United States Patent [19]

Duquette

[11] **3,842,550**

[45] **Oct. 22, 1974**

[54] **AIR SUPPORTED METAL ROOF AND METHOD OF RAISING AND LOWERING**

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[22] Filed: **Oct. 23, 1973**

[21] Appl. No.: **408,511**

[52] **U.S. Cl.** **52/2,** 52/86, 52/528, 52/741

[51] **Int. Cl.** **E04b 1/345**

[58] **Field of Search** 52/2, 86, 309, 528, 588, 52/741, 742, 745

[56] **References Cited**

UNITED STATES PATENTS

3,113,403	12/1963	MacMillan, Jr. et al.	52/2
3,555,758	1/1971	Schroter	52/528

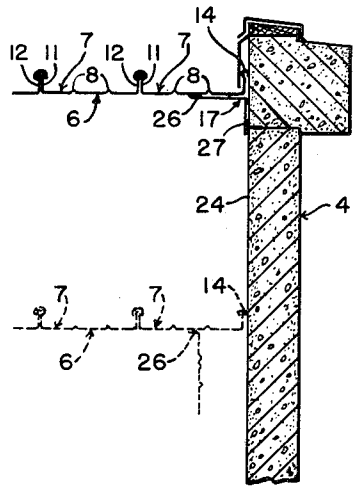
Primary Examiner—John E. Murtagh
Assistant Examiner—Robert C. Farber
Attorney, Agent, or Firm—James R. Cypher

[57] **ABSTRACT**

An air supported building structure having a pair of parallel spaced side walls, a curved sheet metal membrane forming the roof and side walls disposed between the vertical walls, a weight mounted for vertical movement attached to one end of the curved membrane for continuously biasing an end outwardly, the other end of the sheet being permanently attached to the fixed structure such as the vertical walls or the foundation.

An air supported building having a pair of parallel, spaced vertical side walls and a curved sheet metal membrane forming the roof and side walls in which the metal member is composed of elongated channel members in which the sides of the channels are mechanically joined together.

10 Claims, 9 Drawing Figures



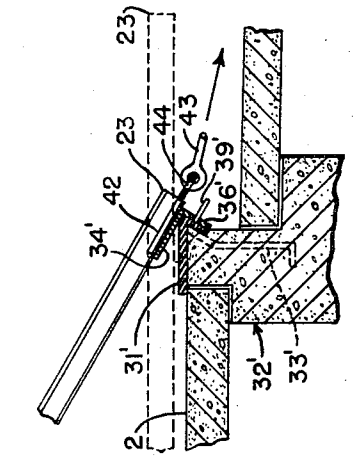


FIG. 3

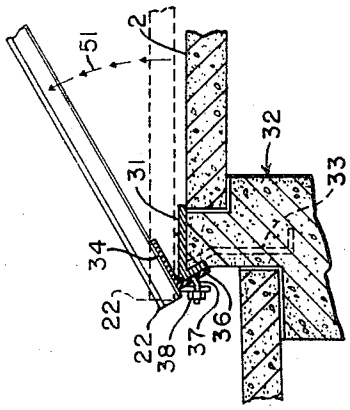


FIG. 2

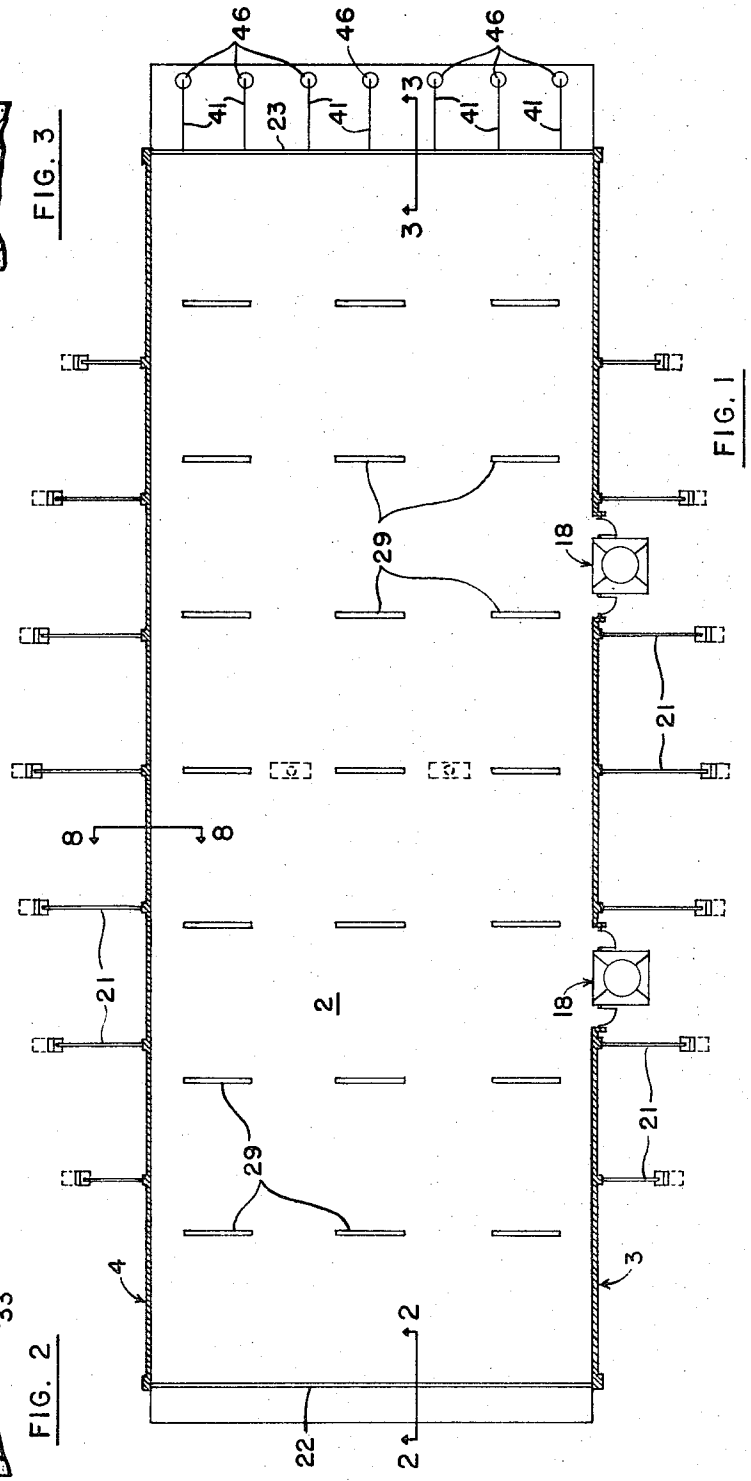


FIG. 1

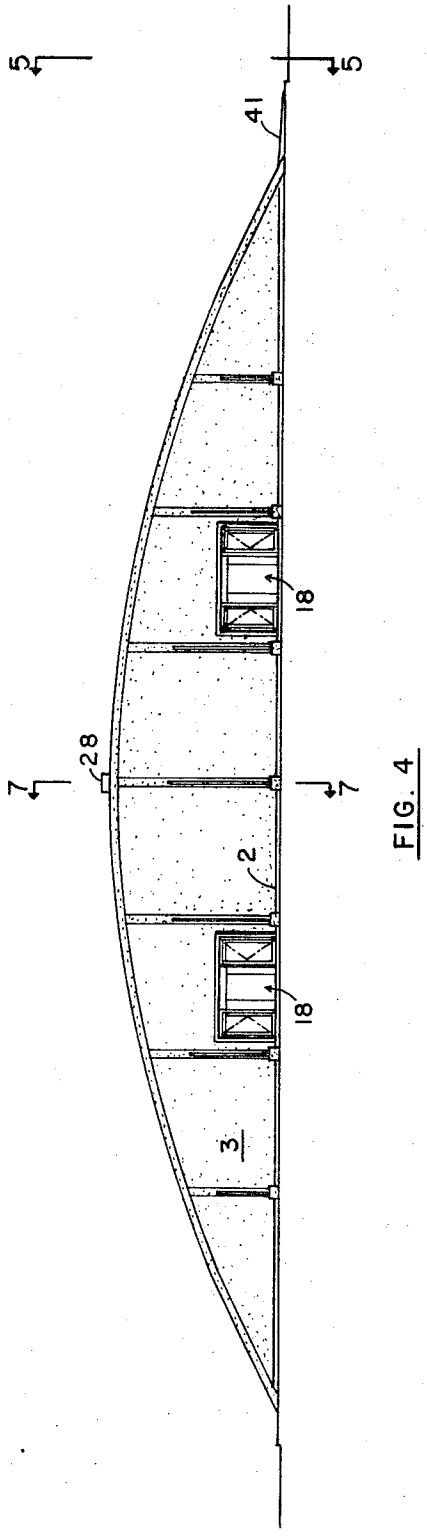


FIG. 4

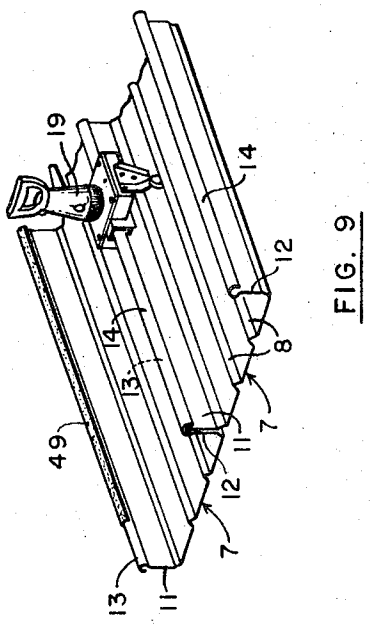


FIG. 9

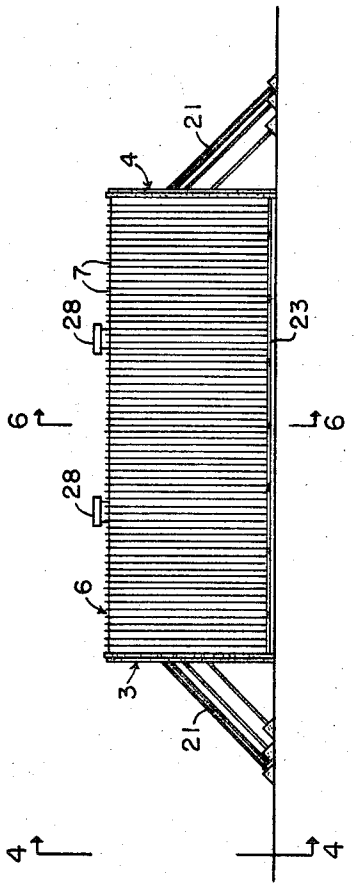


FIG. 5

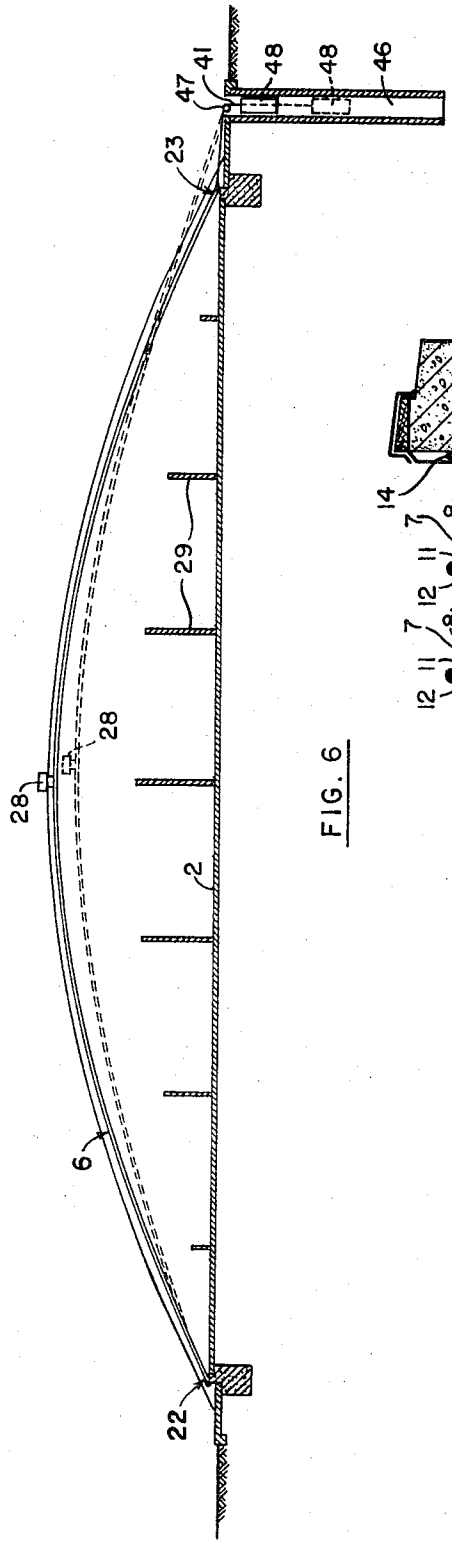


FIG. 6

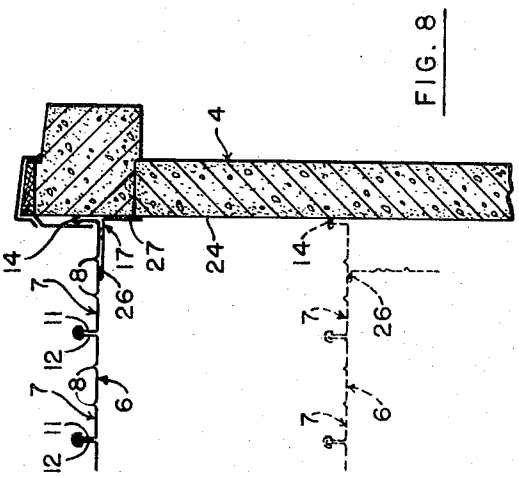


FIG. 8

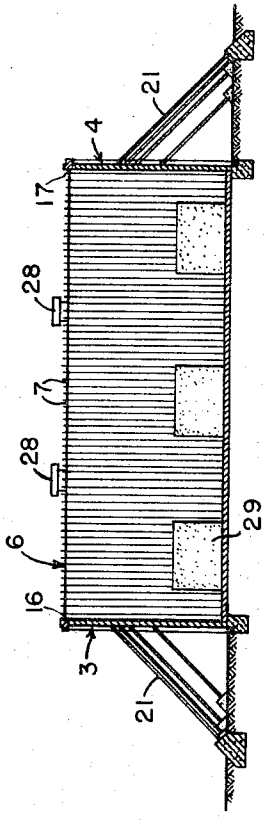


FIG. 7

AIR SUPPORTED METAL ROOF AND METHOD OF RAISING AND LOWERING

BACKGROUND OF THE INVENTION

Air supported structures have been known for some time. The Lanchester U.S. Pat. No. 1,402,077 granted in 1922 taught that large exposition buildings could be constructed by pressurizing a building covered by a canvas roof. The canvas was treated with a coating of bitumen or tar to reduce loss of air. Today, vinyl coated nylon fabrics permit larger and lighter multi-curved air supported structures to be built but such "soft" shelled structures have the same problems of public acceptance that met the Lanchester structure as well as the very real problem of longevity of the fabric materials.

In 1944 Stevens (U.S. Pat. No. 2,355,248) proposed a huge circular air supported structure with a stainless steel roof membrane. The Stevens circular roof solved the longevity problem but the problems of erecting and supporting the multi-curved roof remained unsolved until MacMillian (U.S. Pat. No. 3,113,403) in 1963 proposed a half cylinder shape between parallel rigid side walls.

Applicant knows of no buildings which have been constructed using the Stevens or MacMillan teachings nor of any other air supported structure utilizing a metal roof membrane. Such metal membranes have two basic design problems which are solved by the present disclosure. First, it is very costly to construct a steel membrane of practical size because of the problems of structurally joining long strips of metal in an airtight seal. Secondly, none of the metal membranes thus far proposed can structurally survive a depressurization which would lower the roof to a plane close to the floor. All known metal membranes upon lowering would simply self-destruct.

SUMMARY OF THE INVENTION

The gist of the present invention is the use of a metal panel presently mass produced by Kaiser Aluminum Company of Oakland, Calif. for conventional post and beam construction. The Kaiser roofing and siding system is sold under the trademark designation Zip-Rib and is presently in use by the San Francisco Port Authority on a conventional post and beam building having a roof area of over 870,000 square feet.

The roof system described herein using the Zip-Rib Kaiser panel has the unique ability to structurally survive a depressurization of the building whether by accidental loss of power or planned lowering of the building to floor level or near floor level.

An object of the present invention is to provide a metal roof and side wall construction which is supported by differential fluid pressure which can be constructed from relatively inexpensive readily available panels.

Another object is to provide a metal roof and side wall which can be easily and repeatedly erected and taken down simply by raising and lowering the differential pressure without structurally damaging the metal roof and sidewall membrane.

Still another object is to provide a structure as described which can be assembled from elongated narrow panels which can be transported to the job site on conventional transportation means, and quickly and inexpensively constructed into the desired membrane at the job site.

A further object is to provide a method of safely lowering the building in the event of depressurization which is automatic and requires no special equipment other than the on-site roof lowering permanently installed equipment.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a floor plan view of a building constructed in accordance with the present invention.

FIG. **2** is an enlarged cross sectional view taken along line **2—2** of FIG. **1.**

FIG. **3** is an enlarged cross sectional view taken along line **3—3** of FIG. **1.**

FIG. **4** is a side elevation view taken along line **4—4** of FIG. **5.**

FIG. **5** is an end elevation view taken along line **5—5** of FIG. **4.**

FIG. **6** is a cross sectional view taken along line **6—6** of FIG. **5.** The metal membrane is shown in solid line in the fully raised position and in dotted line in the partially raised position.

FIG. **7** is a cross sectional view taken along line **7—7** of FIG. **4.**

FIG. **8** is a cross sectional enlarged view taken along line **8—8** of FIG. **1.** The metal membrane is shown in solid line in the fully raised position and in dotted line in the partially raised position.

FIG. **9** is an enlarged perspective view of the Zip-Rib panels shown in FIG. **8.**

BRIEF DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

The building structure of the present invention consists briefly of an air impermeable floor **2,** a pair of parallel substantially planar air impermeable side walls **3** and **4;** a metal membrane **6** forming the roof and end walls dimensioned to coact with said side walls in forming an enclosed building space; the metal membrane consisting of a plurality of channel shaped elongated panels **7** having small radius corrugations **8** arranged with their longitudinal axis parallel to the side walls and having an unbroken length equal to the length of the roof and end walls; the panels having parallel upstanding sides or ribs **11** and **12** terminating in outwardly and downwardly curved flanges **13** and **14** of dissimilar radii, the panels being mechanically joined at their sides by positioning the curved flanges one within the other and mechanically reducing the radii of the larger flange until the flanges are in interlocking relationship; means **16** and **17** forming an air impermeable seal between the metal membrane and the side walls; and means **18** for raising the pressure inside the building above the outside pressure sufficient to raise the membrane above the floor and to maintain the membrane above the floor.

Referring specifically to the invention, the panels used are sold under the trademark Zip-Rib by Kaiser Aluminum Company of Oakland, Calif. and are presently available in widths of 12 inches and thicknesses of 0.032 inch, 0.040 inch and 0.050 inch and have a beam strength capable of being used in spans up to 14 feet in conventional construction under load.

The panels are cold rolled into their unique shape and may be manufactured in any length, subject only to the length limitations of shipping conditions. Panel

lengths of 110 feet have been installed on pier terminals by the San Francisco Port Authority. Lengths exceeding such a length can be obtained by forming the panels at the job site from metal coils.

The panels are presently made from aluminum but could also be made from stainless or galvanized steel.

The flanges are locked together by a closure tool **19** available on the market which mechanically reduces the diameter of the curved flange thereby locking the panels together without holes, end laps or welding.

The floor of the building may be of standard construction provided it is impermeable to air to provide differential pressurization of the inside of the building.

The side walls are also standard construction of air impermeable material. The walls must be adequately supported to be free standing, to support lateral loads from the differential pressure, wind loads and earthquake design loads. Buttress members **21** are shown in FIGS. **1, 5** and **7** to take the lateral loads.

As shown in the drawings, the panels are arranged so that their longitudinal axis is parallel to the side walls so that a single panel of unbroken length continues from a first end **22** to a second end **23.** Thus the closure tool can be run from one end of the building to the other and make a continuous closure without a single hole or weld required. Further, all joining of the panels can be done on the flat floor surface at floor level thereby shortening the time to construct the membrane and eliminating all hoisting of the panels to roof elevations as in present standard construction.

Referring to FIG. **8,** a detail of side wall **4** is shown with the membrane **6** being raised (dotted line) and in final raised position (solid line). When the membrane is being raised, no seal is necessary between flange **14** and the wall face **24** but it is advantageous to seal this space when the membrane is raised to final position. A flexible vinyl or rubber strip placed along both edges of the membrane is used. One edge **26** of the seal is attached to the underside of the panel nearest the side wall, and the other edge of the seal **27** is attached to wall face **24.** An identical sealing strip is attached in a similar manner to the other side of the membrane and to the face of wall **3.**

The means for raising the membrane and for holding it in place is provided by conventional blowers **18.** Since Zip-Rib in 0.040 inch thickness weighs only 0.094 lbs. per square foot, a pressure of only about 1 to 5 pounds per square foot is required to raise the membrane. The pressure to hold the membrane in place should be higher so that the membrane will be held rigid. A pressure of about 7.5 pounds per square foot is adequate. The pressure will depend upon wind or snow loads that can be anticipated.

Air inflated structures must be vented to insure a proper supply of fresh air. Air vents **28** may be placed at any place in the structure, but are preferably mounted on the roof to permit the escape of the hottest air. In winter conditions, the air vents could be located at a lower elevation to conserve the warm air.

All air inflated structures should be provided with some means for preventing the roof from descending to floor level so that personnel can escape from the building in the event of a power failure and a lowering of the roof. Actually, it would take several hours for a roof to descend to floor level in the event of a power failure, but in the event of a structural failure resulting in a massive air leak or merely for psychological reasons, a plurality of panels **29** should be erected to project from the building floor at sufficient intervals to prevent the membrane from reaching floor level. Preferably the panels should be at sufficient spacing to support the membrane without damage to the panels.

Referring to FIG. **2,** one method of pivotally affixing the first end of the membrane to the floor in an air impermeable relationship is shown. A metal angle **31** is anchored to the top of the foundation **32** as by a bolt **33.** A second series of angles **34** are attached to the ends of the panels. Flange leg **36** hooks over the angle **31** and will pivotally hold the membrane in place as the membrane is raised. To further lock the membrane in place, a threaded stud bolt **37** is attached to the flange **31** and a slotted opening is made in the flange leg **36** to allow vertical arching movement as the membrane is raised. After the membrane is raised, a nut **38** can be threaded onto the bolt **37.**

The means for attaching the membrane to the other foundation is similar to the attachment above described. The parts are identified by the same numbers with the addition of a prime (') mark. Since end **23** must move laterally, only a positioning stud **39** is attached to the angle **31'** and registers with a slotted opening in angle leg **36'.** The roof lowering mechanism is shown in FIGS. **1, 3** and **6.**

A biasing means is attached to the second end of the membrane to a raised curved position by the pressure means the same mechanism also effects return movement of the second end to a position away from the first end when the pressure means permits the differential pressure to be decreased. A plurality of cables **41** are attached to a bracket **42** carried by each of several panels. A connector **43** inserted through an opening **44** in the bracket pivotally connects the bracket to the cables **41.**

The biasing force could be achieved by motors and automatic switching but a simple and practical system is shown in the drawings by way of example.

A plurality of wells **46** are formed in the ground adjacent the second end **23.** The cable **41** is placed over sheave **47** and suitable weights **48** are attached to the ends of the cables. Thus in the event of pressure failure, the weights automatically drop into the wells and the cables pull the second end horizontally outward from the structure preventing buckling and destruction of the metal membrane.

Air inflated structures require ventilation to atmosphere and the constant replenishment of the air. The membrane, therefore, need not be air tight. Where, however, it is desired to make the membrane air tight and to control the ventilation by more precise controls, a sealing strip of rubber, vinyl or other air and water tight materials can be placed in an elongated strip **49** along the top of the flange **13** in FIG. **9.** This may either be a separate strip or a coating placed on the panel flange in manufacture. The sealing strip would run the entire length of the panel and would be placed on the top of flange **13** or the underside of flange **14.** When the zipper tool **19** crimped the two flanges together, the sealing strip **49** would effectively prevent the passage of air.

The method of constructing a building structure according to the present invention consists briefly of constructing an air impermeable floor **2;** erecting a pair of

parallel substantially planar air impermeable side walls **3** and **4** joining the floor; joining a plurality of channel shaped, ribbed elongated metal panels **7** into a single air impermeable membrane **6** forming the roof and end walls and dimensioned to coact with the side walls in forming an enclosed building space.

The panels have parallel upstanding sides **11** and **12** terminating in outwardly and downwardly curved flanges **13** and **14** of dissimilar radii and are mechanically joined at their sides by positioning the curved flanges one within the other and mechanically reducing the radii of the larger flange until the flanges are in interlocking relationship. The first end **22** of the end wall or membrane is anchored to the floor. An air seal is maintained between the roof and side walls and between the second end **23** and the floor. After the roof has been raised, the second end is anchored to the floor as shown in FIG. **3** to prevent further raising of the roof and end walls. Finally, sufficient air pressure differential is maintained to prevent lowering of the roof and end walls.

As shown in FIG. **2,** the first end is pivotally mounted to the floor to permit the first end to be anchored while the roof is in the horizontal position as shown in dotted lines and while moving through arc **51** to the fully raised position. By providing a pivoting anchorage, as shown, an air impermeable seal may be maintained even though there is some angular displacement of the end wall due to pressure fluctuations.

While the present disclosure contemplates that viable structures can be constructed from Zip-Rib panels and erected according to the method just described, a major feature of the present invention is the solution of the self destruction problem inherent in present metal membrane structures.

As herein described, the method of lowering an air supported metal membrane roof system consists briefly of constructing an air impermeable floor **2**; erecting a pair of parallel substantially planar air impermeable side walls **3** and **4** joining the floor and selecting a flat air impermeable metal membrane forming the roof and end walls. The metal membrane may be constructed from light gauge steel or aluminum in which the joints are arranged so that the membrane may move from a flat position on the floor to an arcuate shape along its longitudinal axis as shown in FIG. **6.** The membrane must also be able to return to its flat shape if the air pressure is removed. The membrane is pivotally anchored to the foundation and floor as shown in FIG. **2** and previously described. Air pressure is introduced beneath the membrane while at the same time maintaining an air seal around the four sides of the membrane. One method of maintaining the seal at the free end **23** while the membrane is being raised is to pile sand on the edge as disclosed in MacMillan U.S. Pat. No. 3,003,403. After the membrane has been raised, the second end **23** is anchored to the foundation and floor as shown in FIG. **3** and as previously described. Sufficient differential pressure is maintained by fans **18.** The biasing force for holding end **23** while the membrane is being raised is shown in FIG. **6** and has been previously described. The same biasing system for lowering the roof membrane is also shown in FIG. **6** and has also been previously described. In the event of pressure failure or for merely taking down the membrane for any reason, the weights **47** move downwardly and pull cables **41** which in turn pull the entire membrane to the right as shown in FIG. **6.** By maintaining a biasing force on the end **23,** the thin sheet metal membrane is prevented from deforming into sharp radius curves and from thereby buckling and destroying the metal integrity of the membrane.

While any metal membrane constructed according to the broad guidelines set forth above will be operative, a preferred choice of materials is the Kaiser Aluminum Company's Zip-Rib deep channel panels.

I claim:

1. A building structure comprising:

a. an air impermeable floor;

b. a pair of parallel substantially planar air impermeable side walls;

c. a metal membrane forming the roof and end walls dimensioned to register with and form a sliding relatively air tight seal with said side walls in forming an enclosed building space;

d. said metal membrane consisting of a plurality of channel-shaped side ribbed, elongated panels arranged with their longitudinal axis parallel to said side walls and having an unbroken length equal to the length to said roof and end walls;

e. said panels having parallel upstanding sides terminating in outwardly and downwardly curved flanges of dissimilar radii;

f. said panels being mechanically joined at their sides by positioning said curved flanges one within the other and mechanically reducing the radii of said larger flange until said flanges are in interlocking relationship; and

g. means for raising the pressure inside said building above the outside pressure sufficient to raise said membrane above said floor and maintain said membrane above said floor.

2. A building structure as described in claim **1** comprising:

a. internal panels projecting upwardly from said floor for receiving and holding said membrane at an elevation above said floor for protecting personnel in the event of an emergency lowering of said membrane; and

b. sealing means forming an air impermeable seal between said membrane and said side walls.

3. A building structure as described in claim **1** comprising:

a. means pivotally affixing a first end of said membrane to said floor in an air impermeable relationship; and

b. biasing means attached to a second end of said membrane permitting movement of said membrane to a raised curved position by said pressure means and effecting movement of said second end to a position away from said first end when said pressure means permits said differential pressure to be decreased and said membrane to be lowered from its fully raised position.

4. A building structure as described in claim **2** comprising:

a. said sealing means including an air impermeable sealing strip mounted along the longitudinal axis of said flanges for compression therebetween upon mechanical reduction of the radii of said flanges.

5. A building structure as described in claim **3** comprising:

a. said biasing means includes pre-selected weights moveable from a first elevation to a second higher

elevation upon raising of said roof and end walls and back to said lower elevation upon lowering of said membrane; and

b. cable means connected to said second end and said weights.

6. A method of constructing a building structure comprising:

a. constructing an air impermeable floor;

b. erecting a pair of parallel substantially planar air impermeable side walls joining said floor;

c. joining a plurality of channel shaped, ribbed elongated metal panels into a single air impermeable membrane forming the roof and end walls and dimensioned to coact with said side walls in forming an enclosed building space, said panels having parallel upstanding sides terminating in outwardly and downwardly curved flanges of dissimilar radii and being mechanically joined at their sides by positioning said curved flanges one within the other and mechanically reducing the radii of said larger flange until said flanges are in interlocking relationship;

d. anchoring a first end of said end wall to said floor;

e. introducing air pressure beneath said roof and end walls to effect raising thereof between said side walls;

f. maintaining an air seal between said roof and side walls and between a second end of said end wall and said floor;

g. anchoring said second end to said floor to prevent further raising of said roof and end walls; and

h. maintaining sufficient pressure within said structure to prevent lowering of said roof and end walls.

7. A method of constructing a building structure as defined in claim **6** comprising:

a. anchoring said first end by a pivotal means permitting angular displacement of said end in relation to said floor while maintaining an air impermeable seal; and

b. providing a sliding, air impermeable seal between said second end and said floor.

8. A method of constructing a building structure comprising:

a. constructing an air impermeable floor;

b. erecting a pair of parallel substantially planar air impermeable side walls joining said floor;

c. selecting a flat air impermeable metal membrane forming the roof and end walls formable in its longitudinal direction into an arcuate shape and deformable to said initial flat shape and dimensioned to coact with said side walls in forming an enclosed building space;

d. anchoring a first end of said end wall to said floor;

e. introducing air pressure beneath said roof and end walls to effect raising thereof between said side walls;

f. maintaining an air seal between said roof and side walls and between a second end of said end wall and said floor;

g. anchoring said second end to said floor to prevent further raising of said roof and end walls;

h. maintaining sufficient pressure within said structure to prevent lowering of said roof and end walls;

i. providing a biasing means having a force acting away from said structure with a force permitting raising of said roof by differential pressure; and

j. providing sufficient biasing force to move said second end away from said structure when the differential pressure is insufficient to maintain said roof and end walls in a raised position so that said membrane may return to said flat form.

9. A method of lowering a building structure as defined in claim **7** comprising:

a. reducing the differential air pressure inside said structure so that it is incapable of maintaining said roof and end walls at a fixed elevation above said floor;

b. pulling said second end wall in a direction parallel to said floor in a direction axially to and away from said building until said ceiling ceases to drop.

10. A method of lowering a building structure as defined in claim **8** comprising:

a. attaching weights to said second end wall in a suspended position so that gravitational force can provide the automatic biasing force necessary to pull said second end outwardly in the event of a decrease in air pressure below the selected pressure necessary to hold said roof in a raised position.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,842,550 Dated October 22, 1974

Inventor(s) William L. Duquette

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 3, line 49, change "0.094" to ---.904---

Signed and sealed this 7th day of January 1975.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

FORM PO-1050 (10-69)

USCOMM-DC 60376-P69
* U.S. GOVERNMENT PRINTING OFFICE : 1969 O—366-334