Feb. 16, 1965 O. W. NEUMARK 3,169,542

INFLATABLE BUILDINGS

Filed Jan. 17, 1962 2 Sheets-Sheet 1

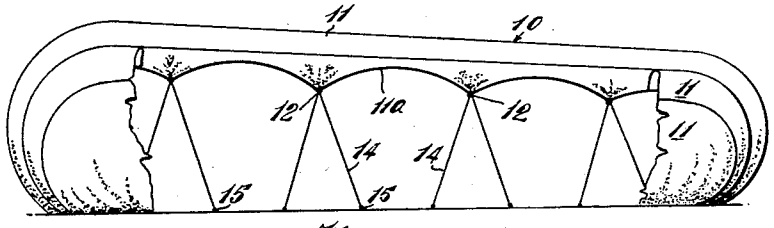

Fig. 1.

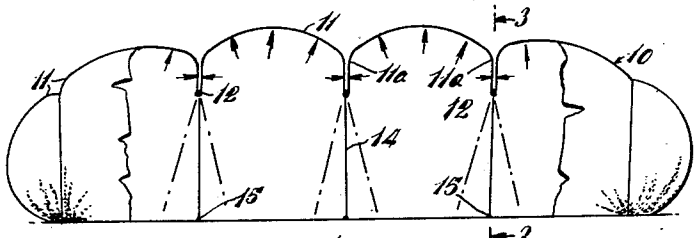

Fig. 2.

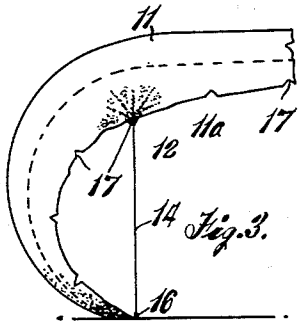

Fig. 3.

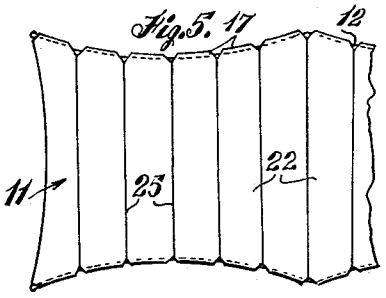

Fig. 5.

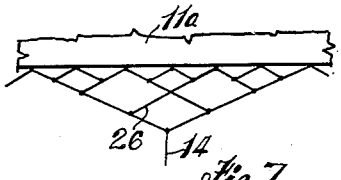

Fig. 7.

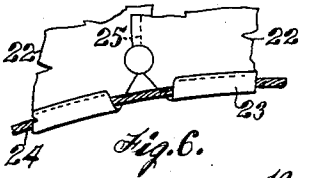

Fig. 6.

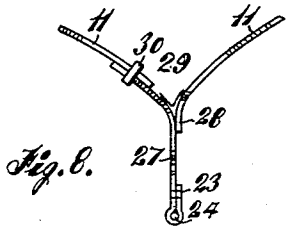

Fig. 8.

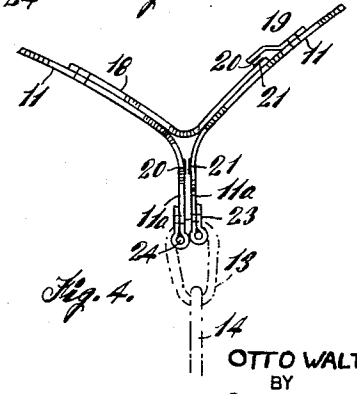

Fig. 4.

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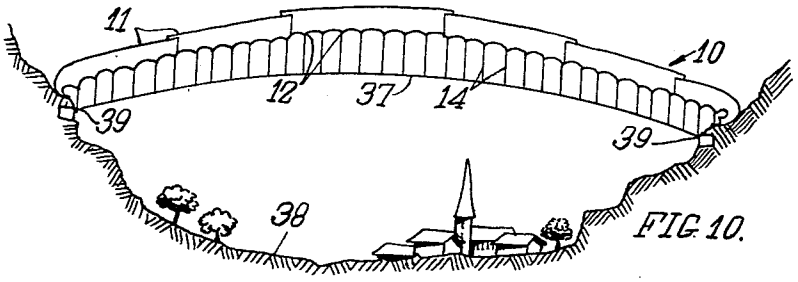

FIG. 10.

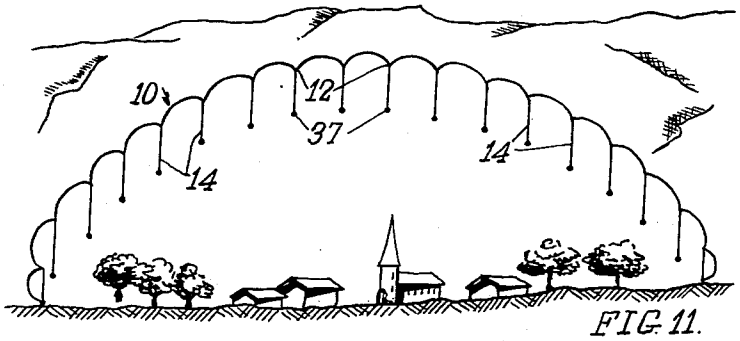

FIG. 11.

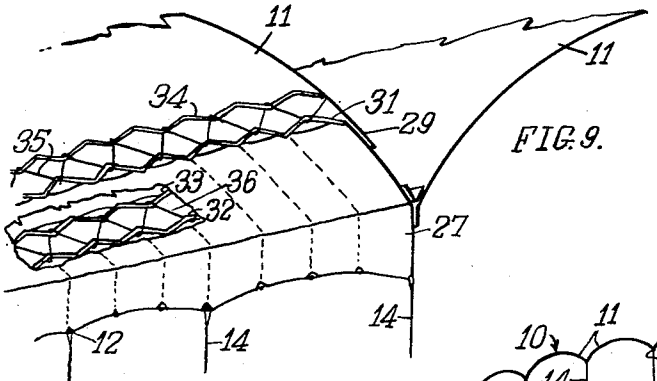

FIG. 9.

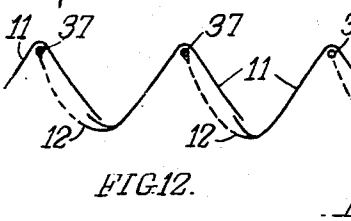

FIG. 12.

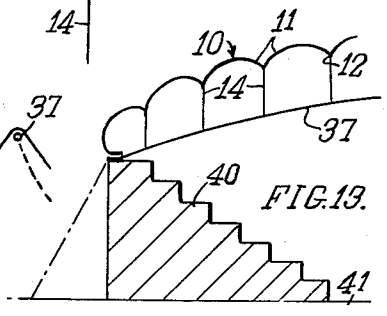

FIG. 13.

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INFLATABLE BUILDINGS

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7 Claims. (Cl. 135—1)

This invention relates to inflatable buildings of the type comprising a canopy of flexible impermeable material which is adapted to be supported solely by a maintained internal air pressure in the region of 0.03 to 0.5 lb. per sq. in. (gauge) and has means for preventing any excessive leakage of such air between its periphery and the ground.

Such buildings (conveniently termed "air supported" to distinguish them from other inflatable types in which the canopy is double-walled and divided into several inflatable segments, or is assocaited with a skeleton of inflatable tubes) are commonly made in a domed or "blister" shape, but have also been designed with a part-cylindrical body portion and rounded ends, a form which is particularly suitable for temporary warehouses, exhibition halls and the like.

Theoretically the ideal cross-sectional shape for such a building is semi-circular, because the uplift forces resulting from inflation then act vertically upon the peripheral anchorage of the canopy, but where the building is to be of considerable span (as in the case of an exhibition hall) this arrangement involves an excessive overall height and renders the building particularly subject to the action of winds which by producing a reduction of atmospheric pressure over a considerable part of its surface and hence increasing local differences between the internal and external pressures, may very greatly augment the normal hoop stress in the canopy material, usually a rubberized fabric.

The wind resistance offered by any air-supported building, and also the quantity of canopy material required to span a given width of floor, can obviously be reduced by bringing the centre (or axis) of curvature below ground level, but this will necessitate a greater radius of curvature, and hence a greater stress in the canopy material, than is the case with a building of semi-circular cross-section, and furthermore as the centre (or axis) of curvature of the canopy is brought below ground level, the uplift forces acting upon its peripheral anchorage acquire an increasing inward horizontal component whose effect is to disturb the security of the air-seal between the canopy and the ground.

The total uplift load, being dependent upon the floor area of the building and the difference between the internal and external air pressures on the canopy, is of course subject to increase by wind forces affecting the pressure differential as above described.

The present invention is based upon an appreciation of the above-mentioned factors, and has for its object to provide an improved construction of air-supported building which can be made of wide span without the use of heavy and expensive material and hence without affecting the portability of the buildings when deflated.

In the case of buildings with very wide spans there may be provided additional anchorages including cables, the ends of which are fixed to suitable supports at higher levels than the area being covered. Guy lines from the canopy are attached to the cables.

These additional anchorages are conveniently arranged in parallel rows, thus producing a reeded effect in the canopy, and preferably the load taken by any one row of such additional anchorages is distributed by attachment of the individual tethering means to a continuous flap or series of flaps dependent from the canopy, such flap or flaps having inverted catenary profiles between its or their successive conections to the tethering means above mentioned.

Longitudinal and/or lateral sway of the inflated building with reference to its peripheral anchorage may be resisted by tethering any given point on the canopy, or on one of the dependent flaps aforesaid, to two pickets or the equivalent which are longitudinally and/or laterally displaced from the vertical through such point.

Normally the peripheral and additional anchorages aforesaid will be made direct to the ground (as by means of screw-pickets), but when the canopy is of very wide span or when it is important to avoid obstruction of the area covered thereby, each row of guys forming the additional anchorages may be connected to a strong cable whose ends are fixed to the ground or to artificial supports, which may be situated at a generally higher level than the area to be covered.

In the accompanying drawings:

FIG. 1 is a part-sectional side elevation of an air-supported building embodying the present invention.

FIG. 2 is a part-sectional end elevation of the same.

FIG. 3 is an enlarged section on the line 3—3 of FIG. 2.

FIG. 4 is a fragmentary cross-sectional view showing a preferred arrangement of the joint between juxtaposed canopy panels.

FIG. 5 is a fragmentary plan view of a preferred form of canopy panel.

FIG. 6 shows a detail of such canopy panel drawn to a larger scale.

FIG. 7 is a fragmentary plan view showing an alternative form of canopy panel, and

FIG. 8 is a view corresponding to FIG. 4 but showing canopy panels of yet another form and one method of joining the same together.

FIG. 9 is a fragmentary perspective view illustrating an alternative method of connecting adjacent canopy panels of the form shown in FIG. 8.

FIGS. 10 and 11 are views corresponding to FIGS. 1 and 2 respectively, but showing the building arranged to roof over a valley.

FIG. 12 is a schematic view showing the canopy of FIGS. 10 and 11 in course of erection, and,

FIG. 13 is a fragmentary view corresponding to FIG. 10 but showing a modified arrangement.

As illustrated in FIGS. 1 and 2 the method of construction forming the subject of the present invention results in an air-supported building of generally rectangular planform, the required canopy 10 being made up of a plurality of elongated panels 11 of flexible impermeable material (such as a coated fabric) which are disposed lengthwise of the building and whose lateral margins 11*a* are arranged to make substantially air-tight contact with one another when the canopy is inflated.

For this purpose each panel 11 is provided with primary tethering point 12 at corresponding equally spaced positions along both longitudinal edges, which are shaped to inverted catenary profiles between such points, the several panels 11 being assembled side-by-side with the

tethering points 12 at one edge of each panel opposite those at the juxtaposed edge of the next panel.

A convenient size for each panel 11 is 120 feet long by 60 feet wide, but should the required length of the canopy 10 exceed that of a single panel, two or more of the latter may be suitably overlapped, with the tethering points 12 of each panel in register with those of the panel or panels overlapping it.

Opposed tethering points 12 of the laterally-juxtaposed panels 11 (or multi-panel canopy sections) are connected together by snap-links 13 (FIG. 4) or equivalent devices from which adjustable guy-lines 14 lead to screw-pickets 15 driven into the ground in parallel rows along the ground-plan of the building, whose dimensions are of course substantially smaller than those of the assembled canopy 10.

The periphery of the latter is located in known manner, either by attachment to screw-pickets 16 at the adjacent corners of the several panels 11 or canopy sections, or by providing at the ends of each such panel or section a tube or pocket for ballasting material.

Inflation of the canopy 10 is effected by means of flexible trunking from an external ventilating fan while the juxtaposed edges of the panels 11 or canopy sections are temporarily held together by spring clips or other means. It may be found desirable to inflate the canopy from one side, the several panels or sections having previously been laid out upon the ground in echelon towards that side so that they will inflate consecutively, the pressure built up beneath any given panel or section tending to seal the joint beneath that panel or section and the one next to be inflated.

Leakage of air beneath the periphery of the canopy 10 may be substantially eliminated by so arranging the guy attachments to its peripheral parts that the latter engage the ground over a width of several feet and are held in contact therewith by the internal pressure to provide a "reflected" seal. When marked uneveness of the ground makes this difficult, loose strips of flexible impermeable material may be arranged to overlie the junction of the canopy with the ground so as to fill out all concavities and thus form supplementary "reflected" seals.

The juxtaposed marginal portions 11*a* of the several panels are restrained by the guy-lines 14 during inflation of the canopy 10 so that the latter eventually assumes a reeded form as shown in FIGS. 1 and 2, the internal pressure acting radially upon the curved surfaces of the panels whilst pressing tightly together with inwardly directed flaps represented by their tethered marginal portions 11*a*, and thus rendering unnecessary any clips or other means previously applied to such portions.

The "round-down" shown at the ends of each reed is produced by suitably gathering up the marginal portions of the adjacent panels 11 as shown in FIG. 3 for which purpose the longitudinal edge of such panels are provided with intermediate tethering points 17, any required number of which may be engaged by a suitable snap-link 13 or the like associated with a further guy-line 14. A similar gathering up of the marginal portions 11*a* may be necessary where the ends of the panels are anchored to the ground, but the resultant folds in the canopy material do not significantly affect the air-tightness of the building, the rate of leakage from the latter being readily maintainable at the minimum needed for effective ventilation.

It will be understood that a short tunnel or vestibule of rigid or relatively rigid construction equipped with doors to serve as an air-lock for inward or outward traffic of personnel or vehicles, may be pushed through the canopy 10 at any of the self-sealing joints between the reeds, the inturned marginal portions 11*a* of the adjacent panels then engaging the exterior of such tunnel or vestibule in an air-tight manner. Emergency exit of personnel in the event of fire can readily be effected without difficulty through any of the canopy joints aforesaid.

In order to increase the stability of the upper part of

the canopy 10 against powerful wind forces, it is preferred not to lead guy-lines 14 vertically from the various tethering points 13, but to connect each of the latter to two or more pickets 15 which are offset horizontally therefrom, and some of these divergent pairs of guy-lines may be arranged in planes longitudinal to the building (FIG. 1) and others in transverse planes (as indicated in FIG. 2).

When the canopy 10 is constrained to a reeded formation as above described, effective drainage is readily effected by adjusting the guy-lines 14 so that all the resultant gullies in such canopy will be slightly inclined towards one end of the building as shown on FIG. 1 or in opposite directions from a watershed at or near the centre of its length.

FIG. 4 illustrates a convenient rain-proof assembly at each such gully, a continuous flap 18 of flexible impermeable material being united externally to each panel 11 near one lateral edge thereof so as to conform to the V section of the gully and the free edge of this gutter flap being overlaid by a narrower flap 19 similarly associated with the adjacent panel. Alternatively flaps such as 18 may be attached to each panel 11 adjacent both lateral edges thereof.

To prevent their disturbance by wind the overlapping edges of the flaps 18, 19 are preferably secured together by means of opposed flexible strips 20, 21 whose respective materials are such that they become mutually adherent on being manually pressed together. Convenient "touch fastener" strips are sold under the registered trademark Velcro, and similar provision may be made between the coacting marginal portions 11*a* of the juxtaposed panels to further seal the joint against air-leakage, particularly during the initial stages of inflation. Other known joining means such as tie-tapes or press-studs may be substituted for the "touch fastener" strips 20, 21 and cords attached to the underside of the gutter flap 18 may be passed between the coacting panel margins 11*a* so that the lay of the gutter, if disturbed during the initial inflation, can readily be re-arranged from inside the building.

Each canopy panel 11 is conveniently made up as shown in FIG. 5 by sewing or otherwise securing together a plurality of strips 22 of coated fabric which extend across the width thereof, consecutive strips being of such lengths, and their ends being straight-cut at such angles that the assembled panel exhibits the required series of catenary curves along both lateral edges. The free longitudinal edge of the endmost strips 22 may likewise be cut as catenaries.

The effect of the catenary curves is, of course, to distribute the tethering stresses as uniformly as possible along the length of the panel 10, the constituent strips 11 before assembly together having their ends hemmed at 23 (FIG. 6) to provide tunnels through which wire or cord reinforcements 24 are threaded. By cutting off the corners of each strip 22 before its ends are hemmed over, the reinforcing members 24 are left exposed, opposite the transverse seams 25 of the panel, to provide the primary and intermediate tethering points 13, 17 for the latter.

FIG. 7 illustrates a modified construction which permits each canopy panel to be made of uniform width throughout, its lateral margins 11*a* being eyeleted at regular intervals for the connection thereto of triangular sections of balloon netting 26 whose apices form the primary tethering points 13, or alternatively radiating cords may lead directly from each of the latter to a suitable number of points on the panel edge so as to spread the tethering stress along it in a similar manner.

If desired, the several panels 11 or canopy sections may be mechanically connected at or near their juxtaposed edges as shown in FIG. 8. In this case each panel is of uniform width and a separate strip 27 of flexible impermeable material is secured along a medial line at 28 to the outer side of one edge only of such panel. The pendant part of this strip 27 has its edge hemmed, reinforced, and formed into a series of catenary curves so as

to correspond to the integral marginal flap **11***a* of one of the panels shown in FIGS. 1 to 6 whilst the other part of the strip is adapted for detachable connection to the free edge **29** of the next panel.

The connecting means indicated at **30** may be of any suitable type; for example the strip **27** and panel edge **29** may be overlapped as shown, a row of studs on one member being passed through eyelets in the other and secured by circlips or the like, or both members may be eyeleted for connection together by Dutch or chain lacing.

Alternatively, the strip **27** and panel edge **29** may be secured together by means of a slide fastener, or similar sets of loops thereon may be interdigitated and a wire or other flexible member threaded through them, or again use may be made of hooks and eyes, or loops and toggles. In all such cases, the joint is preferably covered internally by means of a sealing flap secured to one of the juxaposed members.

Yet another method of mechanically connecting the lateral edges of two adjacent panels **11** is illustrated in FIG. 9. In this case a strip **27** attached to the edge of one panel is overlapped by the marginal portion **29** of the other panel (as shown in FIG. 8), the strip **27** having parallel webbing bands **31**, **32** respectively sewn at intervals along its edge and to its outer side at some distance from such edge, whilst the overlapping portion **29** has further parallel bands **33**, **34** which are similarly secured to its edge and its inner side, and ropes **35**, **36** are threaded through alternate bights of the bands **31**, **34** and **32**, **33** respectively.

Although the invention has heretofore been particularly described with reference to a reeded construction of rectangular building with the reeds running longitudinally thereof, it should be understood that such reeds may equally well be directed at right angles to the length of the building and that the latter may be of square or irregular planform, the reeds in the last-mentioned case being directed either longitudinally or transversely and of different lengths.

The subdivision of the enclosed space by rows of guy-lines leading to ground-anchors does not constitute any serious detriment in the case of an exhibition hall, since stands erected within the latter can be placed in corresponding rows with unobstructed aisles between them.

However, such an arrangement would obviously be impracticable in a building erected over a sports stadium, and for covering such an arena or when the building is made of very wide span for the purpose of roofing over a valley or other natural feature (for example, to conceal or shelter military installations located therein) the method of anchorage illustrated in FIGS. 10 and 11 may be adopted, each row of guy-lines **14** forming the additional anchorages being connected to a strong cable **37** whose ends are fixed to the ground or to artificial supports, which will normally be at a higher level than the area to be covered. It should be emphasized however, that in erecting such a building the contour of the ground covered is quite unimportant; that is to say, the building can be arranged to conceal or shelter a hillock just as easily as a depression.

When roofing over a valley **38** as shown, a plurality of such cables **37** of appropriate length and breaking strain are slung side-by-side between reinforced concrete blocks **39** or other secure fixtures provided at equal horizontal intervals, along opposite sides of such valley. As seen in elevation, each such side has the cable attachment points **39** situated along an upwardly convex line, whilst the endmost cables **37** may have their extremities fixed at or adjacent the floor of the valley **38**.

Suitable members of the panels **11** are assembled in endwise overlapping relation to form complete canopy sections each of a width somewhat greater than the horizontal spacing of the cables **37** and exceeding by one the number of such cables provided.

In erecting the canopy **10** the several multipanel sections thereof are hauled endwise on to the sagging cables **37** and allowed to drape over the latter as shown in FIG. 12, while the connection of their lateral edges (preferably by the means illustrated in FIG. 9) and attachment of their guy-lines **14** to the cables is being progressively effected.

When the whole area to be concealed or sheltered has been covered in this manner, the periphery of the canopy **10** (as represented by the free edges of its two endmost sections and the extremities of those intervening) is located either by attachment to screw-pickets or by ballasting as previously described.

On inflation of the canopy **10** to a reeded form, the uplift load is transmitted through the rows of guy-lines **14** to the cables **37** which thereupon adopt inverted catenary curves as shown.

The canopy may, of course, be stabilized against wind forces, by connecting each of several tethering points **12** to spaced points on the adjacent cable **37** or to corresponding points in two adjacent cables.

When a similar building is to be erected over a sports stadium or the like, the cables **37** may be anchored to the tops of stands or banked seating **40** around the arena **41**, as shown in FIG. 13, or such stands or banking may provide abutments for cables anchored at ground-level externally thereof. It will be noted that FIG. 13 also illustrates the alternative arrangement of the canopy **10** with its reeds running transversely of the cables **37**.

I claim:

1. An inflatable building comprising, a canopy composed of a plurality of connected flexible strips having inturned longitudinal edge portions forming dependent flaps, the flaps on one panel being facially opposed to those on adjacent panels, loop members passing through the flaps of adjacent panels, tethering cables extending from the loop members to the ground, and drain strips on the canopy mounted over the meeting points of adjacent flaps and bridging the points of connection of the same.

2. An inflatable building as provided for in claim 1, wherein the tethering cables extend divergently from the loop members to the ground, and detachable fastening means provided between the faces of the flaps to couple the same together.

3. An inflatable building according to claim 1 in which touch fastener strips are located on adjacent panels, said touch strips being adhered to each other and sealing against air pressure leakage at the junction of said panels.

4. An inflatable building comprising, a canopy composed of a plurality of connected flexible panels at least one of which has inturned longitudinal edge portions forming dependent flaps, the flaps on one panel being facially opposed to the adjacent panel, the lower edges of adjacent panels being out of contact, a strip having one edge attached to an intermediate portion of said one panel, said strip depending below said panels, and means on the lower end of said strip for anchoring the same to a fixed base.

5. An inflatable building according to claim 4 in which a drain band is attached to the outer face of said canopy at the junction of said strip with said adjacent panel.

6. An inflatable building comprising a plurality of elongated panels convex in cross-section and located side-by-side, the lower edges of adjacent panels being in juxtaposed position over a substantial area, air pressure within said canopy pressing on said panels causing said lower edges to seal the joints between said adjacent panels against leakage from inside the canopy, means attached to said lower edges at spaced points having tethers thereon extending to and anchored in a fixed base.

7. An inflatable building comprising a canopy composed of at least one pair of convex panels connected together at their lower edges, said connection including the lower edges of said panels being inturned, means securing the lower edges together and anchoring said panels to a fixed base, touch fastener strips facing each other on said lower edges of said panels, said touch fastener strips being

adhered to each other and sealing against air leakage out of said building at the connection between said panels.

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