Nov. 29, 1966 P. GUGLIOTTA 3,288,158

MOVABLE ROOF STRUCTURE

Original Filed May 31, 1963 3 Sheets-Sheet 1

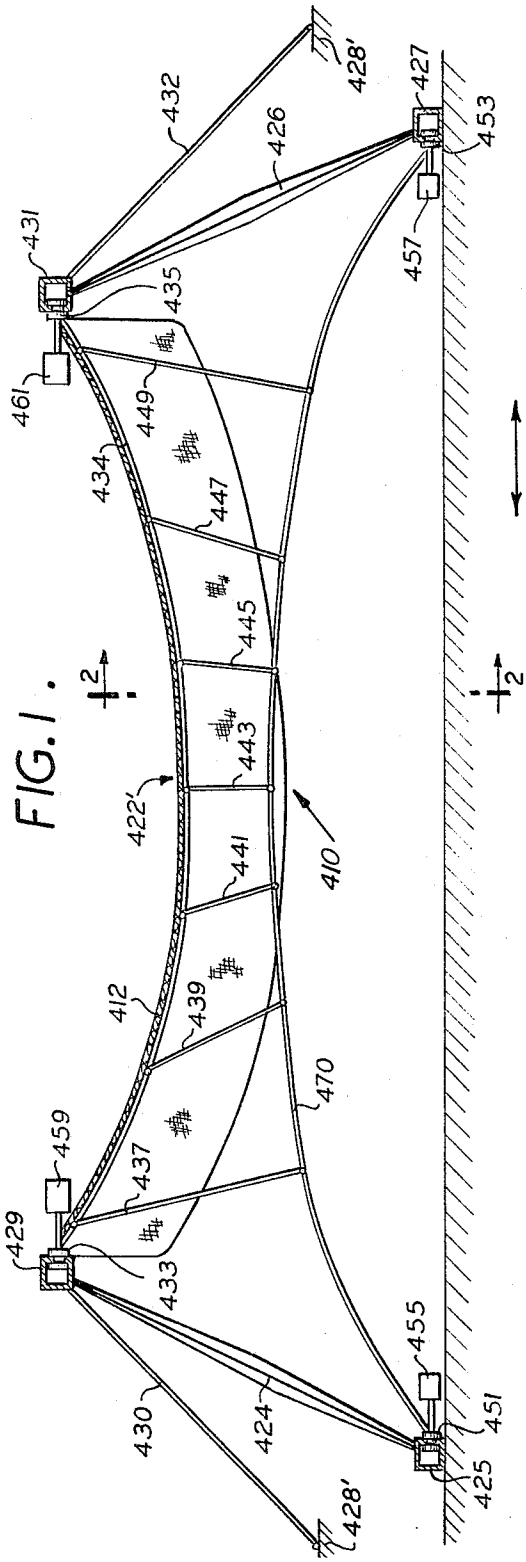


FIG. 1.

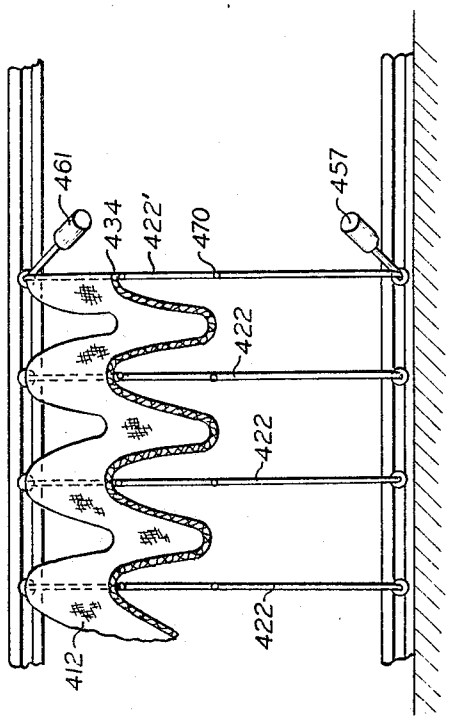


FIG. 2.

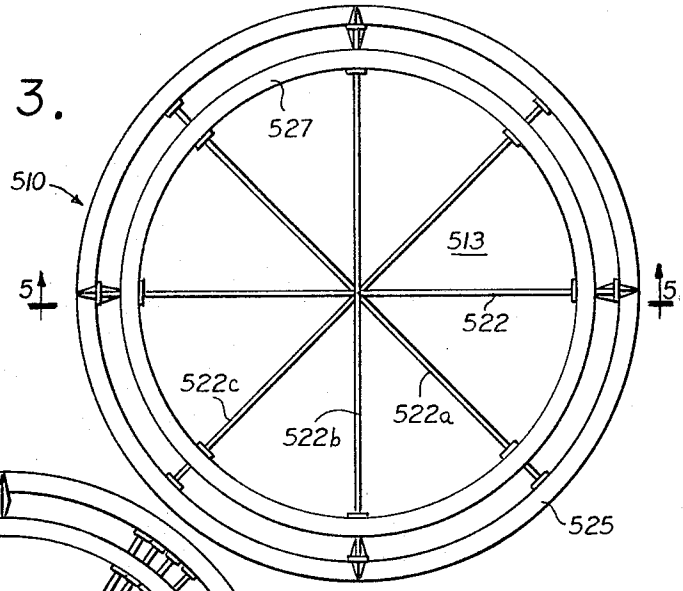
INVENTOR
PAUL GUGLIOTTA
BY
Hubbell, Cohen & Stiefel
ATTORNEYS.

Nov. 29, 1966 P. GUGLIOTTA 3,288,158

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FIG. 3.



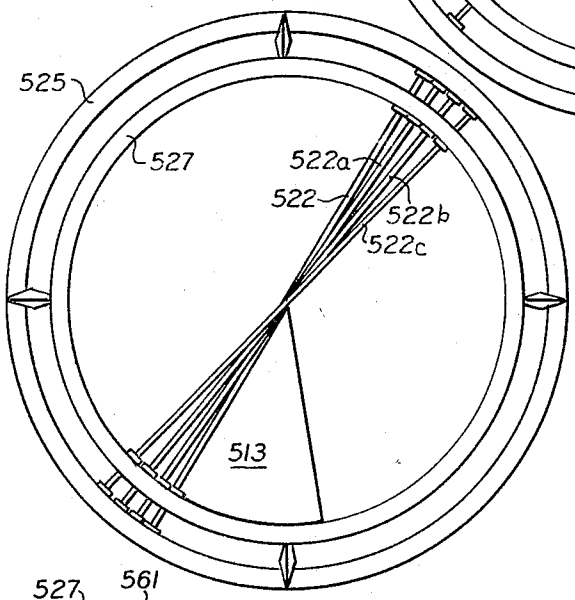


FIG. 4.

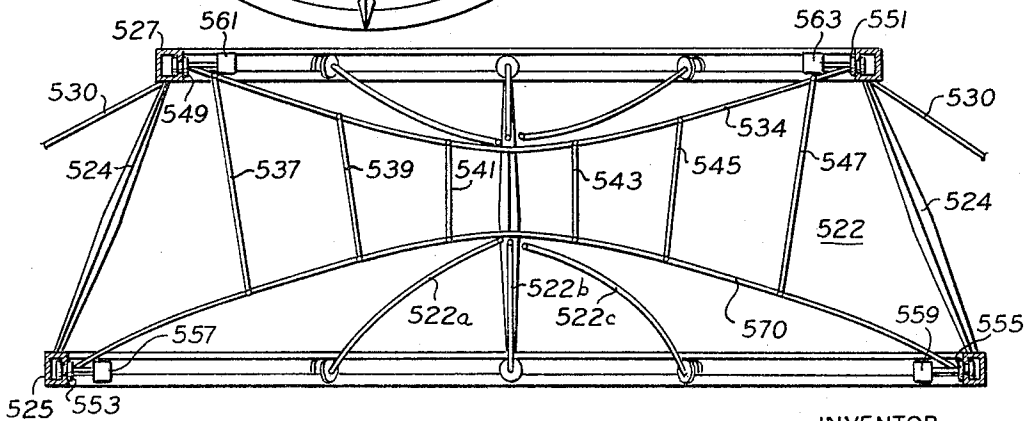


FIG. 5.

INVENTOR
PAUL GUGLIOTTA
BY
Hubbell, Cohen & Stiefel
ATTORNEYS.

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FIG. 6.

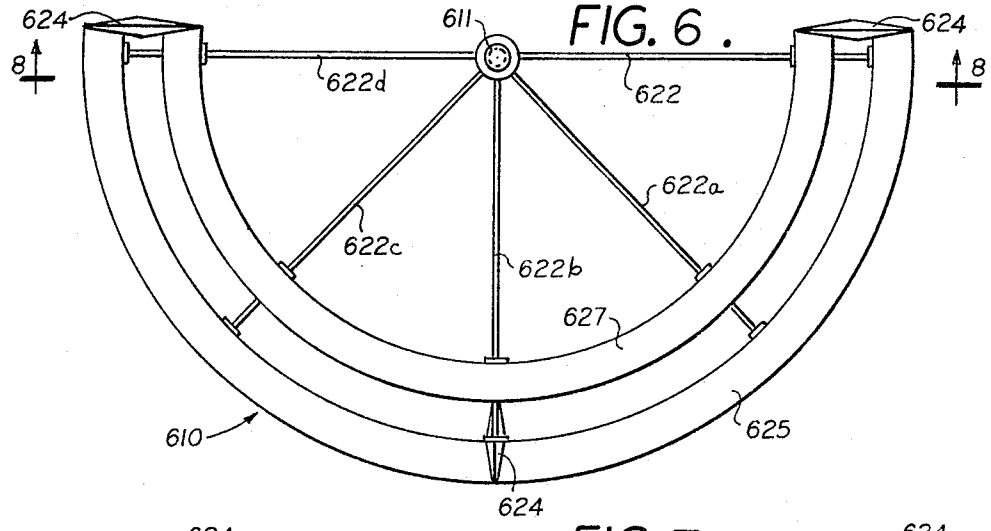
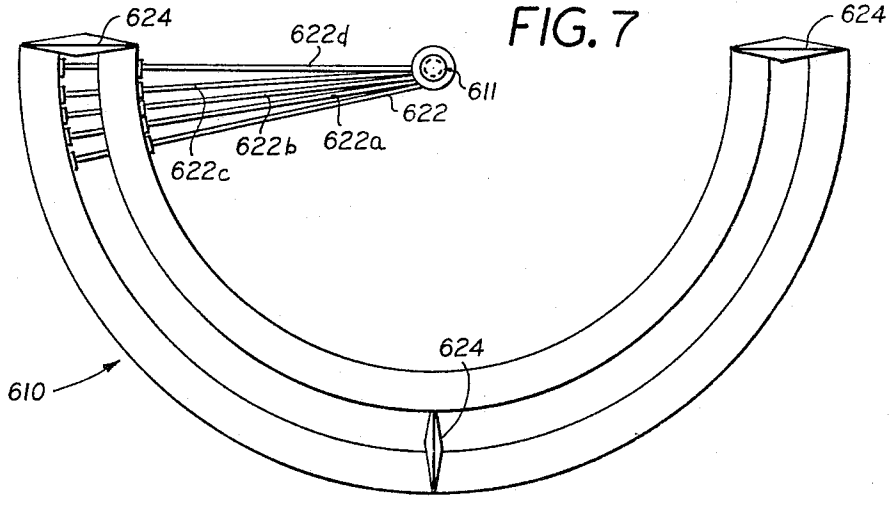


FIG. 7



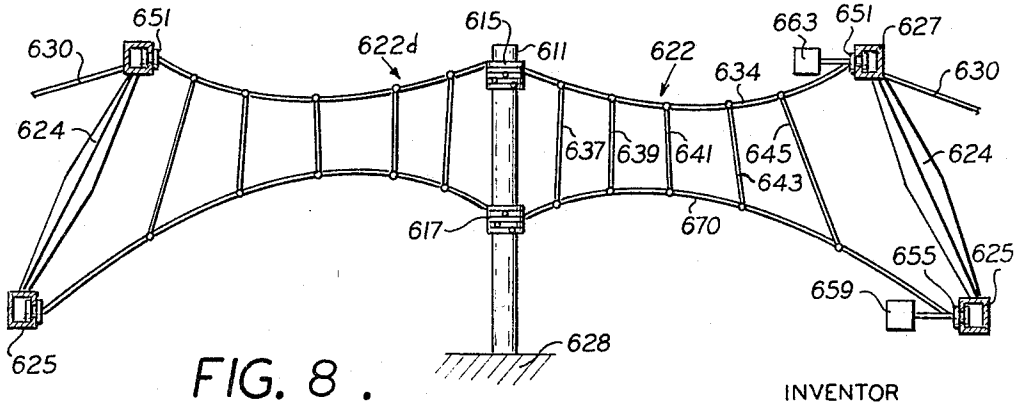


FIG. 8.

INVENTOR
PAUL GUGLIOTTA
BY
Hubbell, Cohen & Stiefel
ATTORNEYS.

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MOVABLE ROOF STRUCTURE

Paul Gugliotta, 28 South St., New York, N.Y.

Original application May 31, 1963, Ser. No. 284,633, now Patent No. 3,211,163, dated Oct. 12, 1965. Divided and this application Dec. 28, 1964, Ser. No. 421,537
3 Claims. (Cl. 135—5)

This invention relates to movable roof structures and especially to movable roof structures for covering large openings and spans.

This application is a division of my earlier filed copending application Serial No. 284,633 filed by me on May 31, 1963, for "Movable Roof Structure," now Patent No. 3,211,163.

The desirability of movable roof structures has long been recognized especially for auditoriums, stadia and the like. The desirability of having an open air structure for such purposes is great. However, if a function, play, tournament, game or the like is scheduled for an open air structure and the weather becomes inclement, it is often necessary to cancel the event which leads to serious disruption of the schedules of both the performers and the spectators. Moreover, serious economic losses may result. Accordingly, it has long been recognized that a movable roof which could be employed in inclement weather to protect the participants and spectators of such events from the weather is extremely desirable. Unfortunately, to date, most movable roof structures have proved so costly that they have not been extensively employed.

The present invention is directed to a new and improved movable roof structure which is inexpensive to construct and is highly dependable.

Another object of the present invention is the provision of a new and improved movable roof structure wherein substantially all of the structural means for supporting the roof are in tension.

Still another object of the present invention is the provision of a new and improved movable roof structure employing interacting cables as the main structural elements for supporting the movable roof whereby to greatly reduce the cost of said structure.

A further object of the present invention is the provision of a new and improved movable roof structure employing as the main supporting means for the movable roof two catenary cables which catenaries are capable of spanning long distances and still yielding an effective support structure at low cost.

In accordance with the present invention, a movable roof of a flexible or flaccid nature is supported from an upper concave downwardly extending catenary, which catenary operates in conjunction with a lower upwardly extending catenary cable for preventing upward movement of the roof under wind pressure and the like. The lower catenary is supported by the upper catenary by distributed hangers or suspenders.

The above and other objects, characteristics and features of the present invention will be more fully understood from the following description taken in connection with the accompanying illustrative drawings.

In the drawings:

FIG. 1 is a sectional view of a movable roof structure embodying the present invention showing one module of the support structure for the roof;

FIG. 2 is a sectional view taken along the line **2—2** in FIG. 1;

FIG. 3 is a top plan view of a modified form of auditorium having a movable roof structure embodying the present invention, the structure being shown in the connection it would be in when the roof is closed and the roof being deleted in order to illustrate other parts of the invention;

FIG. 4 is a view similar to FIG. 3 showing the structure in the condition it assumes when the roof is open;

FIG. 5 is a sectional view taken along the line **5—5** in FIG. 3;

FIG. 6 is a view similar to FIG. 3 showing still another form of auditorium with movable roof structure embodying the present invention;

FIG. 7 is a view similar to FIG. 6 showing the structure in the condition it assumes when the roof is open; and

FIG. 8 is a sectional view taken along the line **8—8** in FIG. 6.

One illustration of a desired form of the invention is shown in FIGS. 1 and 2. In this form the structure **410** is substantially rectangular (but may be any shape with distance between points **429** to **431** constant). In such an arrangement the cable assemblies or modules **422** are in spaced parallel relation and between them define a substantially rectangular structure. Each of the modules **422** in the structure **410** includes a plurality of spaced apart left hand braces **424** and a corresponding plurality of opposed spaced apart right hand braces **426**, the braces being tied down by cables **430** and **432**, respectively, extending from the tops of the braces to fixed foundations **428'**. Fixed in the vicinity of the bottoms of the braces **424** and **426** are tracks **425** and **427** and fixed to the tops of the braces **424** and **426** are upper tracks **429** and **431**, respectively. In connection with each module **422** there is an upper catenary cable **434** which extends from upper track **429** to upper track **431** and is held therein by suitable grooved wheels **433** and **435** which are adapted to move longitudinally of the tracks **429** and **431** but are interengaged with the tracks to prevent axial movement thereof. Depending from the upper catenary **434** and fixed thereto at spaced intervals are hangers **437**, **439**, **441**, **443**, **445**, **447** and **449** all of which are fixedly connected at their lower ends to a lower catenary cable **470** which extends from track **424** to track **427** and is held in said tracks by grooved rollers **451** and **453**, respectively, which rollers are substantially identical in construction to the rollers **433** and **435**. It will be seen that the hangers **437** to **449** inclusive are so proportioned so as to hold the cable **470** in the catenary configuration. Secured to the upper catenary **434** and lying over said upper catenary is a flexible or flaccid roof **412** of any suitable material hereinbefore mentioned.

As previously stated all of the cable modules **422** are of substantially identical construction. However, the cable module defining one of the sides of the structure **410**, which cable module is the one actually shown in FIG. 1, is slightly different from the remaining cable modules **422** and is therefore identified by the reference numeral **422'**. The only difference between the module **422'** and the other module **422** is that four motor means **455**, **457**, **459** and **461** are respectively associated with wheels **451**, **453**, **433** and **435** for driving said wheels of said sidemost module **422'**. The motors **455**, **457**, **459** and **461** are adapted to all rotate at substantially the same speed and thereby advance the catenaries **434** and **470** together with their associated hangers in a direction perpendicular to the plane of the drawing of FIG. 1 which direction is designated by the arrow in FIG. 2. When it is desired to open the roof, the motors are all energized simultaneously and advance the module **422'** to the left as viewed in FIG. 2 whereby to cause the roof **412** between the module **422'** and the module immediately adjacent thereto to drape downwardly in a loop. Continued movement of the motor driven module **422'** will cause it to abut against the next adjacent module **422** and push it to the left whereby to collapse the next segment of the roof **412** and this progressive collapsing will continue until all of the modules are in mutually abutting relation with all of them disposed as far leftward as the track means

will permit. This will give a complete open space to the major part of the arena, stadium or auditorium with only a very small section along the side remote from the module 422′ being covered by the collapsed or folded roof. When it is desired to close the roof the motor means 455, 457, 459 and 461 are energized in a reverse direction to move the module 422′ to the right as viewed in FIG. 2 whereby to extend the roof 412 between the module 422′ and the module 422 immediately left of it at which point the roof will be under tension and will pull the next module along in spaced relation with the module 422′. By doing this the next section of the roof will be brought under tension to pull still the next cable module along until all of them are restored to the spaced apart relationship to define a roofed structure 410.

Various types of motor control means may be incorporated in order to insure the proper directionality of movement of the motors and in order to insure de-energization when a desired location of the module 422′ is achieved.

Other shapes of buildings may be employed wherein the catenaries themselves are moved on track means. Such other shape of buildings is shown in FIGS. 3 through 5 wherein the structure takes a circular configuration, the circular building being designated by the reference numeral 510. In this building a plurality of substantially identical modules 522, 522A, 522B and 522C are included, all of which span the entire structure along a diameter thereof. Distributed along the base at the outer perimeter of the structure 510 is a circular track 525. Extending upwardly from the base and being inwardly inclined are a number of distributed rigid braces 524 which are held in position by cable tie-downs 530. Supported by the tops of the braces 524 is a second circular track 527. Of course braces 524 may also extend vertically or be inclined outwardly.

Each of the modules includes an upper catenary 534, a multiplicity of hangers fixed to and depending therefrom which hangers are designated 537, 539, 541, 543, 545 and 547 and which hangers are fixed at their lower ends to a lower catenary cable 570 which is held in the catenary configuration by proportioning the lengths of the hangers. As each of the modules extends across a diameter of the building structure 510 they would normally be intersecting. Accordingly, the catenaries are arranged to be disposed slightly above or slightly below one another to permit the crossing of each for a full diameter. This is best shown in FIG. 5. The ends of the upper caternaries 534 are fixed to centrally grooved rollers 549 and 551 disposed in track 527 in diametrically opposed relation and adapted to move longitudinally of said track but, due to the interfitting of the groove in each of the rollers with a flanged track portion the rollers are prevented from moving transversely of the track. Disposed in the lower track 525 in association with each of the modules are a second pair of rollers 553 and 555 which are secured to the ends of the lower catenary 570. Rollers 553 and 555 are constructed substantially the same as the rollers 549 and 551 and are therefore free to rotate and move longitudinally of the track 525 but are prevented from moving transversely thereof.

The upper catenary 534 in all of the modules are overlaid by and secured to a circular flexible or flaccid roof covering 512 (not shown) which roof covering overlies the entire structure except the pie shaped portion between the right hand part of module 522 and the right hand part of module 522C. Secured to the right hand part of module 522 and cantilevered out to overlie the area between the right hand part of module 522 and the right hand part of module 522C is a pie shaped rigid roof portion 513 that is actually cantilevered out from the upper catenary cable 534 of module 522. Thus it will be seen that when the structure is in the condition shown in FIG. 3 the entire structure will be covered by the flexible canvas overlying the entire assembly of upper catenary cables 534 except for the portion overlaid by the rigid roof covering part 513.

In driving relation with the rollers associated with one of the modules, here shown as module 522, are four motor means 557, 559, 561 and 563, all of which are adapted to rotate their respective rollers 553, 555, 549 and 551. The motors are paired so that the motor means 557 and 561 rotate in the same direction which direction will always be opposite to the direction of rotation of the motor means 559 and 563. Thus when the motor means are all energized, and they all operate at the same uniform speed, the module 522 will rotate about a central axis which axis is the same as the central vertical axis of the building 510. When the building is in the condition shown in FIG. 3 wherein the roof structure is closed, the motors will be energized in such a manner as to rotate the module 522 in a clockwise direction which rotation will, by virtue of tension in the roof 512 and by engagement of adjacent modules, impart similar rotation to the modules 522*a*, 522*b* and 522*c* whereby to rotate all of the modules until they assume the condition shown in FIG. 4 wherein they are all resting in substantially side-by-side relation extending diametricaly across the now open roof structure. The only portions of the structure which will be covered will be that directly underlying the modules and that which underlies the rigid roof segment 513. When it is desired to reclose the roof the motor means is energized in reverse direction and the modules will be returned to the condition shown in FIG. 3. It is obvious that various motor control means may be employed in connection with this structure in order to facilitate the energization and de-energization of the motor means automatically or manually.

Still another form of movable roof structure embodying the present invention may be employed which form of the invention is illustrated in FIGS. 6 through 8, inclusive. In this structure which is designated by the reference character 610, we find the building takes a semicircular shape. The center of the semi-circle is designated by the reference numeral 611 and is provided with a vertical shaft which may be braced by suitable stays and the like that are not shown. Extending radially outward from the shaft 611 are a plurality of cable modules 622, 622*a*, 622*b*, 622*c* and 622*d*. Each of the cable modules includes an upper catenary cable 634 which extends from the shaft 611 to an outer track 651 which is secured to the upper end of a brace 624 that is held in its illustrated condition by any suitable means such as fixed stays 630. The other end of the upper catenary is fixed to a collar 615 which is rotatably disposed on the central shaft 611. Depending from the upper catenary cable 634 are a plurality of fixed hangers 637, 639, 641, 643 and 645 which are proportioned to define a catenary configuration along their bottoms. The bottoms of all of the hangers are fixed to a lower catenary cable 670 having one end thereof secured to a rotatable collar 617 on the vertical shaft 611 and the other end thereof secured to a roller 655 that is mounted in a lower semicircular track 625 that is disposed in a circle described by the bottoms of the braces 624. The roof 612 (not shown) is made of flexible flaccid material of the type hereinbefore described, and is secured to all of the upper catenaries 634 in overlying relation with the catenaries.

Connected to the upper roller 651 of the module 622 is a motor means 663 and a motor means 659 is connected to the roller 655 at the bottom of the module 622. The two motor means 659 and 663 are adapted to operate at the same rotational speed and in the same direction. Accordingly, when the motor means are energized in one direction they will tend to rotate the entire module 622 in a clockwise direction about shaft 611 as viewed in FIG. 6 whereby to collapse the pie-shaped segment of the roof 612 between modules 622 and 622*a*, and rotation will continue until the module 622 engages the module 622*a* and pushes it clockwise. This rotation will con-

tinue to ultimately push ahead modules **622***b* and **622***c* until finally all of the modules will be disposed in substantially side-by-side relation with the module **622***d* as shown in FIG. 7. In this condition the roof is clearly open. When it is desired to close the roof the motor means **659** and **663** are both energized in the reverse direction whereby to move the module **622** in a counterclockwise direction which movement will continue until the roof loop between the modules **622** and **622***a* is taut upon which occurrence the roof will pull the module **622***a* in a counterclockwise direction and then **622***b* in said direction and so forth until the roof resumes the condition shown in FIG. 6.

While I have herein shown and described the preferred embodiments of the present invention, it will be understood that various changes and modifications may be made therein within the scope of the appended claims without departing from the spirit and scope of this invention.

What I claim is:

1. A movable roof structure comprising a pair of upper longitudinally extending spaced apart guide means and a pair of lower longitudinally extending spaced apart guide means, a plurality of cable modules extending transversely of said guide means, each of said cable modules including an upper downwardly curving cable having its ends movably mounted on said upper pair of guide means, a lower upwardly curving cable having its ends movably secured to said lower pair of guide means, a plurality of hangers secured to and depending from said upper cable and secured to said lower cable for supporting same, a flaccid roof secured to said upper cables, and means for moving said cable assemblies toward and away from one end of said structure for opening and closing said roof.

2. A movable roof structure comprising an upper circular guide means, a lower circular guide coaxial with said upper guide means, a plurality of angularly related diametrically extending cable modules, each of said modules comprising an upper downwardly curving cable having its ends movably mounted on said upper guide means at diametrically opposed points, a lower upwardly curving cable having its ends secured to said lower guide means at diametrically opposed points, a plurality of hangers secured to said upper and lower cables for supporting said lower cable on said upper cable, and means for rotating said cable modules about their centers.

3. A movable roof structure comprising an upper arcuate guide means, a lower arcuate guide means, a vertical support extending through the centers of said two guide means, a plurality of angularly related radially extending cable modules, each of said cable modules comprising an upper downwardly curving cable having one end rotatably mounted on said vertical support and the other end movably mounted on said upper guide means, a lower upwardly curving cable having one end rotatably mounted on said vertical support and its other end movably mounted on said lower guide means, a plurality of hangers connected to said upper and lower cables for supporting said lower cable on said upper cable, and means for rotating at least some of said modules toward and away from one end of said arcuate guide means.

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HARRISON R. MOSELEY, *Primary Examiner.*

L. J. SANTISI, W. E. HEATON, *Assistant Examiners.*