United States Patent [19]

Rosenblatt

[11] **3,922,827**

[45] **Dec. 2, 1975**

[54] **HYPERBOLIC TOWER STRUCTURE**

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[52] **U.S. Cl.** **52/245;** 52/80

[51] **Int. Cl.** **E04h 5/12**

[58] **Field of Search** 52/80, 81, 245, 236, 643, 52/648, 650, 653, 655, 73

[56] **References Cited**

UNITED STATES PATENTS

3,300,942	1/1967	Horstman	52/80 X
3,603,051	9/1971	Lussky	52/245
3,618,277	11/1971	Waters	52/245 X
3,648,990	3/1972	Stoker	52/245 X

OTHER PUBLICATIONS

Article "Torsion Tower," Architectural Record, May, 1963, pages 91 & 92.

Primary Examiner—Price C. Faw, Jr.

[57] **ABSTRACT**

A tower structure consisting of a central vertical frame shaft surrounded by an outer structure in the form of a hyperboloid of revolution composed of two sets of intersecting straight linear structural elements arranged to define the hyperboloid, the linear elements being connected at their intersections to the central shaft by horizontal radial bracing members. The outer structure may be formed by successively connecting preassembled sub-assemblies consisting of segments of the linear elements with radial bracing members attached thereto. The central vertical shaft contains means of access to the upper levels, such as stairways, ladders, elevators, and the like, and a plurality of horizontal deck levels are provided within and on top of the tower structure.

15 Claims, 17 Drawing Figures

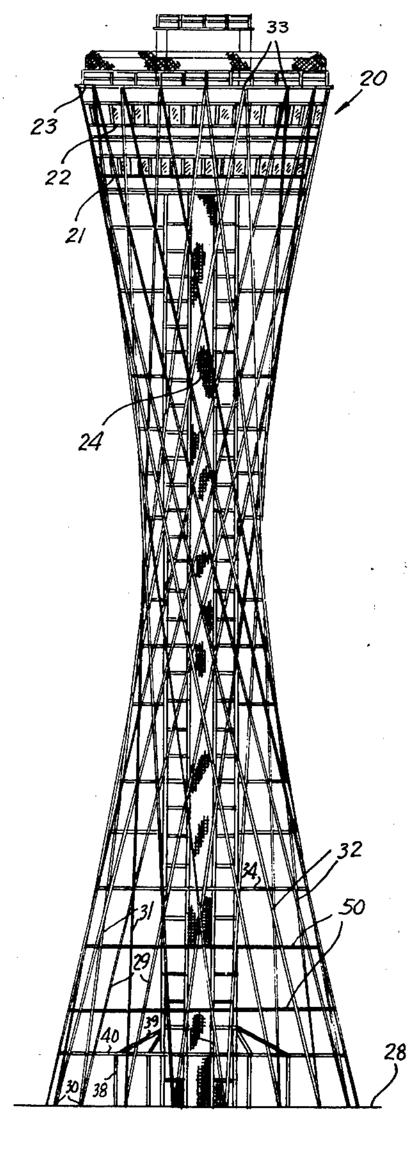

FIG. 1.

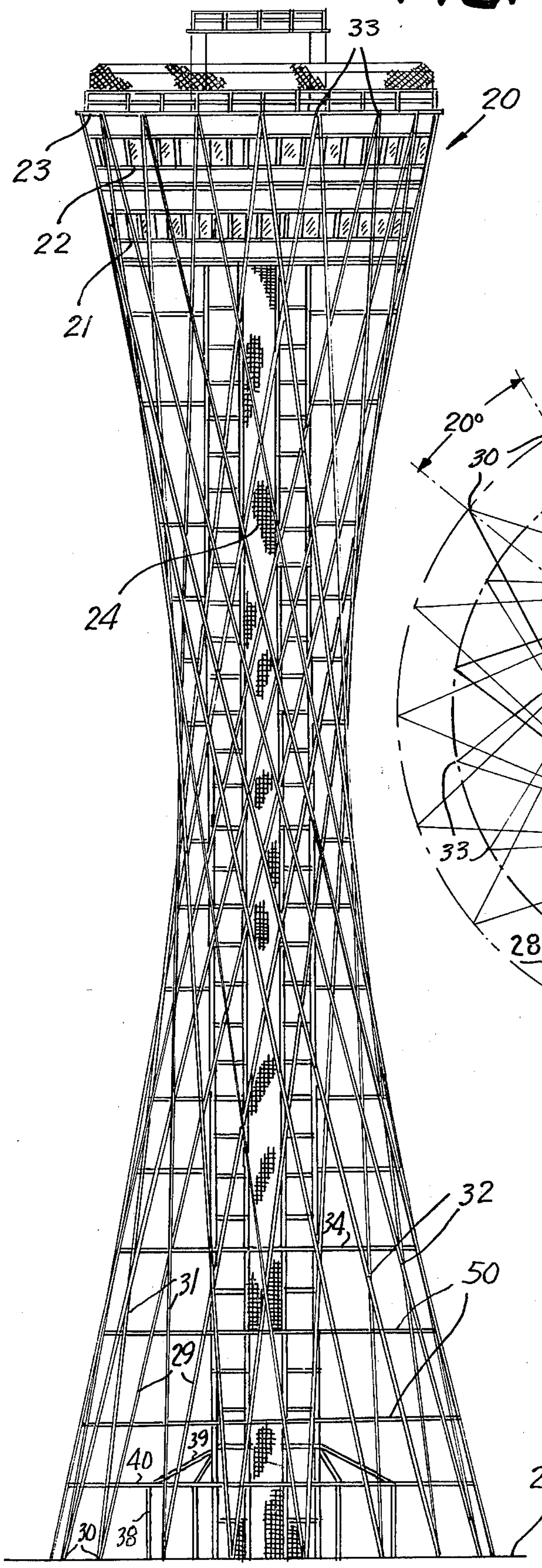
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FIG. 2.

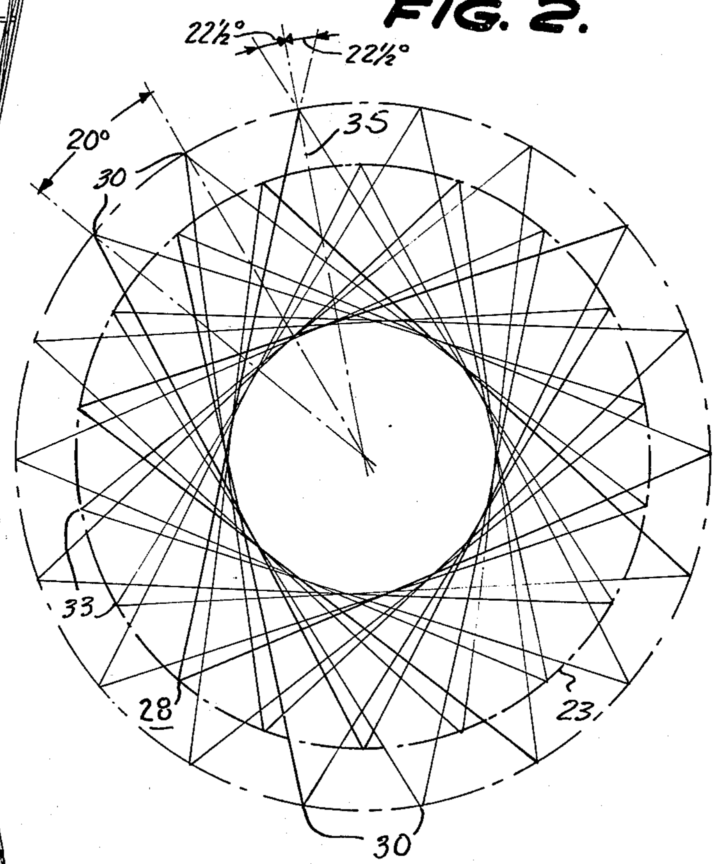
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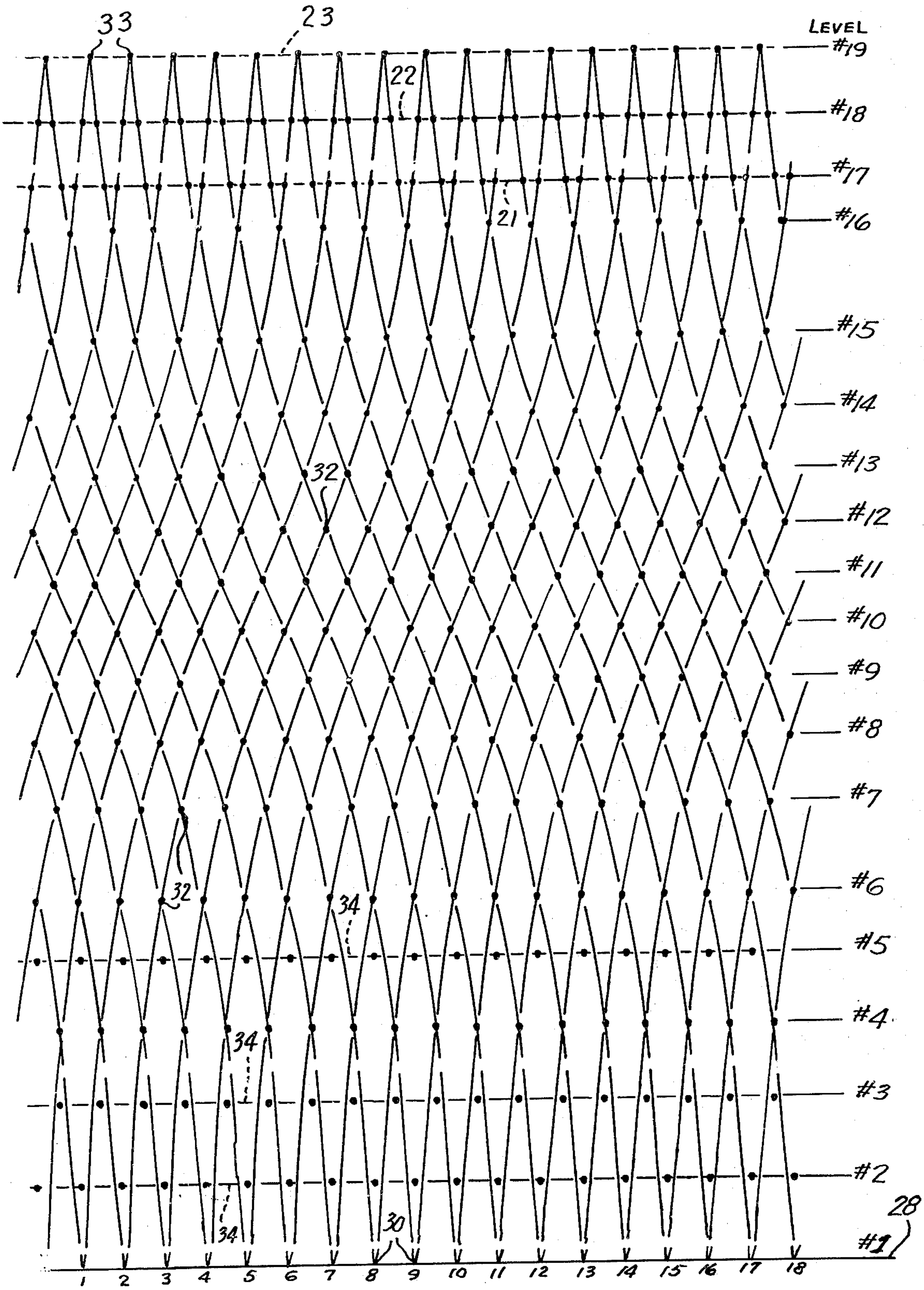
FIG. 3.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#1
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FIG. 4.

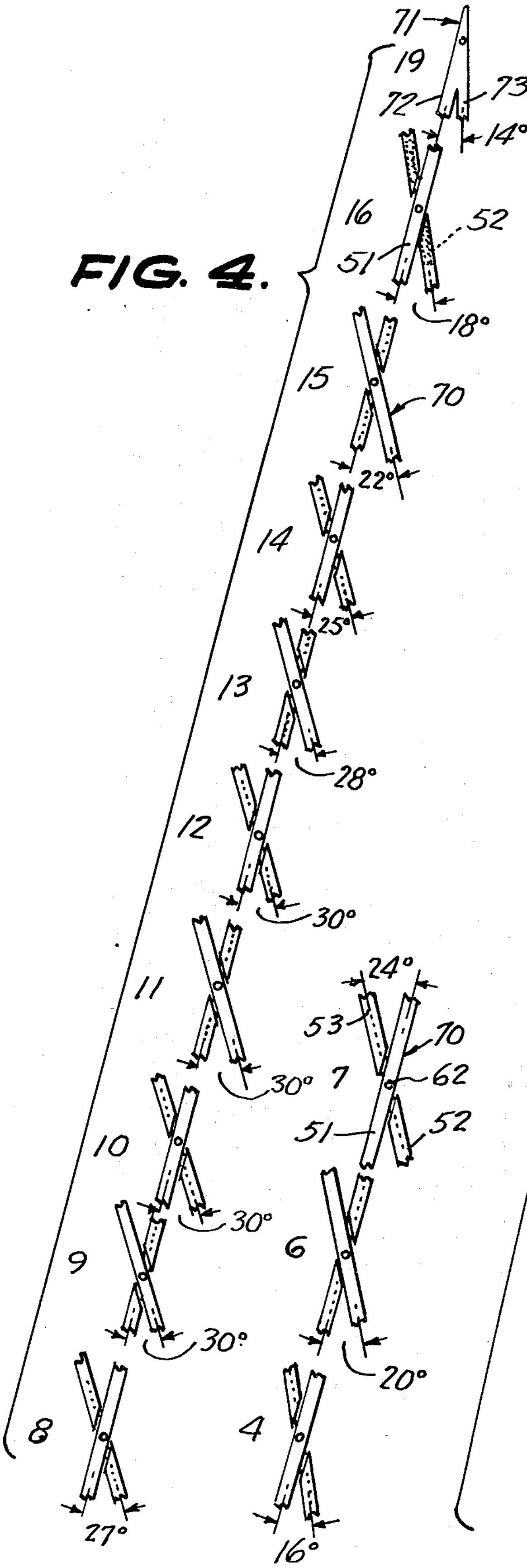
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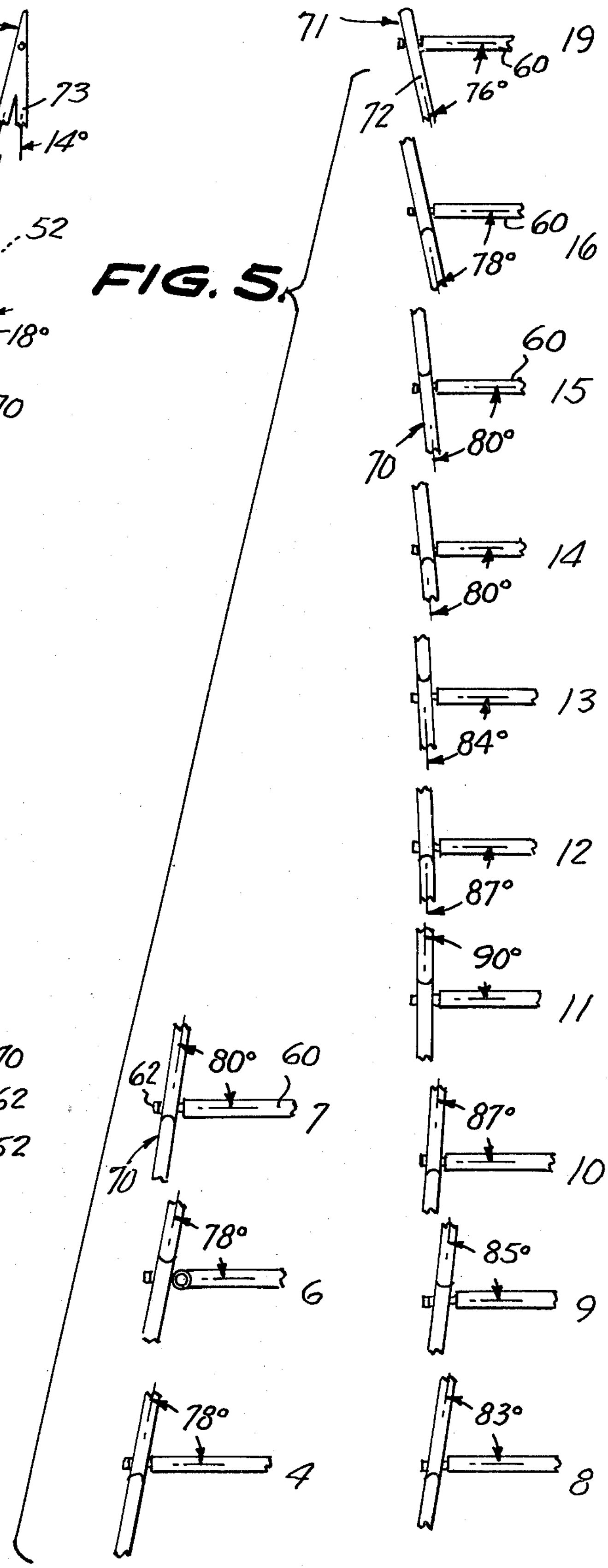
FIG. 5.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11
62
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83°
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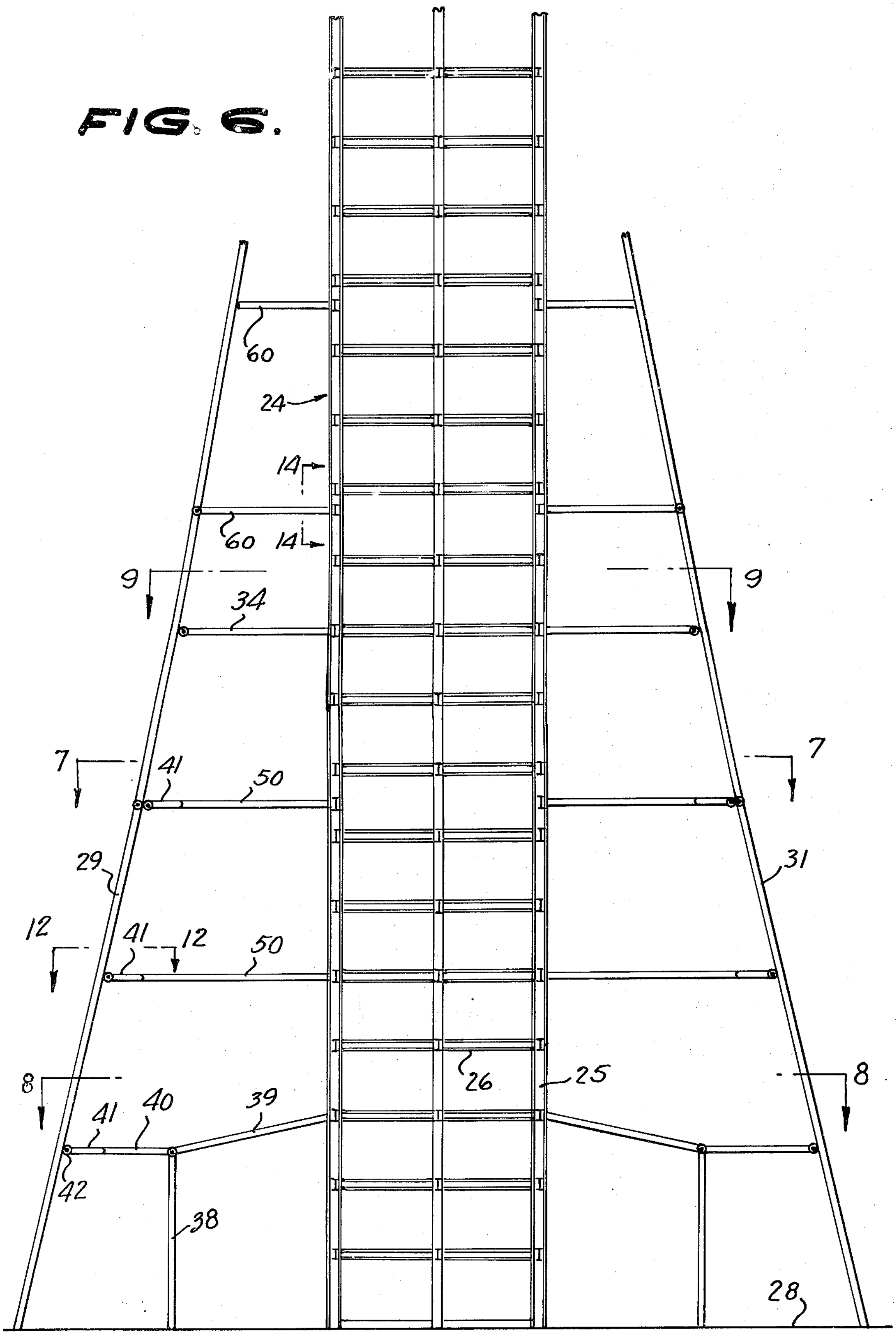
FIG. 6.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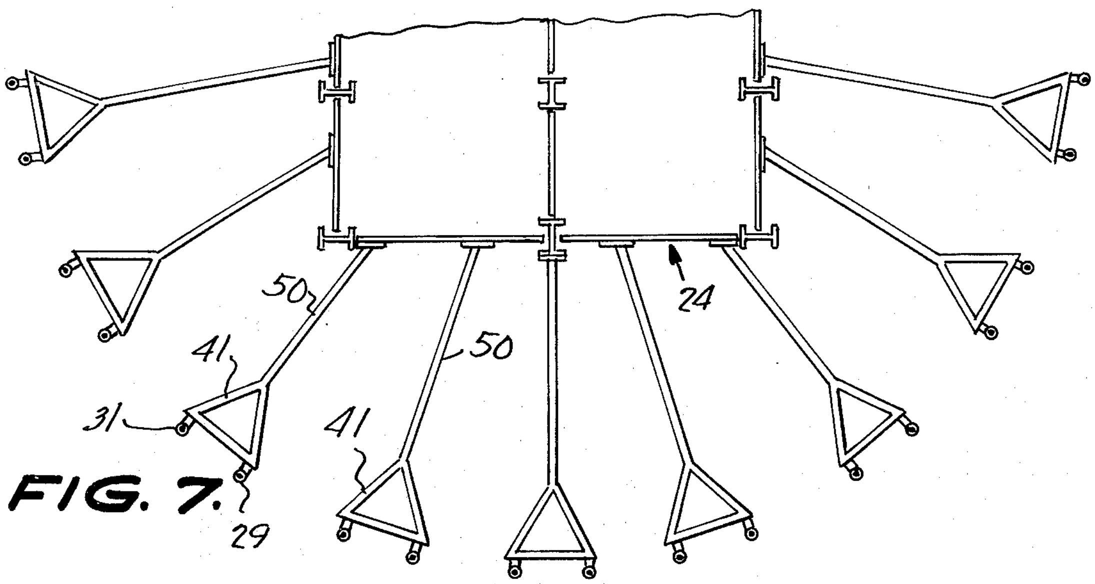


FIG. 7.

FIG. 8.

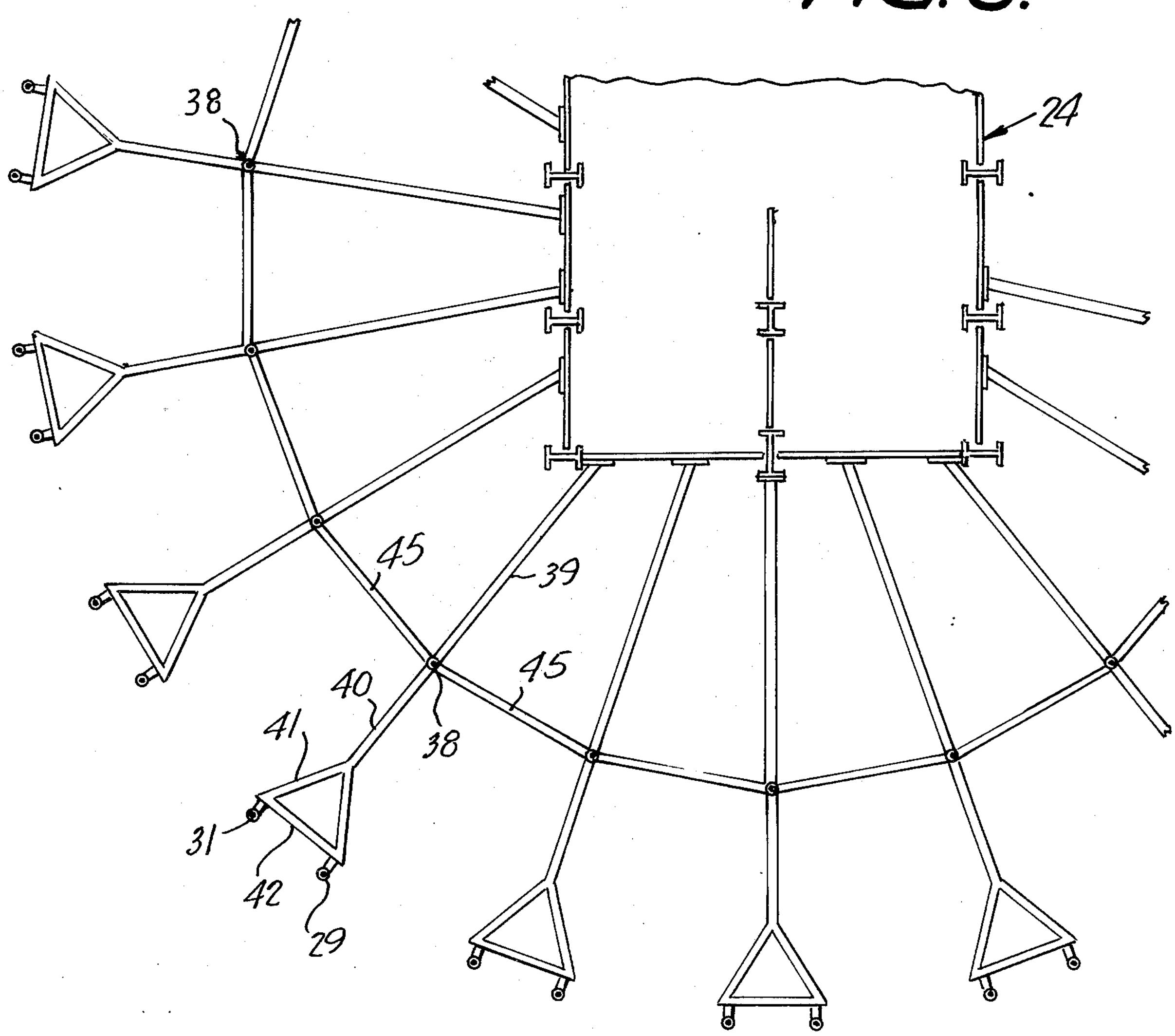


FIG. 9.

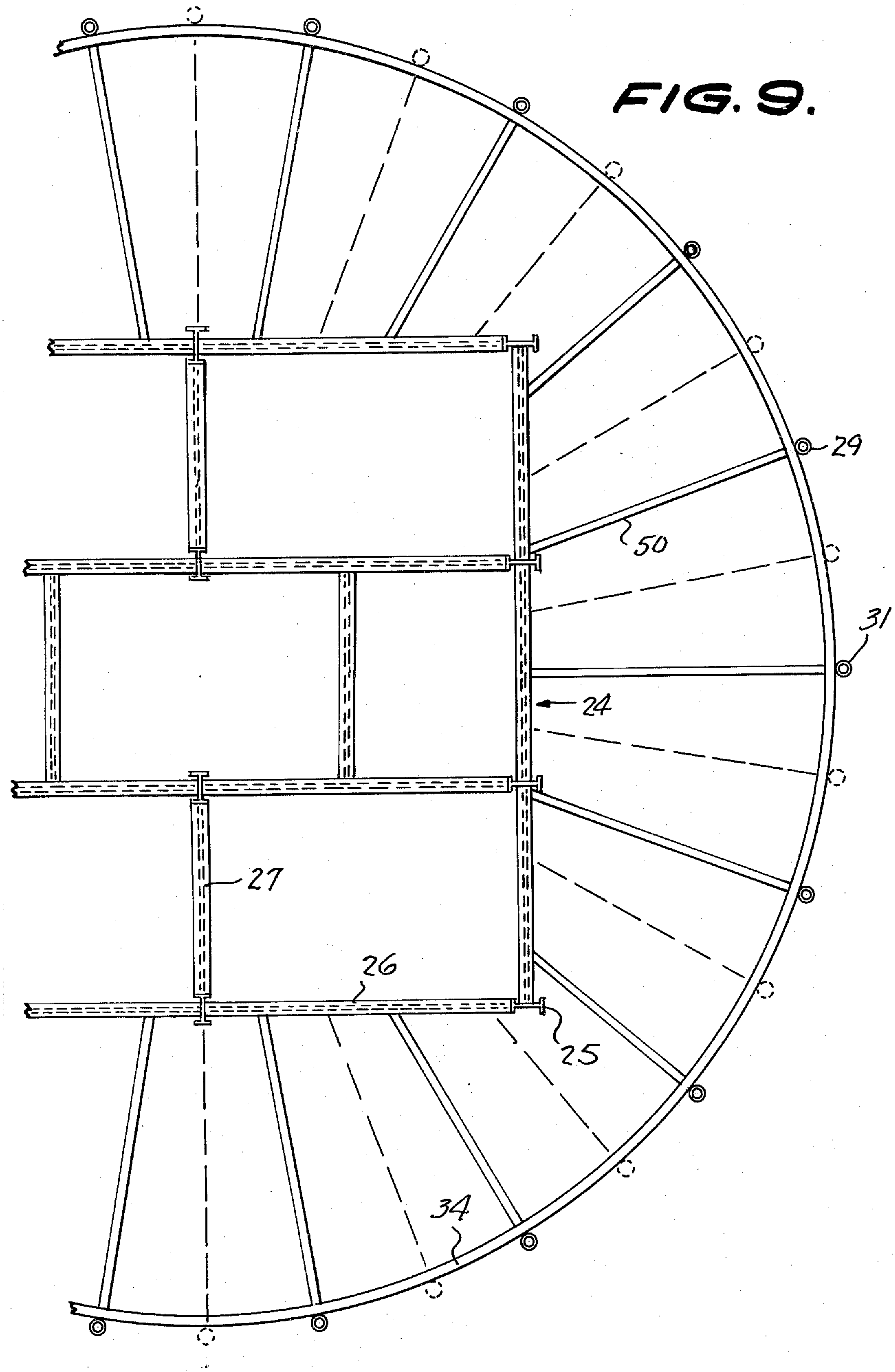


FIG. 10.

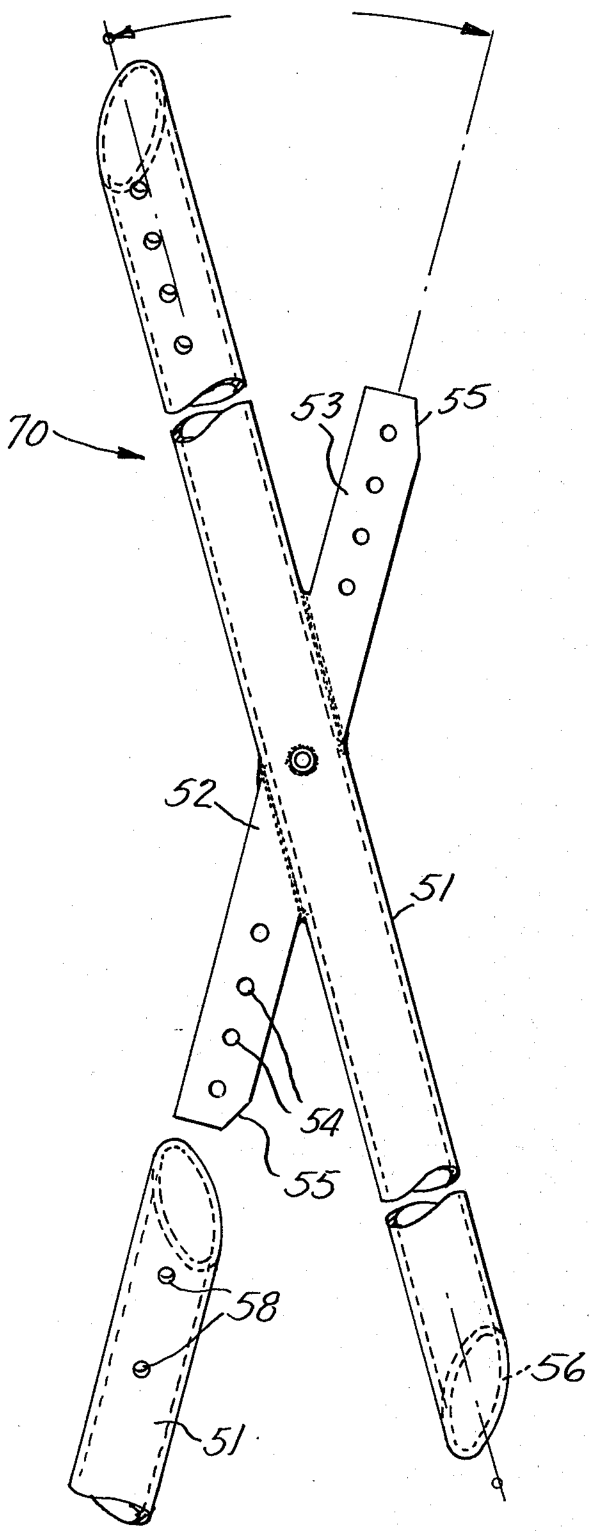


FIG. 11.

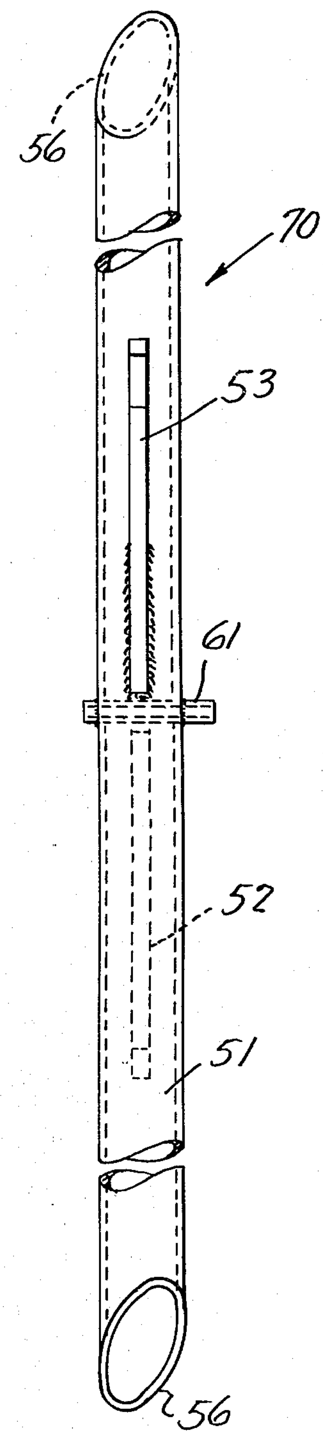


FIG. 12.

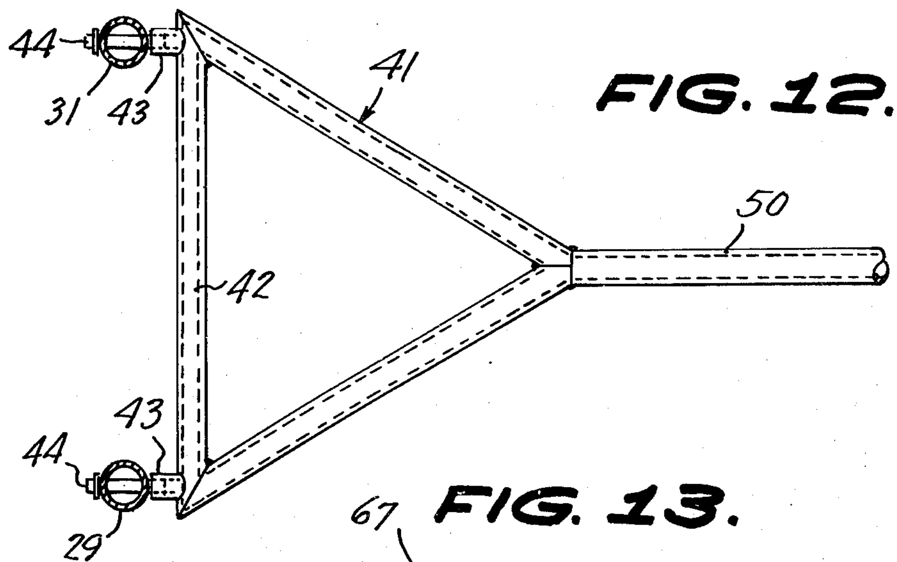


FIG. 13.

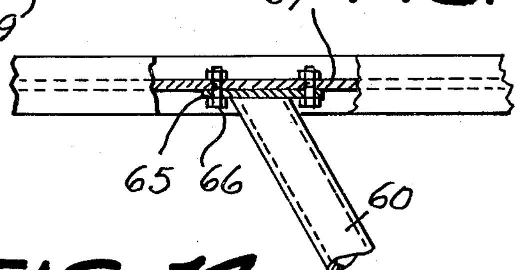


FIG. 14.

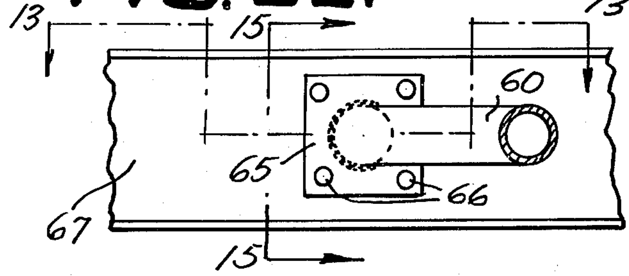


FIG. 15.

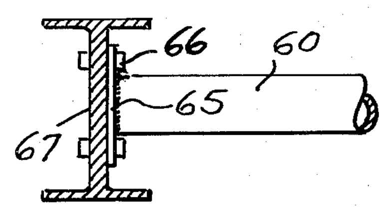


FIG. 16.

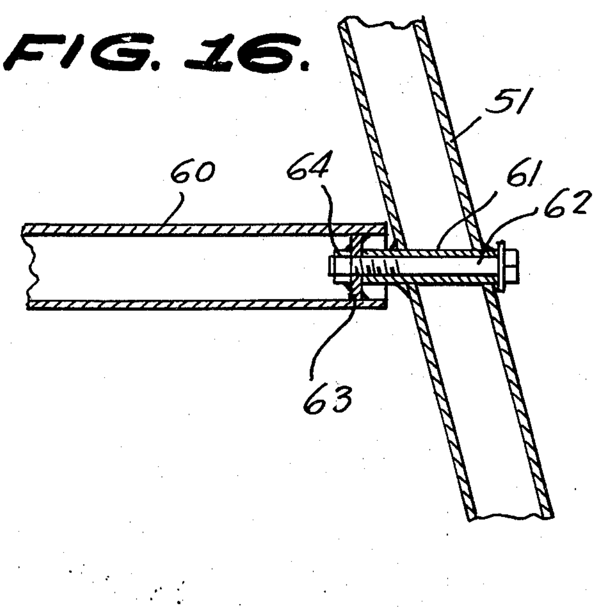
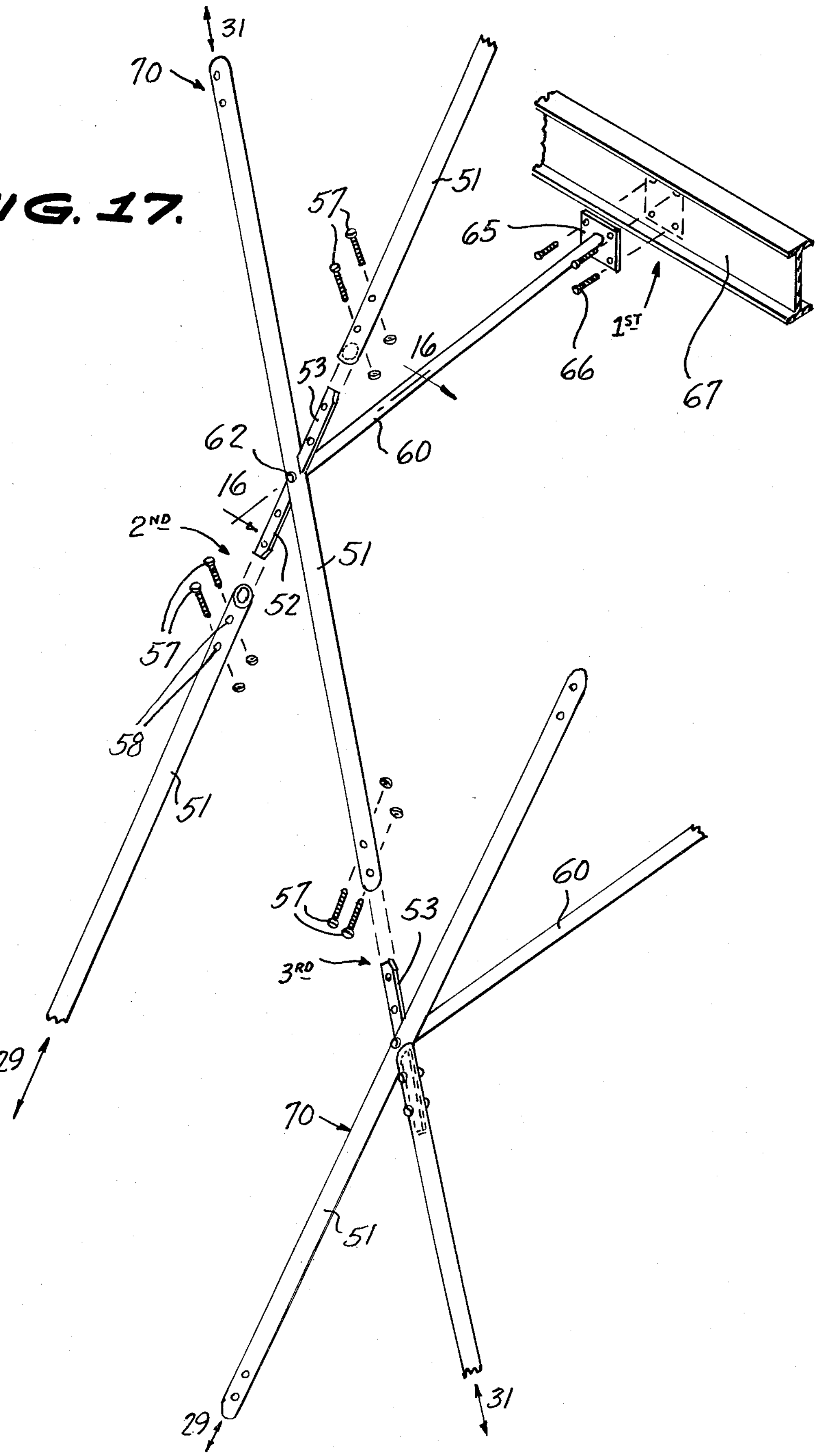


FIG. 17.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HYPERBOLIC TOWER STRUCTURE

This invention relates to building structures, and more particularly to an improved tower structure in the form of a hyperboloid of revolution.

A main object of the invention is to provide a novel and improved tower structure which is relatively easy to erect, wherein wind forces and other lateral forces are efficiently resisted by axial forces developed in outer linear structural members, and wherein the outer linear structural members serve as supporting means as well as bracing means for the structure.

A further object of the invention is to provide an improved tower structure which employs relatively lightweight structural members to maintain it in erect position and to resist lateral and other forces, the structural elements employed being relatively expensive, being easy to install, and providing a final structure of high strength and pleasing appearance.

A further object of the invention is to provide an improved tower structure substantially in the form of a hyperboloid of revolution composed of intersecting straight linear structural elements and having a central vertical shaft portion which may contain means of access to the various levels of the tower structure, such as stairways, ladders, elevators and the like, the improved tower structure being capable of erection by the use of preassembled sections which are relatively light and easy to handle and which thereby enable the tower structure to be built economically and without requiring the use of expensive equipment.

A still further object of the invention is to provide an improved tower structure having high structural rigidity and strength relative to the weight of metal employed in the structure and at the same time providing a highly pleasing esthetic effect so that it improves the general appearance of the environment in which it is installed

A still further object of the invention is to provide an improved tower which is relatively simple in construction, which is adequately braced to withstand maximum expected wind forces and other types of loading, which has a pleasing shape, and which can be quickly and expensively erected.

Further objects and advantages of the invention will become apparent from the following description and claims, and from the accompanying drawings, wherein:

FIG. **1** is an elevational view of a typical hyperboloidal tower structure constructed in accordance with the present invention.

FIG. **2** is an enlarged top plan view of the hyperboloid-defining framework of the tower structure of FIG. 1 and illustrating the manner in which the linear hyperboloid-defining elements are oriented.

FIG. **3** is a developed diagrammatic view of the hyperboloid-defining elements employed in the tower structure of FIG. **1** and showing intersection points of the structural elements at the various levels of the tower structure.

FIG. **4** is a fragmentary elevational view showing intersection joint elements along a composite linear structural element forming part of the tower structure of FIGS. **1, 2** and **3** and showing the different intersection angles at the various levels of the tower structure.

FIG. **5** is a fragmentary side view substantially showing the intersection joint elements of the composite linear structural elements of FIG. **4** and illustrating the variation of the angle between the horizontal radial brace elements and the intersection segments to which they are connected at the various levels of the tower structure of FIGS. **1, 2** and **3.**

FIG. **6** is a fragmentary enlarged vertical cross-sectional view taken through the lower portion of the hyperboloidal tower structure shown in FIG. **1.**

FIG. **7** is an enlarged fragmentary horizontal cross-sectional view taken substantially on the line **7—7** of FIG. **6.**

FIG. **8** is a fragmentary enlarged horizontal cross-sectional view taken substantially on the line **8—8** of FIG. **6.**

FIG. **9** is an enlarged fragmentary horizontal cross-sectional view taken substantially on the line **9—9** of FIG. **6.**

FIG. **10** is an enlarged fragmentary front elevational view of a typical hyperboloid-defining linear structural segment employed in the tower structure of FIG. **1.**

FIG. **11** is a side elevational view of the structural segment shown in FIG. **10.**

FIG. **12** is an enlarged horizontal cross-sectional view taken substantially on the line **12—12** of FIG. **6.**

FIG. **13** is a fragmentary horizontal cross-sectional view taken substantially on the line **13—13** of FIG. **14.**

FIG. **14** is an enlarged fragmentary vertical cross-sectional view taken substantially on the line **14—14** of FIG. **6.**

Fig **15** is a vertical cross-sectional view taken substantially on the line **15—15** of FIG. **14.**

FIG. **16** is an enlarged fragmentary vertical cross-sectional view showing the details of the connection of a horizontal radial brace member to its associated hyperboloid-defining structural segment, such view being taken substantially on the line **16—16** of FIG. **17.**

FIG. **17** is an enlarged fragmentary perspective view showing a pair of preassembled hyperboloid-defining structural sub-assemblies and showing how they are interconnected and are connected to the interior vertical shaft structure, illustrating the manner in which connections are made at three points for each structural sub-assembly in the course of erection of the hyperboloidal tower structure.

Two general types of tower structures have been commonly employed for many years. The free standing tower is essentially a structure in which all lateral forces are resisted by bending or flexural resistance of the tower shaft. The guyed tower is the alternative form in which the shaft structure resists all vertical loads, including the vertical components of forces in the guys, and lateral forces are resisted by flexible guys capable of tension resistance only. Wind forces of a guyed tower induce tension reactions in the windward guys, and the leeward guys contribute nothing to the support of the tower.

In a tower constructed in accordance with the present invention, the hyperbolic arrangement of the bracing system permits the lateral forces to be resisted in tension in those hyperbolic elements inclined from the ground with components in the direction of the wind, while those inclined in opposition to the wind are capable of providing support in compression reactions. Thy system, according to the present invention, is therefore braced rather than guyed.

Mathematically, a form of tower such as that proposed herein has been known for centuries as the "hyperboloid of one sheet", or as the "hyperboloid of revolution of one sheet". This form is also one of the family of mathemetically defined forms known for centuries as "ruled quadric surfaces". This family of mathematical forms is characterized by the fact that, though the surface is doubly curved in space, it may be generated by straight lines.

In recent years, the development of the use of a variety of structures depending for their stiffness on surface curvature has attracted widespread interest. These structures have led to the evolution of much literature in the field under the generic term "thin-shell structures". They have taken their most varied development in moldable materials (concrete, plastics, etc.) which lend themselves to curved surface forms.

The development of structures of these types fabricated of structural steel has been more limited due to the essentially linear form in which steel members are produced. Shell structures in steel have been developed by applications of line increment approximations of curved surfaces (for example, Fuller's geodesic dome), and by application of the other doubly curved ruled quadric surfaces which inherently may be described by systems of straight lines — the hyperbolic paraboloid roof form. The concept of the present invention extends the shell structure principles to a vertical form to provide a ruled quadric surface from linear materials and thereby gains the efficiency of a shell structure in a vertical tower form formerly available only to relatively horizontal roof structures. The characteristics of high stiffness for minimum materials used, conversion of bending forces to membrane stresses, and weight savings, well known in the literature of shell theory, all become available to the tower form in the present invention.

Towers in the form of continuously-skinned hyperbolas of revolution have previously been built (for example, the Seattle "Space Needle", cooling towers for nuclear power plants, and the like). The structure of the present invention employs an open lattice form of this shell, uniquely suited to fabrication from long linear materials (pipe, tubing, bars, rolled or drawn structural shapes, and the like).

For example, as shown in FIG. 1, a tower structure is illustrated, comprising an intersecting network of pipes, each of which is a line element of the two sets of line families which define a hyperboloid of revolution. The distance between consecutive intersections along each line element will vary with the choice of number of line elements to be used, the ratio of plan diameter to waistline diameter, and the ratio of plan diameter to waistline height. As the number of line elements is increased, the full shell surface is more nearly developed.

As the distance intersections is increased, the length of each structural element forming a segment of a line between intersections is increased, the structural element forming a segment of such a line becoming susceptible to local column buckling, a phenomenon well described in the literature on structural theory. Resistance to local buckling of this type can be provided by selecting a structural member providing adequate radius of gyration in its section geometry, or by providing intermediate bracing to reduce its free buckling length. As will be presently explained in detail, with reference to FIG. 7, 8 and 9, an arrangement of horizontal radial members is employed to provide bracing against local buckling tendencies. Also, rigid ring members could be employed to provide a similar function. An example of a ring member so employed is illustrated in FIG. 9. The radial members also permit lateral forces from the central shaft structure to be transmitted to the external hyperbolic system.

Referring more particularly to the drawing, FIG. 1 shows a typical observation tower **20** constructed in accordance with the present invention. The tower **20** is provided with deck areas at several levels near its top, for example, the deck structures shown respectively at **21, 22** and **23.** Access to these deck areas is provided through a central framed shaft **24** containing both elevators and stairways.

In the typical example illustrated, a substantial amount of structure is required for the support of the stairways and guidance of the elevators, and the vertical loading resulting therefrom is carried essentially by the framing of the central shaft structure, presently to be described, the lateral loads being transmitted to the exterior hyperbolic elements. It is to be noted that in other applications within the concept of the present invention, in which the need for vertical traffic volume handling is not so great (for example, radar-radome support towers or the like), the vertical loads could be carried by the hyperbolic elements themselves. In the typical embodiment illustrated in the drawings, the tower **20** is fabricated mainly from steel pipe and rolled structural steel shapes. Other embodiments within the concept of the present invention could be fabricated from other structural materials, including wood, aluminum, a variety of plastic materials with or without reinforcements, or the like.

The central vertical structure **24** comprises a vertical frame of substantially rectangular horizontal cross-sectional shape which is fabricated from rolled structural steel members comprising vertical rolled steel structural shapes **25** and horizontal rolled shape-beams **26** secured together to define the aforesaid vertical central frame. As shown in FIG. 9, the vertical frame structure includes the internal horizontal brace members **27** which may comprise rolled steel structural members such as I-beams. The vertical frame structure **24** may be suitably anchored to a horizontal supporting base slab **28.**

The hyperbolic outside framing comprises a first set of inclined linear elements **29** connected at their bottom ends to the base slab **28** at uniformly spaced points **30** circularly arranged concentrically with the vertical axis of the central shaft structure **24** and an equally and oppositely inclined second set of linear elements **31** connected to the slab **28** at the points **30** and intersecting the first-named linear elements **29** at a multiplicity of intersection points **32**, at which points the linear elements are connected together in a manner presently to be described, whereby to define a hyperboloid of revolution leading upwardly to the top deck **23** in the manner shown in FIGS. 1 and 2, the top ends of the linear elements **29** and **31** are connected together to uniformly spaced points **33** at the periphery of the top deck **23.** Lateral bracing may be provided, as will be presently described, by radial brace rods connecting the intersections **32** with the central vertical shaft structure **24** or by the provision of vertically spaced horizontal rigid brace rings **34** connected to the hyperboloid-defining linear elements **29** and **31** in the manner illustrated in FIGS. 1 and 9.

In a typical embodiment, such as is illustrated in FIGS. 1 and 2, the base connection points **30** may have an angular spacing of 20° relative to the vertical axis of the tower, and the linear elements 29 and 31 may be so inclined as to have vertically projected angles of 22½° relative to and on opposite sides of a vertical radial plane **35** passing through the vertical axis of the tower.

FIG. **3** is a theoretical developed view of the hyperboloidal tower structure defined by the above-mentioned linear elements **29** and **31**, said linear elements being shown as being somewhat sinuous in the theoretical presentation of FIG. **3**, although in actuality the elements are straight. FIG. **3** illustrates various successive levels spaced vertically on the tower structure, designated respectively from one to nineteen, the levels from four to sixteen corresponding to the levels of intersection points **32** of the linear elements **29** and **31**. Brace rings **34** may be employed at the levels **2**, **3** and **5**, and the upper levels **17**, **18** and **19** corresponding to the levels of the horizontal deck structures **21**, **22** and **23**.

The tower structure is provided with a bottom bracing framework comprising vertical post members **38** anchored to the base slab **28** and rising for a substantial height, the post members **38** being at equal radial distances around the vertical axis of the tower and being uniformly spaced relative to each other. The top ends of the post members **38** are connected to the central shaft structure **24** by upwardly and inwardly inclined tie bars **39**. The top end of each vertical post member **38** is likewise connected to a pair of outwardly adjacent linear members **29** and **31** by horizontal tie bars **40** provided at their outer ends with linearly triangular-shaped frame portions **41** substantially in the form of equilateral triangles, said frame portions **41** being rigidly connected to their associated tie bars **40**. The triangular portions **41** have outer horizontal bar elements **42** at the opposite end portions of which are secured outwardly extending short cylindrical members **43**, **43** in which are secured respective fastening bolts **44**, **44** which are engaged through the linear members **31** and **29** and are suitably fastened thereto. See FIG. **12**.

The top ends of the vertical post members are further rigidly connected by horizontal tie bars **45** which are thereby substantially circularly arranged around the vertical central shaft structure **24**, as will be apparent from FIG. **8**.

As shown in FIGS. **6** and **7**, at levels spaced upwardly along the tower structure, adjacent pairs of linear members **31** and **29** are similarly connected to the central vertical shaft structure **24** by horizontal radially directed tie bar elements **50**, similar to the previously described tie bar elements **40**, and provided with the triangular outer connection frame elements **41**, as shown in FIG. **12**. Thus, in a typical embodiment illustrated there are two sets of radial tie bar members **50** and associated outer connection frame structures located above the bottom bracing structure including the vertical post members **38** and inclined tie bar elements **39**. As shown in FIG. **6**, a horizontal rigid circular connection ring member **34** may be employed at the next connection level to interconnect the linear members **29** and **31**. As above mentioned, additional rigid horizontal ring members **34** may be employed in the same manner at various other levels of the tower structure.

To facilitate the erection of the tower structure and simplify fabrication thereof, the linear members are preferably formed from combinations of preassembled elements such as those shown in FIGS. **10** and **11**, the preassembled elements being utilized in the manner illustrated in FIG. **17**. Thus, the segments of the linear members may comprise main tubular body portions **51** to the opposite sides of which are rigidly secured aligned flat bar segments **52** and **53** appropriately angled in accordance with specific intersections of the linear members of the tower structure. The aligned flat bar members **52**, **53** are apertured, as at **54**, to receive fastening bolts and are beveled, as at **55**, to facilitate their insertion into the open end portions of body members **51** of adjoining preassemblies.

The end portions of the body members **51** are beveled, as shown at **56**, and are suitably shaped to conform with the contours of the body members **51** adjacent the flat bar elements **52**, **53** when segments are joined together in the manner illustrated in FIG. **17**. Thus, the lower bar elements **52** are inserted into the top ends of the subjacent body members **51** and are fastened thereto by bolts **57** extending through apertures **58** which register with selected pairs of apertures **54**. The upper splice bar elements **53** are received in the lower ends of the main body members **51** of the next upwardly adjacent sub-assembly to be connected at the intersection. In this manner, the linear elements may be built up from sub-assemblies such as shown in FIGS. **10** and **11** in the manner illustrated in FIG. **17**, and the hyperbolic lattice of the tower structure may be built from such sub-assemblies.

As shown in FIG. **17**, the sub-assembly may include a radially directed tie bar element **60** extending from the intersection toward the central shaft structure **24** and being adapted to be horizontally secured to said central shaft structure. Thus, as shown in FIG. **16**, a suitably inclined sleeve member **61** may be secured in the body member **51** of the subassembly, being rigidly secured as by welding, or the like, through which a bolt **62** extends which engages through an annular washer **63** welded in the end portion of the associated radial tie bar element **60**, the bolt **62** being threadedly engageable with a nut element **64** welded onto the washer **63**. Thus, the associated radial tie bar element **60** may be secured to the body member **51** of the sub-assembly and will be properly oriented relative thereto because of the particular orientation of the bolt sleeve element **61** employed in the body member **51**. Each tie bar element **60** is provided at its end with a rigidly connected flange **65** adapted to receive fastening bolts **66** for securing the tie bar element to the web **67** of an I-beam forming part of the adjacent central shaft structure. Flanges **65** and fastening bolts **66** may be similarly employed with the previously described tie bar elements **39** and **50** for connecting the inner ends of the tie bar elements to the webs **67** of I-beams forming the adjacent portions of the central shaft structure **24**, the connections being shown in detail in FIGS. **13**, **14** and **15**.

As mentioned above, each sub-assembly unit comprises a tubular segment **51** with its aligned bar elements **52** and **53** rigidly secured thereto and its appropriate tie bar tubular element **60** secured thereto by a bolt **62** in the manner illustrated in FIG. **16**. In assembling the tower structure, each subassembly unit, such as the unit designated generally at **70**, in FIG. **17**, is installed by three-point securement; first, at the web portion **67** of the adjacent I-beam element of the central shaft structure, employing the bolts **66** with the flange element **65** of the tie bar member **60** to secure the flange element **65** to the web **67** in the manner illustrated in FIG. **17**; second, by engaging its downwardly extending bar element **52** in the top end of the tubular member **51** of one subjacent previously installed assembly and securing the member **52** in said top end by means of bolts **57**, as shown in FIG. **17**; and third, by telescopically engaging the lower end of its tubular member **51** over the upwardly directed bar element **53** of the next adjacent previously installed sub-assembly and fastening said lower end to the upwardly extending bar member **53** by means of bolts **57**, as is also clearly shown in FIG. **17**. Thus, in beginning the erection of the tower, respective sets of tubular members **29** and **31** are suitably anchored to the base slab **28**, the tubular members being of length sufficient to extend up to the fourth level shown in FIG. **3**, the members being connected together by the interior framework previously described and illustrated in FIGS. **7**, **8** and **9**, details of which are also shown in FIGS. **12** to **16**. From this point, the remaining construction may be performed by employing the above-described sub-assemblies **70**. At the uppermost level, namely, that shown at No. **19** in FIG. **3**, preassembled top members **71** (see FIG. **4**) may be employed having downwardly divergent elements **72**, **73** suitably designed to interfit with the subjacent installed assemblies **70**. The top assemblies **71** are provided with the inwardly directed radial tie bar elements **60** like those employed with the previously described sub-assemblies **70**.

As shown in FIGS. **4** and **5**, in a typical embodiment of a tower constructed in accordance with the present invention, the top elements **72** and **73** converge at an angle of **14°**, and the angle of convergency between the bar elements **52** and main body portions **51** of the sub-assemblies below increases downwardly to a maximum of **30°** at the waist portion of the tower, the angle of convergency then decreasing downwardly below said waist portion, the lowermost convergency angle shown, namely, that at the level No. **4** being **16°**. Similarly, the angles between the radial tie bar members **60** and the planes of the other elements of the sub-assemblies vary. For example, at the top sub-assemblies **71**, the bottom angle between the tie bar element **60** and the plane of the members **72**, **73** is **76°**. This angle increases downwardly with the other sub-assemblies until it reaches a maximum of **90°** at the waist portion of the tower structure, after which the top angle decreases so that it becomes **78°** at the lowermost sub-assembly, namely, the sub-assembly at the level No. **4**.

Design factors such as those above mentioned may be readily calculated prior to the erection of the tower, so that the sub-assemblies can be prepared prior to erection and can be then readily installed in the field.

It will be noted that the sub-assemblies **70** are generally similar in design except that those employed to align with the linear elements **29** will have their radial tie rod element **60** reversed in direction with respect to the sub-assembly elements employed to align with the linear elements **31**. In other words, as shown in FIG. **17**, comparing the two adjacent sub-assemblies **70** shown therein, the lower sub-assembly **70** has its bar element **53** extending upwardly in a direction to be received in the lower end of the main segment **51** of the upwardly adjacent sub-assembly **70**, extending in the direction of the linear members **31** of the structure, whereas the upwardly extending bar element **53** of the upper assembly **70** extends in a direction aligned with the direction of the other structure-defining linear elements **29**.

It will be apparent to those skilled in the art that a variety of alternative means of fabricating the necessary connection details are available, the choice being a matter of engineering and construction economics applied to the intended materials of construction and intended erection conditions. The hyperbolic elements may be butt spliced along their lengths and connected at their intersections by bolting, welding, riveting, be screw connections or by being glued, depending on the materials employed. The intersection connection elements may comprise hub castings, preformed molding, weldments, or may comprise rectangular or circular flat gusset or splice plates to which the intersecting members are attached by any of the connection methods mentioned.

In the detailed specific embodiment illustrated in the drawings and described above, the hyperbolic elements **51** are fabricated from steel pipe in pieces substantially equal to the length of two consecutive segments with an intersection point near its center, at which the associated radial brace element **60** is attached. Each successive level may be erected by connections to the bar elements **53** of the level below, permitting each sub-assembly including a member **51** and its radial brace element **60** to have three point of support as it is installed, thereby eliminating the need for secondary supporting means during erection before the connections are finally made. Each successive erection level takes the form of an overlapping lattice similar to that of a lamella arch roof in timber construction.

While a specific embodiment of an improved hyperboloidal tower structure and a method of erecting same have been disclosed in the foregoing description, it will be understood that various modifications within the spirit of the invention may occur to those skilled in the art. Therefore, it is intended that no limitations be placed on the invention except as defined by the scope of the appended claims.

What is claimed is:

1. A tower structure comprising:

a. the base;

b. two sets of oppositely inclined intersecting circularly arranged linear structural elements on said base extending upwardly therefrom to define a vertical hyperboloid of revolution of one sheet;

c. central vertical shaft means within said hyperboloid of revolution;

d. brace means interconnecting said linear elements to resist buckling thereof including radial horizontal tie rod members connecting intersections of said linear members to said central vertical shaft means;

e. said linear structural elements being defined by successively connected segments, said segments having aligned bar elements projecting from the intermediate portions of said segments on opposite sides thereof oriented to interlock with adjacent oppositely inclined segments and defining intersections on the linear structural elements therebetween;

f. means fastening said bar elements to said adjacent segments; and

g. means connecting said radial horizontal tie rod members to said intersections.

2. The tower structure of claim **1**, and wherein said brace means includes rigid horizontal members connected to the linear elements at a plurality of vertically spaced levels on the structure.

3. The tower structure of claim **1**, and wherein said brace means includes substantially rigid horizontal circular ring members connected to the linear elements.

4. The tower structure of claim **1**, and at least one horizontal deck structure secured to the top end portions of said linear structural elements.

5. The tower structure of claim **1**, and flange means on the free ends of the tie rod members for connecting said free ends to said central vertical shaft means.

6. The tower structure of claim **1**, and wherein said segments comprise main tubular body members, said bar elements projecting from opposite sides of the intermediate portions of said tubular body members and being receivable in the ends of the main tubular body members of said adjacent oppositely inclined segments.

7. The tower structure of claim **6**, and wherein said tie rod members comprise tubular elements provided at their outer ends with bolt-receiving washer means secured therein, and said means connecting said tie rod members to said intersections comprises bolts extending through the intermediate portions of the main tubular body members and lockingly engaged with said washer means.

8. The tower structure of claim **7**, and wherein the intermediate portions of the main tubular body members are provided with tubular guide sleeves rigidly secured therethrough for receiving said bolts.

9. A tower structure comprising:

a. a base;

b. two sets of oppositely inclined intersecting circularly arranged linear structural elements on said base extending upwardly therefrom to define a vertical hyperboloid of revolution of one sheet;

c. central vertical shaft means within said hyperboloid of revolution;

d. brace means interconnecting said linear elements to resist buckling thereof including radial horizontal tie rod members connecting intersections of said linear members to said central vertical shaft means;

e. the top ends of the respective sets of linear structural elements converging and being connected together at their top intersections; and

f. a deck structure peripherally secured to said top intersections.

10. The tower structure of claim **9**, and wherein the bottom ends of the respective sets of linear structural elements converge at said base.

11. The tower structure of claim **9**, and wherein said base includes upstanding bottom segments of said oppositely inclined linear structural elements.

12. The tower structure of claim **11**, and rigid bottom brace means connecting said bottom segments to said central vertical shaft means.

13. A tower structure comprising:

a. a base;

b. two sets of oppositely inclined intersecting circularly arranged linear structural elements on said base extending upwardly therefrom to define a vertical hyperboloid of revolution of one sheet;

c. central vertical shaft means within said hyperboloid of revolution;

d. brace means interconnecting said linear elements to resist buckling thereof, including radial brace members connected between said central vertical shaft means and said linear elements, said brace members having triangular end loop portions. the linear elements being connected to outer corner portions of said triangular end loop portions.

14. The tower structure of claim **13**, and wherein the linear structural elements are defined by successively connected segments.

15. The tower structure of claim **14**, wherein said segments have projections extending from their intermediate portions jointed to interlock with adjacent oppositely inclined segments.

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