable structure comprised of a plurality of cells, each cell being made of two principal walls of flexible membrane spaced apart by side walls of flexible membrane, said principal and side walls being hermetically joined together around their edges, said edges being essentially straight to define a polygon in which two of said side walls form acute angles at their points of junction with a third side wall, said edges and side walls of adjacent cells being joined together to form seams, said seams defining tension members when said cells are inflated to distend said walls in tension.

17. The structure of claim 16, in which said cells are oriented in the structure with respect to each other to project at least some of said seams across said structure in diagonally crossed relation to other of said seams to constitute a truss system of said tension members.

18. An inflatable structure comprised of a plurality of cells, each cell being made of two principal walls of flexible membrane hermetically joined together around their edges, said edges being essentially straight to define a polygon in which two principal edges form acute angles at their points of conjunction with a third principal edge, the edges of adjacent cells being joined to form seams, said seams defining tension members when said cells are inflated to distend said walls in tension, said seams between adjacent cells being provided with intercommunication means by which differences in fluid pressure within the cells may become substantially equalized.

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