United States Patent [19]

Fuller

[11] **3,866,366**

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[54] **NON-SYMMETRICAL TENSION-INTEGRITY STRUCTURES**

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[52] **U.S. Cl.** **52/81,** 52/648

[51] **Int. Cl.** **E04b 1/32**

[58] **Field of Search** 52/81, 648

[56] **References Cited**

OTHER PUBLICATIONS

The Dymaxion World of Buckminster Fuller, Robert Marks, 1960, Reinhold Pub. Corp., pp. 160–161, FIG. k11.

Primary Examiner—Ernest R. Purser
Assistant Examiner—Carl D. Friedman
Attorney, Agent, or Firm—Smythe & Moore

[57] **ABSTRACT**

A building structure composed of column-like discontinuous compression members held by a plurality of tension elements, the column-like compression members being held in spaced relation by tension elements attached adjacent the ends of the column-like compression members. In the form shown, there are what can be termed two substructures, one at the top and one at the bottom, each substructure having pentagonal configurations of parallel lesser circles formed by column-like members and tension elements at its base, said pentagonal configurations being twisted relative to each other so as to provide rectangular openings therebetween. There are column-like compression members between the substructures held in spaced relation to each other and to the substructures by tension elements. The entire combination produces a generally spherical-like building structure.

7 Claims, 12 Drawing Figures

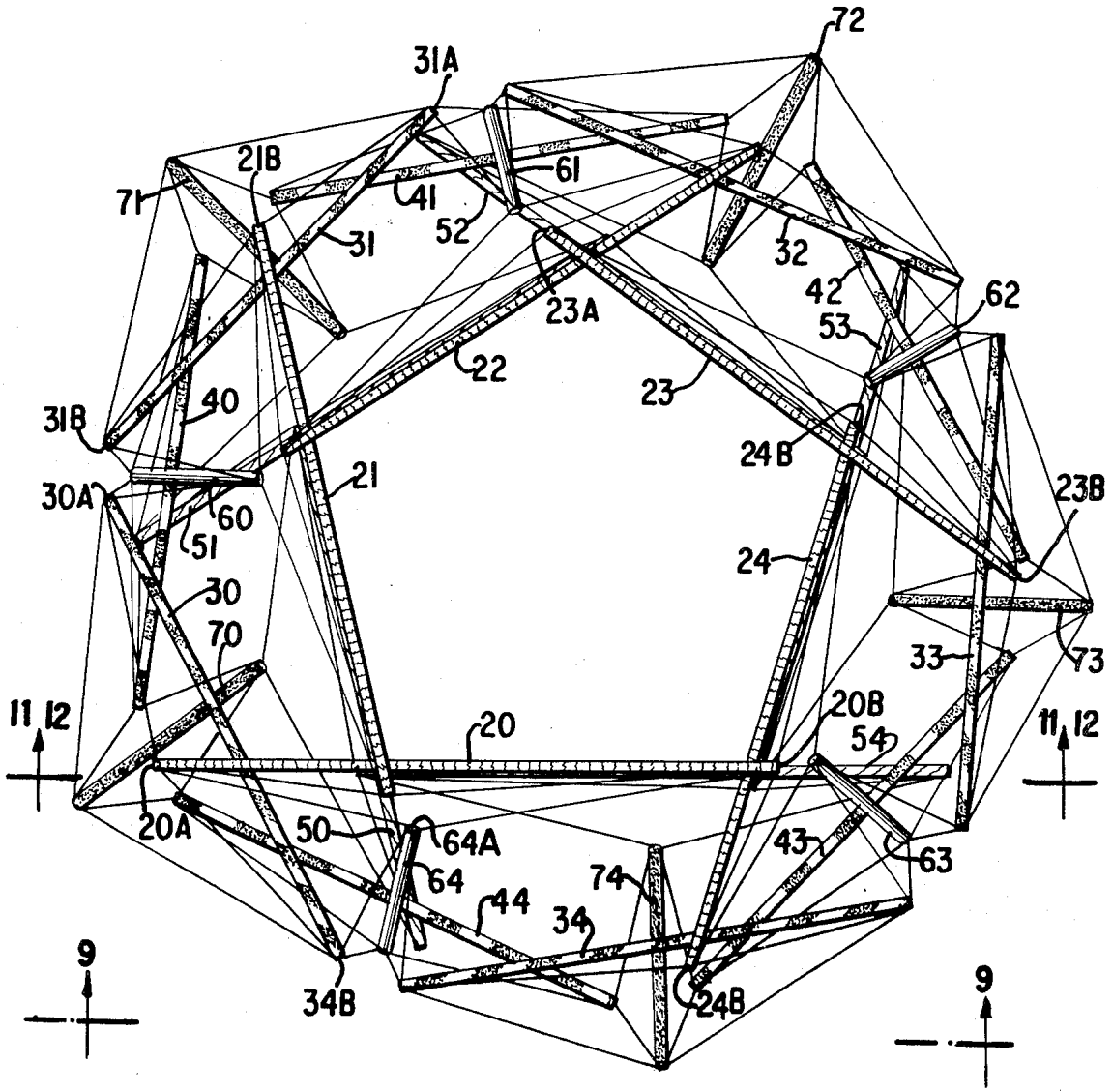


FIG. 1

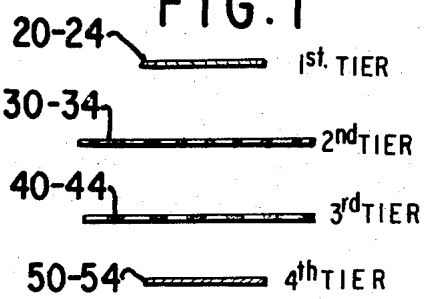


FIG. 2

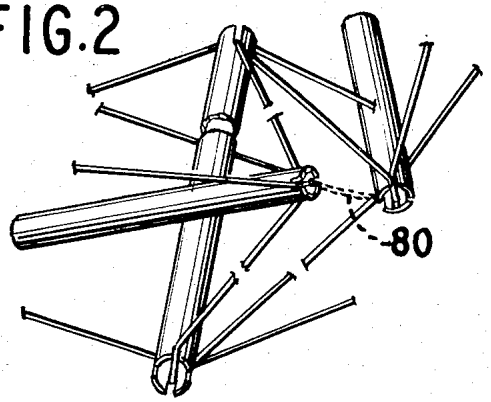


FIG. 3

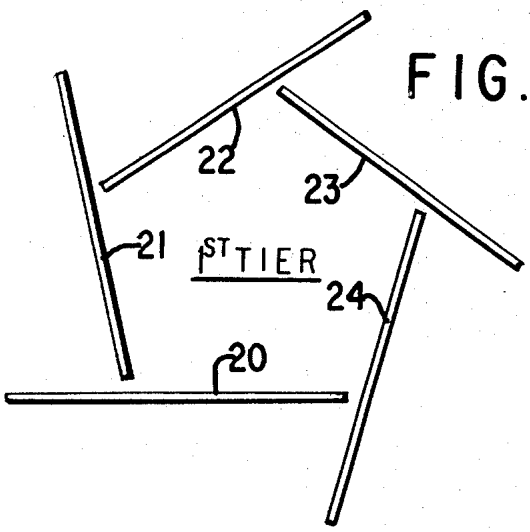
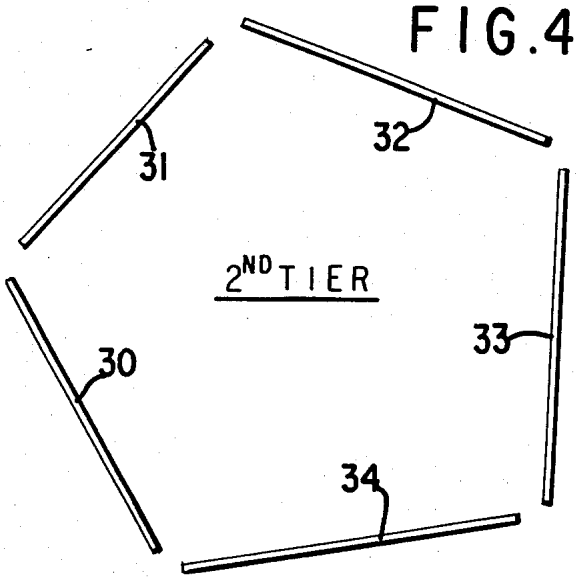


FIG. 4



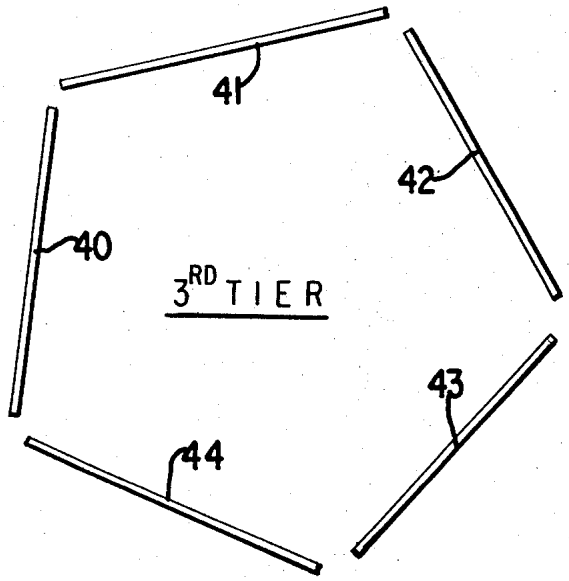


FIG. 5

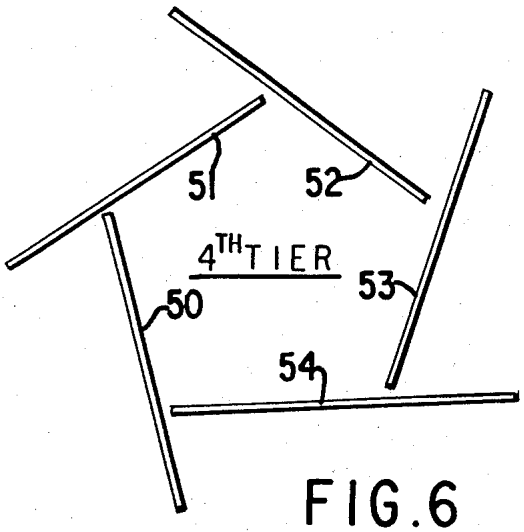


FIG. 6

FIG. 7

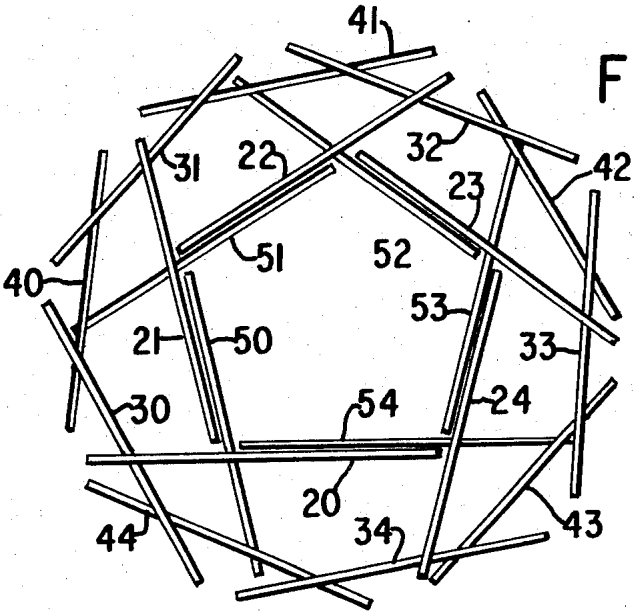

41
31
22
32
23
42
51
52
40
53
21
50
33
30
54
24
20
34
43
44

FIG. 8

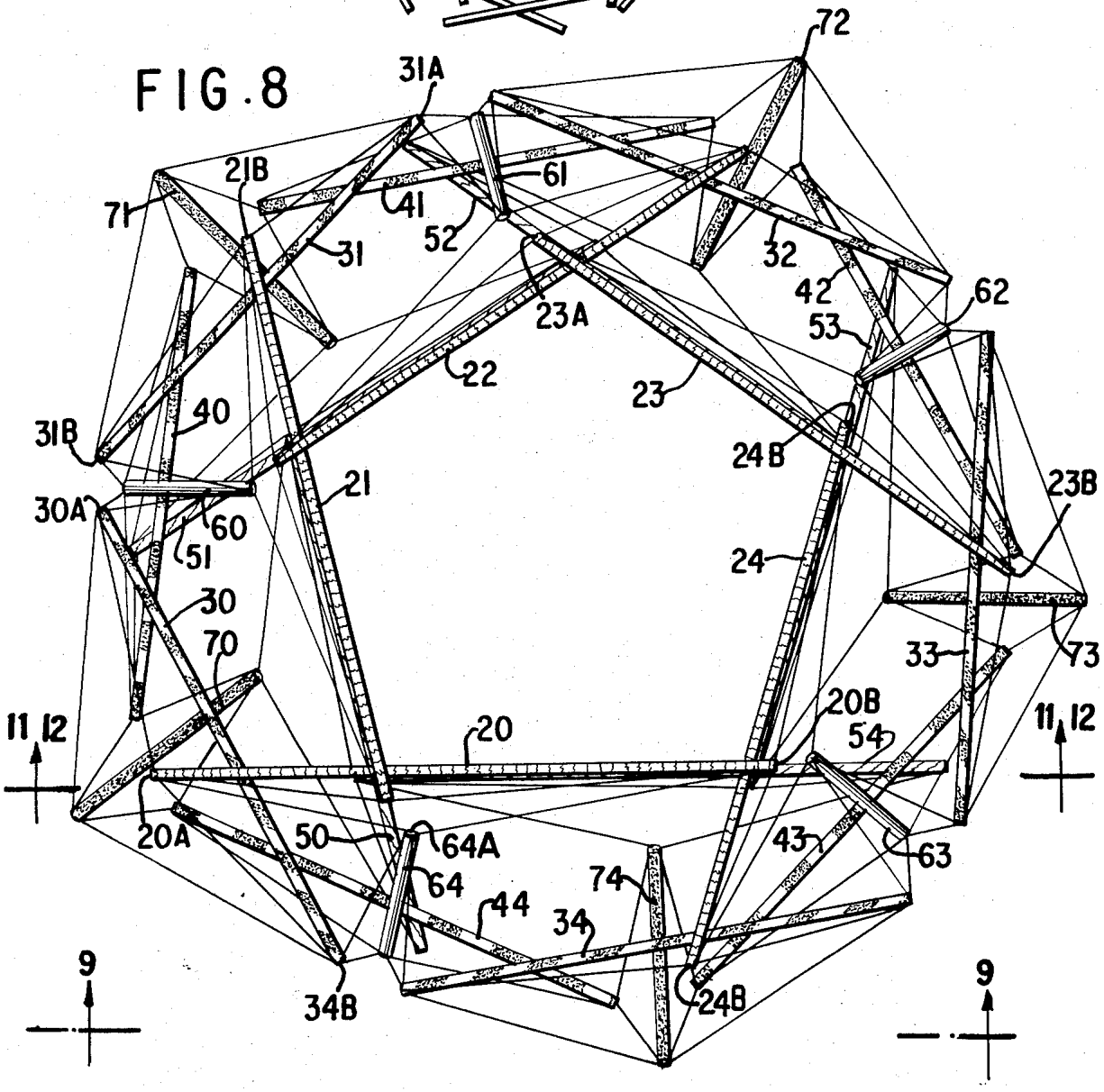

72
31A
21B
61
71
41
52
31
32
42
62
23A
53
22
23
40
31B
24B
21
23B
30A
60
51
24
30
70
33
73
11
12
20B
54
20
20A
50
64A
43
63
64
74
44
34
34B
24B
9
9

FIG. 9

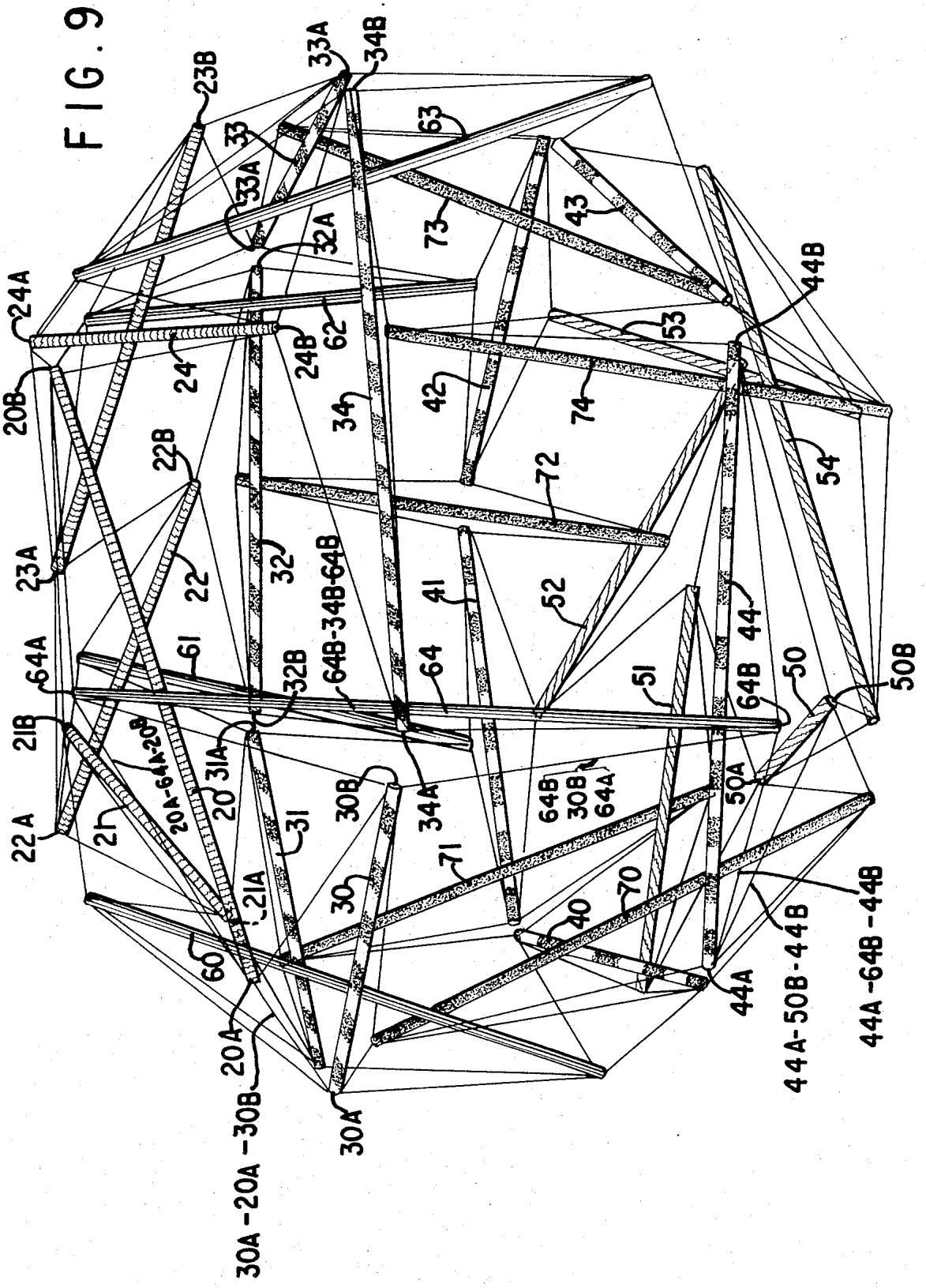

23B
33A
34B
33
63
33A
32A
73
43
24A
44B
62
24B
24
53
20B
34
42
74
22B
72
54
23A
32
64B-34B-64B
22
41
52
61
64
44
64A
32B
51
64B
50
50B
21B
20A-64A-20B
20
31A
30B
34A
64B
30B
64A
50A
22A
21
31
71
21A
30
40
70
60
20A
44A
44A-50B-44B
44A-64B-44B
30A-20A-30B
30A

FIG. 10

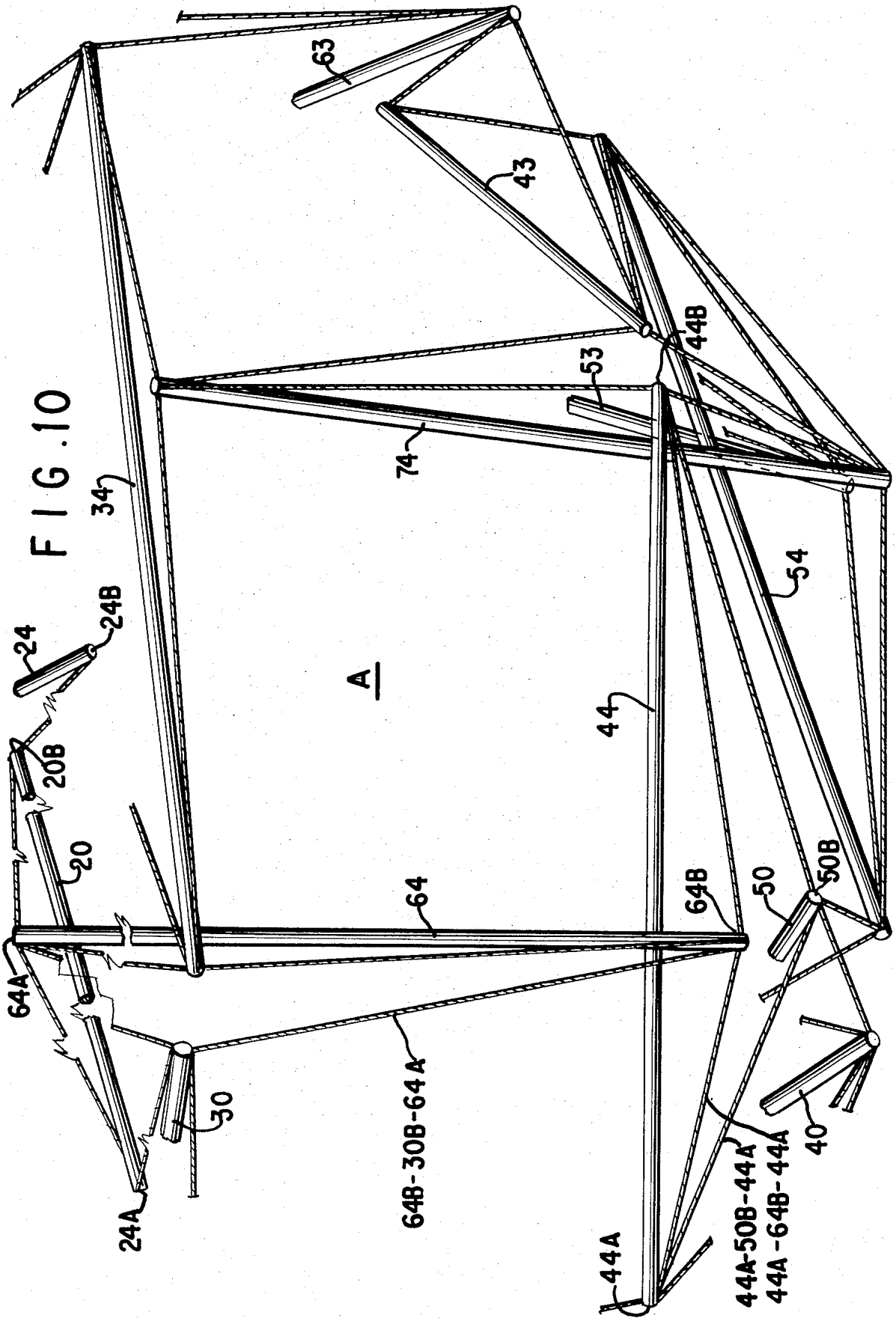
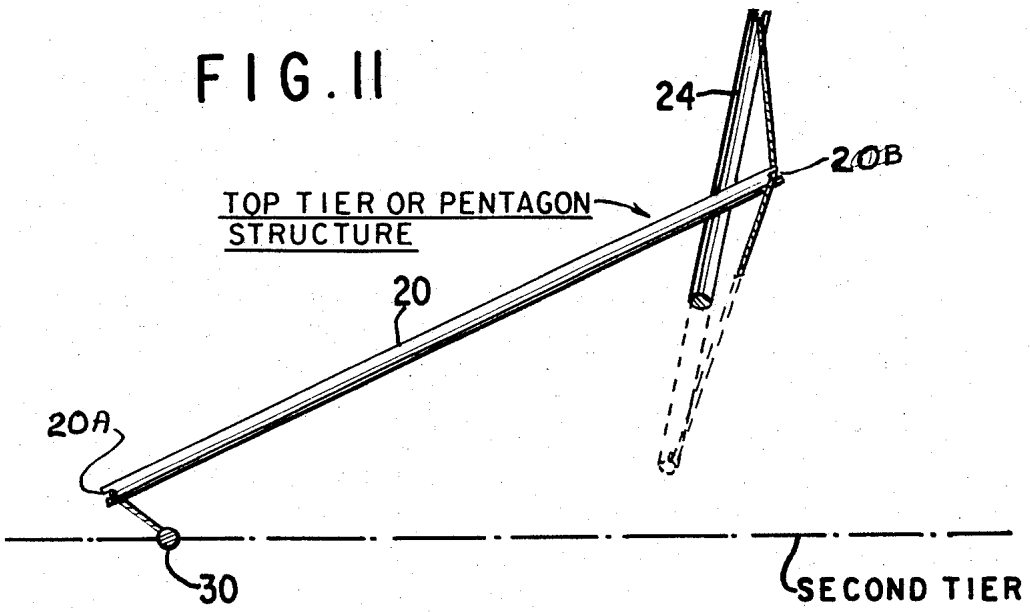

63
43
44B
53
74
34
54
24
24B
20B
20
A
44
64
64B
50
50B
64A
30
64B-30B-64A
24A
44A
44A-50B-44A
44A-64B-44A
40

FIG. 11


24
20B
TOP TIER OR PENTAGON STRUCTURE
20
20A
30
SECOND TIER

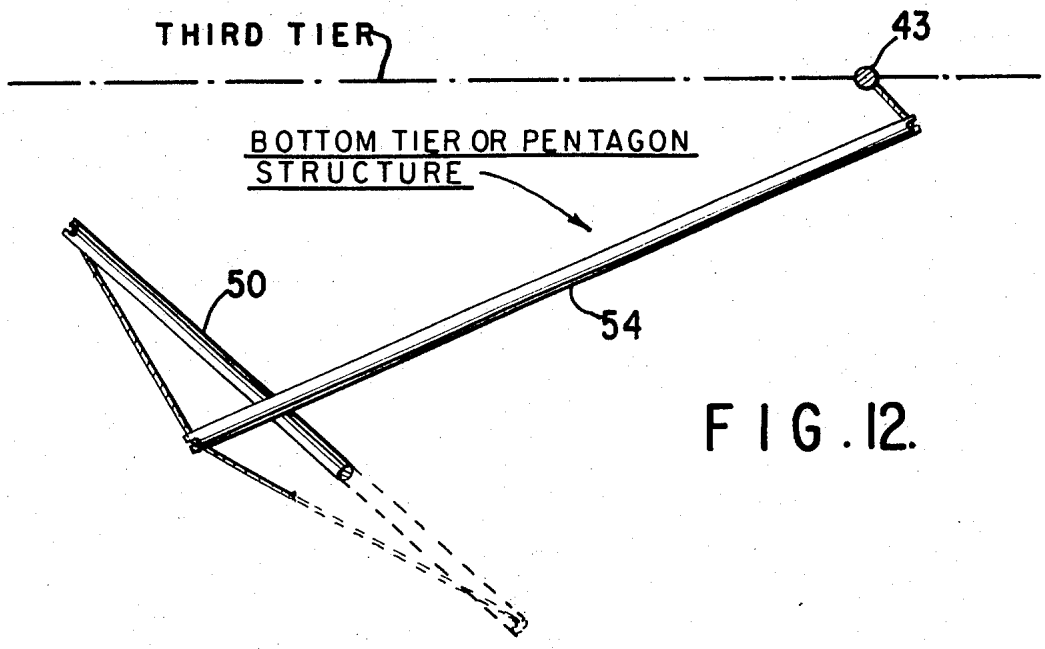

THIRD TIER
43
BOTTOM TIER OR PENTAGON STRUCTURE
50
54

FIG. 12.

NON-SYMMETRICAL TENSION-INTEGRITY STRUCTURES

This invention relates to building structures and particularly to one of the tension-integrity type of structure.

The present invention is an improvement on and a variation of tension-integrity structures, such as shown in prior U.S. Pat. No. 3,063,521, Nov. 13, 1962. The structures involved are known generally as geodesic-type dome structures. The tension-integrity structure is one that is of generally spherical form having discontinuous compression columns joined with tension elements in a manner to provide the aspect of discontinuous compression and continuous tension sometimes referred to as "Tensegrity" structures. In some instances, it has been found desirable in a structure of the type involved herein to have rectangular-like areas or zones for windows, walls, doors, or the like.

One of the objects of the present invention is to provide an improved tension-integrity type structure having zones of rectangular-like configuration.

Another of the objects of the invention is to provide a tension-integrity type of structure wherein a portion can be prefabricated.

In one aspect of the invention and in the form shown, the generally spherical-like building structure can have a substructure at the top and a substructure at the bottom, the bases of the substructures being spaced from each other, the bases being of pentagonal configuration which are twisted relative to each other in a manner to provide rectangular-like facets therebetween. The substructures and spacing of the pentagonal configuration, which are lesser circles as compared with great circles, are formed by a plurality of column-like compression members joined by a plurality of tension elements, such as wire or rope, the column-like members being axially spaced relative to each other by the tension elements which are attached near the ends of spaced column-like members. The pentagon of the top substructure above tha aforementioned lesser circle has five column-like members forming a generally pentagonal configuration. The bottom substructure has five column-like members in a pentagonal configuration and below its lesser circle which is the reverse of the top pentagon. Column-like members extend between the two substructures and are joined thereto with tension elements, the reversal of the top and bottom pentagons resulting in the twisting of the lesser circle pentagons relative to each other. It is to be understood that various frequencies can be used and various types of enclosures or panels employed.

Other objects, advantages and features of the present invention will become apparent from the accompanying description and drawings, which are merely exemplary.

In the drawings:

FIG. 1 represents four tiers, the top two representing the top substructure and the lower two representing the lower substructure;

FIG. 2 is a fragmentary perspective of a column-like member with four tension elements attached adjacent the ends thereof for attachment to other column-like members;

FIG. 3 is a schematic representation of the relationship of the column-like members of the top pentagonal configuration;

FIG. 4 is a schematic representation of the upper substructure pentagonal lesser circle or base;

FIG. 5 is a schematic representation of the lower substructure pentagonal lesser circle or base showing the same in its rotated position relative to the lesser circle pentagon of FIG. 4;

FIG. 6 is a schematic representation of the column-like members of the bottom pentagonal configuration which is similar to FIG. 3 but is in a reversed relationship; FIG. 7 is a top view showing generally the manner in which the column-like members appear;

FIG. 8 is a top view generally similar to FIG. 7 but showing the tension elements between the column-like members;

FIG. 9 is a perspective side view of FIG. 8 taken in the general direction 9—9 of FIG. 8;

FIG. 10 is an enlarged fragmentary view of the upper and lower vertical columns together with related columns and tension elements, there being five of each around the periphery;

FIG. 11 is a fragmentary view of the top substructure looking generally in the direction 11—11 of FIG. 8; and

FIG. 12 is a fragmentary view of the lower substructure looking generally in the direction 12—12 of FIG. 8.

Proceeding next to the drawings wherein like reference symbols indicate the same parts throughout the various views, a specific embodiment of the present invention will be described in detail. In the interest of simplicity, reference symbols have not been included in all of the figures.

The column-like members can be made of wood, aluminum, plastic or any suitable material. The ends of the column-like members can be notched or otherwise fitted to hold the tension elements or wires at the ends of said column-like members. Each column-like member will have four tension elements emanating from each end thereof as shown in FIGS. 2 and 10.

In FIGS. 3, 4, 5, and 6, for purposes of description, the general relation of the column-like members before they are joined together with the tension elements is shown. As can be seen, the top pentagonal configuration, illustrated in FIG. 3, is oriented in a clockwise configuration as compared with the counterclockwise configuration of the bottom pentagonal configuration shown in FIG. 6. As will be explained hereafter, the upper substructure base lesser circle pentagon configuration of FIG. 4 is twisted in the final assembled structure relative to the lower base lesser circle pentagon configuration of FIG. 5.

FIG. 7 illustrates the relation of the members in the final assembled structure, the elements of FIGS. 3 to 6 being combined therein.

Referring now particularly to FIGS. 8 and 9, the top pentagonal configuration will be described. Column-like members 20, 21, 22, 23 and 24 are attached or supported by tension elements to other of the column-like members so as to be axially spaced therefrom. For example, column-like member 20 has a tension element 20A–64A–20B leading from end 20A to an end 64A of vertical column-like member 64 (FIG. 9) and thence to end 20B. Additionally, a tension element 30A–20A–30B from end 20A to end 30A and end 30B of the column-like member 30 of the lesser circle pentagon of the top substructure.

Vertically extending column-like members 60, 61, 62, 63, 64 extend between tension elements fastened to

the column-like members **40, 41, 42, 43** and **44** of the lower substructure lesser circle pentagon and tension members between their opposite ends and column-like members of the top pentagon configuration column-like members **20, 21, 22, 23, 24.**

Similarly, vertically extending column-like members **70, 71, 72, 73, 74** extend from tension elements attached to the ends of the upper lesser circle pentagon members **30, 31, 32, 33, 34** and tension members attached to column-like members **50, 51, 52, 53** and **54** of the lower pentagonal configuration.

The lower pentagonal configuration is similar to the top configuration except that it is reversed, as can be seen in FIGS. **3** and **6.**

In FIG. **10,** the column-like members are numbered so as to agree with FIGS. **8** and **9.** One set of members will be described, the others being similar thereto. Upwardly extending member **64** has end **64B** connected to member **44** of the lower lesser circle pentagon by tension element **44A–64B–44B.** End **64B** of member **64** is also connected to end **30B** of upper lesser circle pentagon member **30** and end **64A** by tension element **64B–30B–64A** as well as to lesser circle member **34** by tension elemment **64B–30B–64A.** The upper end **64A** of **64** also is connected to the ends of the upper pentagonal configuration member **20** by tension element **20A–64A–20B.** The end **50B** of member **50** connects to member **44** by tension element **44A–50B–44B.** There are five lower and five upper vertical column-like members repeated in a similar manner. The term "vertical" means generally vertical when the structure is oriented as shown.

It can be seen that the column-like compression members are held in axially spaced relation to each other by the tension elements.

As a result of the combination of column-like elements and tension elements shown and described, there will be rectangular-like facets such as depicted at A (FIG. **10**) between the upper lesser circle including elements **30, 31, 32, 33, 34** and the lower lesser circle formed by elements **40, 41, 42, 43, 44.**

FIGS. **11** and **12** show the relation of **3** of the elements of the top tier and of the bottom tier.

As seen in FIG. **2,** a loose connecting wire or elements **80** can be used so as to limit outward movement.

Merely by way of example, the structure of the present invention can be formed of thirty aluminum struts or column-like members, each 36¾ inches long and 1 inch outside diameter with one-fourth inch slots formed in each end thereof for receiving the tension elements. The tension elements can be made of synthetic fiber line having a length of about 37½ inches between ends of the column-like member, there being a distance of about 5 inches from the middle point of the tension element to the column-like member when the line is stretched tight and engages other elements of the combination. It is understood that these dimensions will vary according to material of the line or rope and other dimensions of the structure. Also, the tension elements combination can be prefabricated and the column-like members inserted therein when and where the structure is to be erected.

It will be understood that various details of construction and arrangement of parts may be changed without departing from the spririt of the invention except as defined in the appended claims.

What is claimed is:

1. In a generally spherical-like building structure, the combination including a like pair of substructures, each being comprised of a plurality of column-like compression members and a plurality of tension elements, the column-like members being held in axially spaced relationship to one another by the tension elements being attached adjacent the ends of spaced column-like members, pentagon lesser circle configurations at the base of each substructure, and a plurality of column-like members between said substructures and extending directly therebetween and holding said substructures in spaced relation, said column-like members being held in axially spaced relation thereto by tension elements so that pentagon lesser circle configurations are displaced relative to each other.

2. In a building structure as claimed in claim **1** wherein there is a top and bottom substructure, each substructure having a pentagonal-like configuration of column-like compression members located outside of said lesser circle configurations, said pentagonal-like configuration being reversed in the top substructure in relation to the bottom substructure.

3. In a building structure as claimed in claim **1** wherein there are rectangular-like apertures between said substructures.

4. In a building structure as claimed in claim **2** wherein there are rectangular-like facets between the substructures.

5. In a building structure as claimed in claim **1** wherein each of the column-like members between the substructures has tension elements connecting one of the ends thereof to pentagon lesser circle configurations at the base of a first substructure and the other end thereof connected to a pentagonal-like configuratuion of column-like members outside of said lesser circle of the substructure other than said first substructure.

6. In a building structure as claimed in claim **5** wherein the pentagonal-like compression members located outside of said lesser circle configurations are reversed relative to each other.

7. In a building structure as claimed in claim **1** wherein the tension elements are prefabricated and the column-like elements inserted therein thereafter.

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