United States Patent [19]

Nierle

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[54] **THREE DIMENSIONAL CONSTRUCTION**

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Mar. 20, 1970 Switzerland 4224/70

[52] **U.S. Cl.** ..... **52/648,** 287/546, 52/646, 52/655, 52/758 H

[51] **Int. Cl.** **E04h 12/10**

[58] **Field of Search** ..... 52/646, 648, 655; 287/546, 287/189.36 F; 49/29

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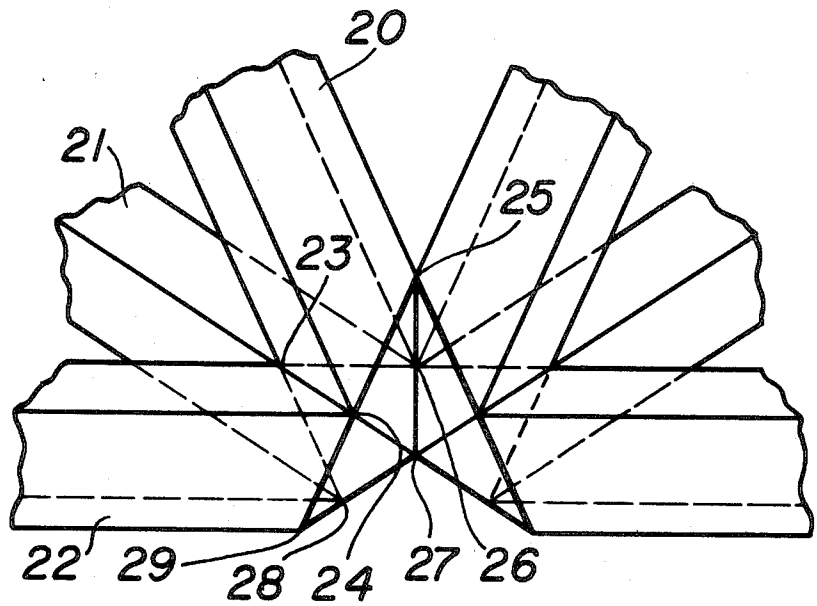
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Primary Examiner—Frank L. Abbott
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[57] **ABSTRACT**

A three dimensional structure comprises a plurality of bars, the end parts of which have, in cross-section, the shape of an equal sided parallelogram two angles of which equal 70°32′. The end parts terminate with a shape defined by two plane surfaces intersecting along a shorter diagonal of said parallelogram, each plane surface making an angle of substantially 54°44′ with a plane through said shorter diagonal and cutting the end part in two, said shape consisting of a pair of equilateral triangles with said shorter diagonal as a common side. The geometrically shaped end parts of adjacent bars cooperate to define an angular array in which the bars can be fixed.

6 Claims, 13 Drawing Figures



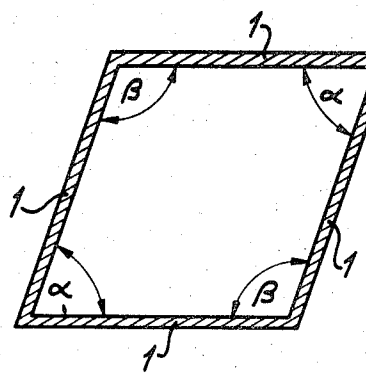


FIG.1

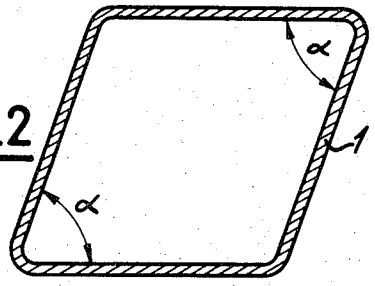


FIG.2

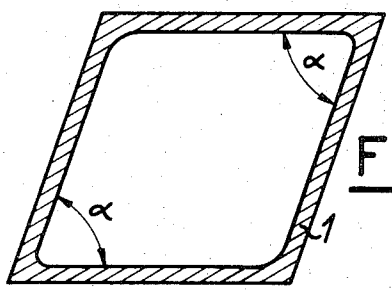


FIG.3

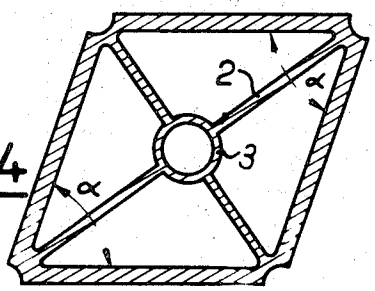


FIG.4

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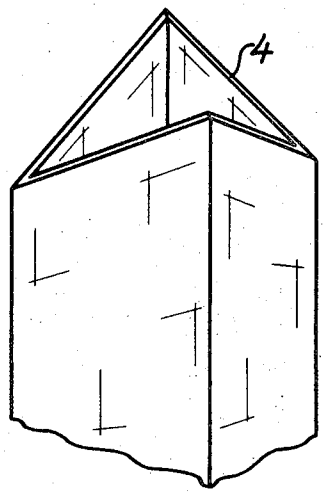


FIG.5

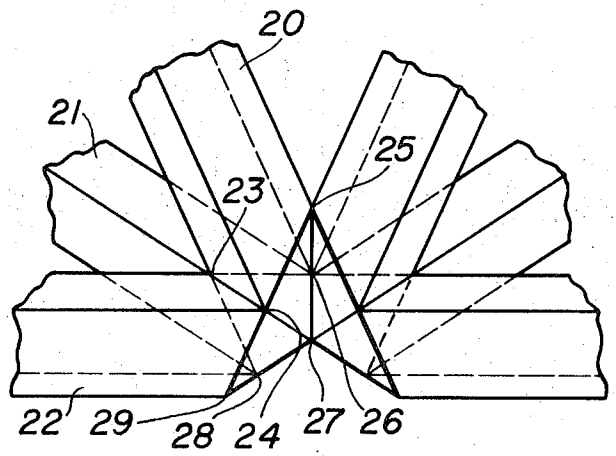


FIG.6

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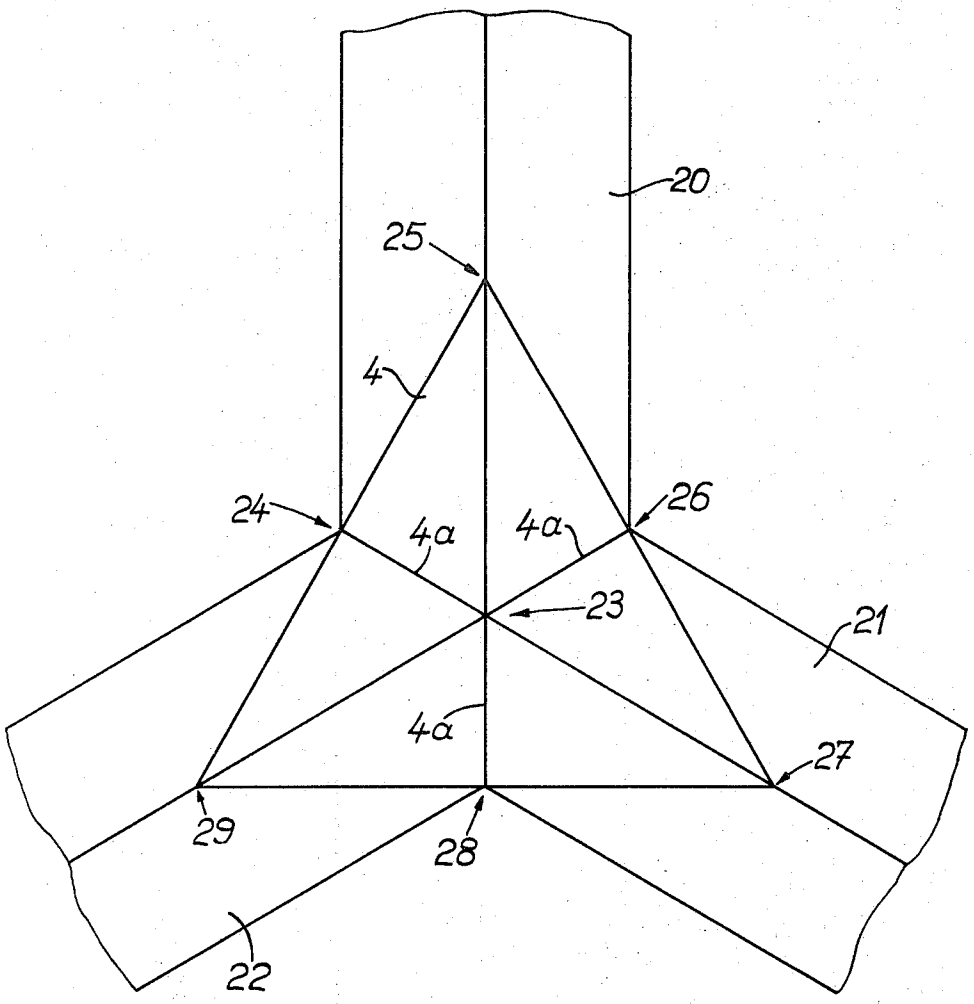


FIG. 6A

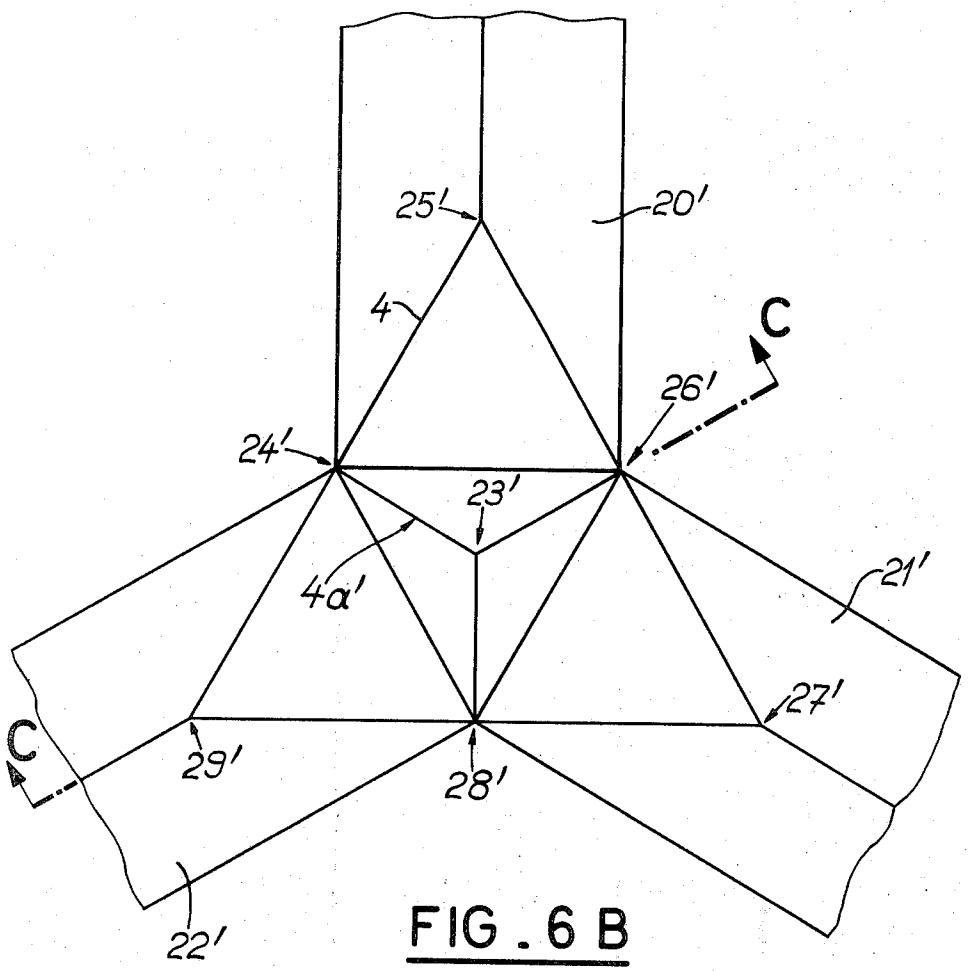


FIG. 6 B

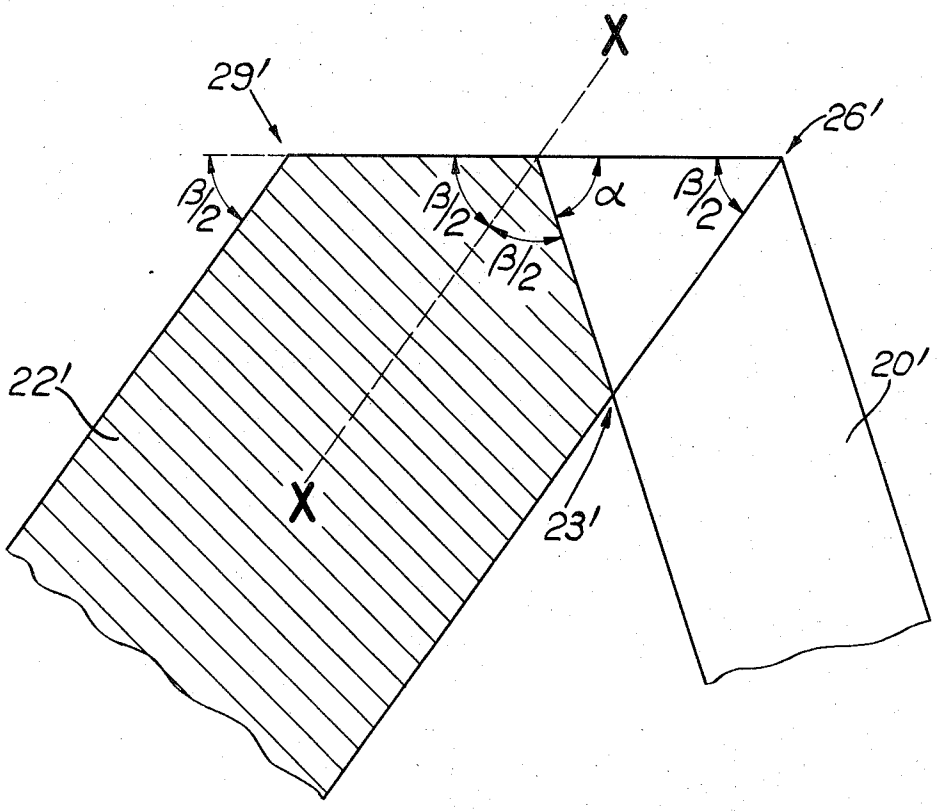


FIG. 6 C

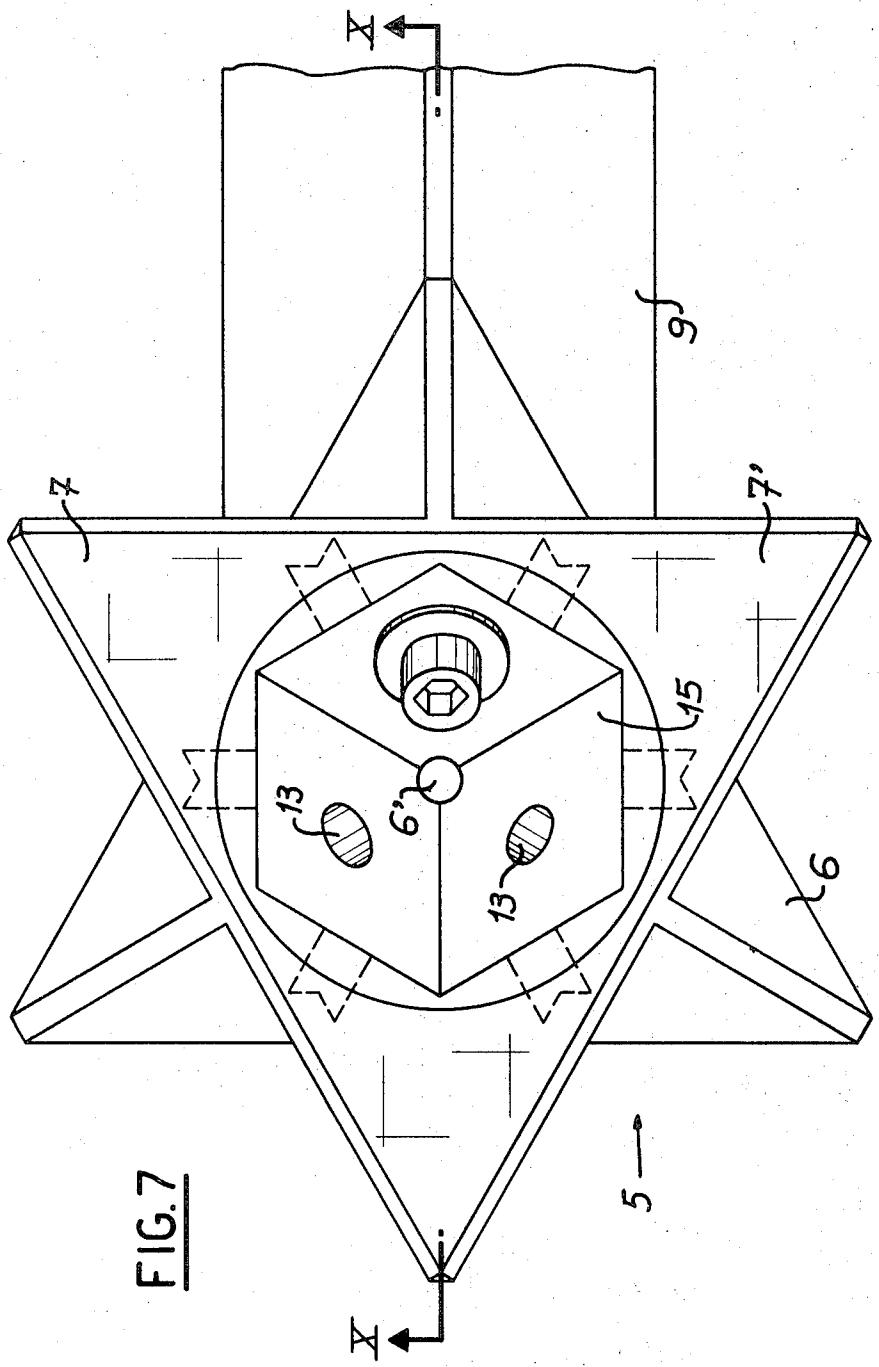


FIG. 7

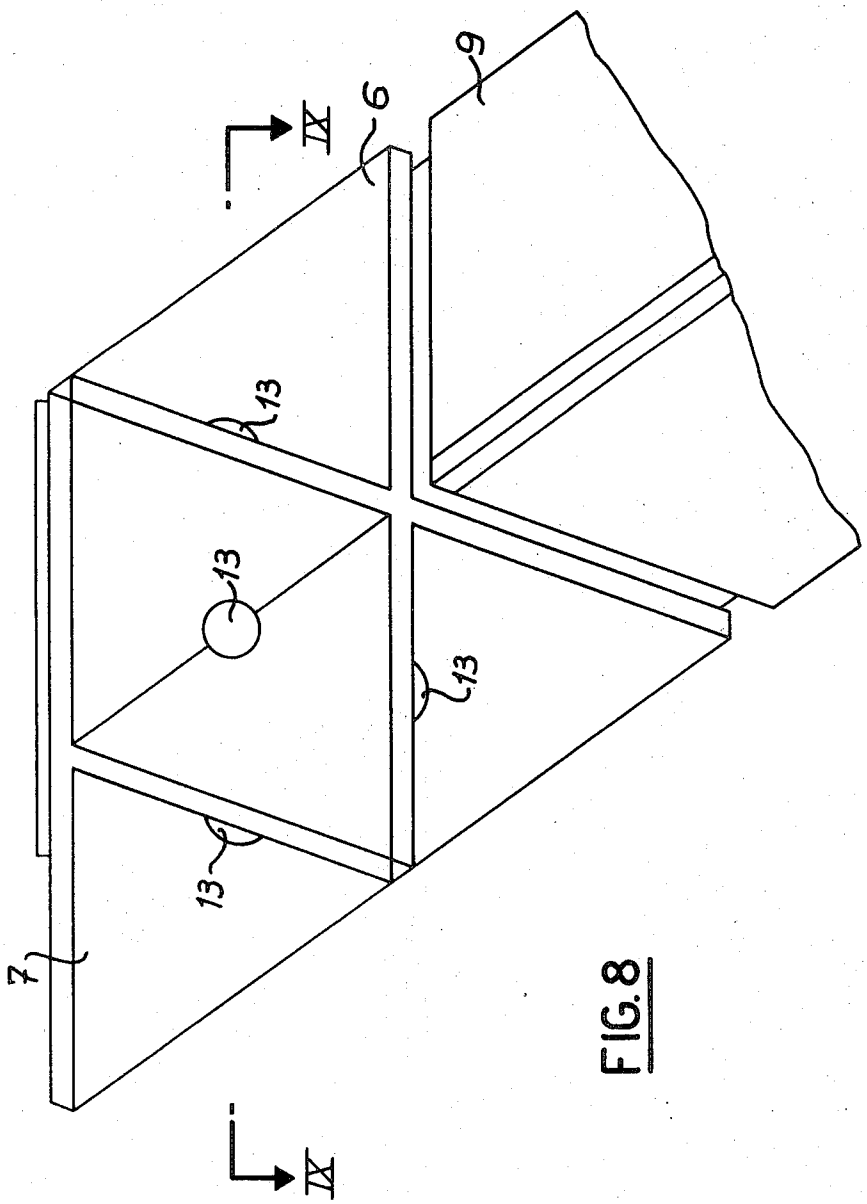


FIG.8

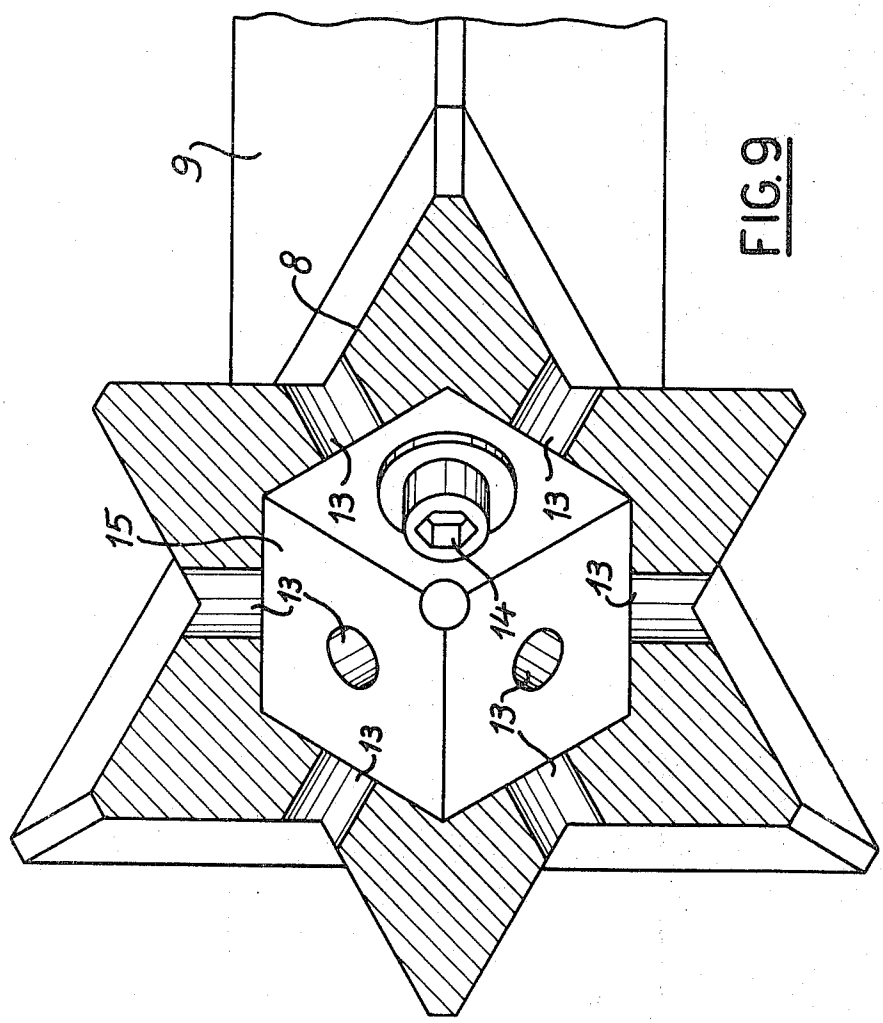


FIG.9

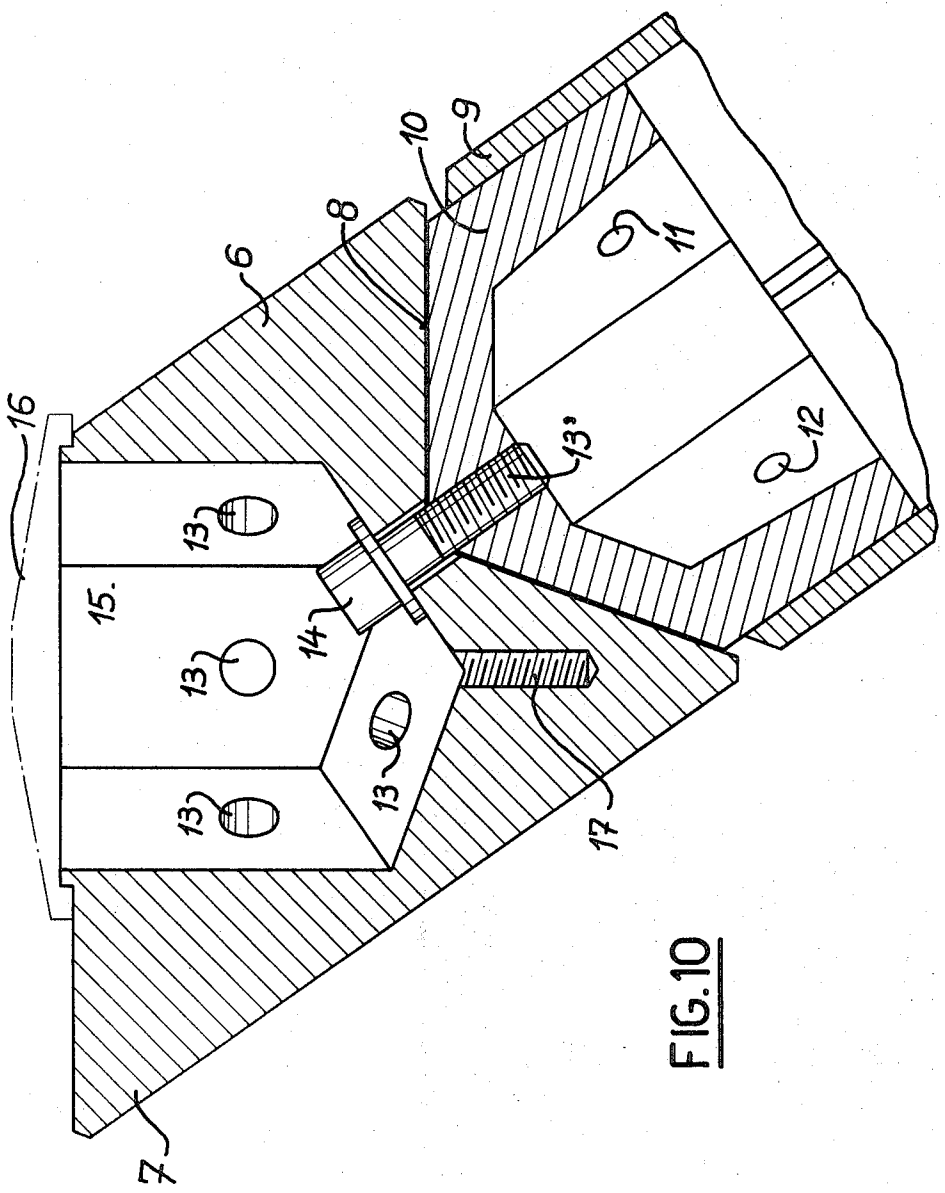


FIG. 10

THREE DIMENSIONAL CONSTRUCTION

BACKGROUND OF THE INVENTION

A present trend in building techniques is directed towards light architectural structures which enable maximal use of the material employed whilst equalizing distribution of the stresses and strains produced.

One particular development is the so-called "space structure," i.e., a three dimensional network of assembled elements with joints or crossings towards which the various elements of the structure, such as tubes or section bars, converge.

In order to assemble the structural elements at the joints of the network, various types of connection piece can be used. For example, a connection piece for tubular elements may be formed by a sphere the surface of which has circular holes oriented in the appropriate direction. The tubular elements of the structure are then fitted into the holes and welded to the sphere.

The manufacture of known connection pieces is in general costly, and assembly is often difficult.

In French Patent No. 1 331 991 it has been already proposed to provide a three dimensional assembly of bars having equal-sided parallelogramic cross-section, one angle of which is equal to 70° 30′, which is the angle between two faces of a regular tetrahedron. However, the aim of this patent is to eliminate assembly joints in the structure, the bars being theoretically infinitely long, and being assembled together at the crossing surfaces of the bars, for example by bolts.

SUMMARY OF THE INVENTION

It is a primary object of the invention to provide an enlongated member having geometrical characteristics which make it particularly suitable for assembly with a plurality of like members into a three-dimensional structure, joining together of the members being simply achieved by employing the special geometrical characteristics of the members.

Another object of the invention to provide three-dimensional structures comprising joints at each of which three, six, nine or 12 like members are fixed in angular array by simple means relying on the special geometrical characteristics of the members.

According to a main aspect of the invention, an elongated member for use in a three dimensional structure comprises at least one end part having a cross-section in the shape of an equal sided parallelogram two of the angles of which are substantially 70° 32′, said end part terminating with a shape defined by two plane surfaces intersecting along a shorter diagonal of said parallelogram, each plane surface making an angle of substantially 54° 44′ with a plane through said shorter diagonal and cutting the end part in two, said shape consisting of a pair of equilateral triangles with said shorter diagonal as a common side.

Another aspect of the invention is a three dimensional structure comprising three elongated members as above defined having like end parts, and comprising means for joining said three members is an angular array in which said members converge together with their end parts adjacent one another, wherein said shorter diagonals of the three end parts are arranged to form an imaginary equilateral triangle, one of each pair of equilateral triangles lying in the plane of said imaginary equilateral triangle, and the other of each pair of

equilateral triangles forming, with said imaginary equilateral triangle, a regular tetrahedron.

Two, three or four sets of three members joined together as defined above can be fixed in angular array about the faces of a regular tetrahedron the edges of which are of a length double that of said shorter diagonals, or about the tri-lateral faces of a regular semi-octahedron the edges of which are also of a length double that of said shorter diagonals.

DESIGNATION OF THE DRAWINGS

Further objects and advantages of the invention will be apparent from the following description of preferred embodiments of the invention, and with reference to the accompanying drawings in which:

FIG. **1** is a cross-section of a first embodiment of tubular bar for use in a three-dimensional structure;

FIG. **2** is a cross-section of a second embodiment of tubular bar;

FIG. **3** is a cross-section of the third embodiment of tubular bar;

FIG. **4** is a cross-section of a fourth embodiment of tubular bar;

FIG. **5** is a perspective view of a bevelled end of a tubular bar;

FIG. **6** is schematic perspective view of a connection of six tubular bars according to the invention;

FIG. **6A** is a schematic plan view of one of the basic assemblies of three tubular bars of FIG. **6**;

FIG. **6B** is a view similar to FIG. **6A**, but showing bars having solid end parts;

FIG. **6C** is a schematic cross-section taken along line C—C of FIG. **6B**;

FIG. **7** is a plan view of a connecting element for a joint according to the invention;

FIG. **8** is an elevational view of this connecting element;

FIG. **9** is a cross-section according to line IX—IX of FIG. **8**; and

FIG. **10** is a cross-section according to line X—X of FIG. **7**.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring to FIG. **1**, a tubular metal bar has a wall **1** of constant thickness, the inner and outer surfaces of this wall being, in cross-section, in the shape of an equal sided parallelogram (hereinafter referred to as "diamond shaped"), the acute angle of which is equal to the angle formed by two faces of a regular tetrahedron, namely 70° 32′. Of course, the supplementary angle β is equal to 109°28′.

The tubular bar shown in FIG. **2** has a similar cross-section, but the inner and outer surfaces at the four corners are rounded. Again, the wall **1** is of constant thickness.

In the bar of FIG. **3**, the external periphery of the cross-section is diamond shaped, as for the outer surface of the bar of FIG. **1**, whilst the inner surface is generally diamond shaped, but with curved corners, as for the inner surface of the bar of FIG. **3**. In this embodiment, the wall **1** is no longer of constant thickness, but is reinforced at the angles located on the shorter diagonal of the parallelogram.

In FIG. **4**, the tubular bar has a generally diamond shape, but the apices of which have arcuate cavities, in cross-section. The inside of the tubular bar comprises four bridging pieces **2** connecting the apices of the bar

to a central element 3 of circular shape that can be used, for example, for fixing the bar. The pieces 2 and element 3 can be continuous along the entire length of the bar so as to reinforce same, or can be discontinuous.

These tubular bars can be made of steel, aluminium of aluminium alloy, in plastic material, or in any other appropriate material, and can be manufactured by drawing.

As shown in FIG. 5, an end of each bar is bevelled to a special shape which enables the bars to be assembled into three dimensional structures in a simple manner, as will be described below. The end of the bars are cut through the shorter diagonal this angle B/2 being shown in FIG. 6c of the cross-sectional parallelogram by symmetrical planes separated by an angle of 109°28′, i.e. each making an angle of 54° 44′ with the central plane of the bar through said shorter diagonal. The edges 4 thus formed on the bar are of an equal length which is, moreover, equal to the length of the shorter diagonal of the cross-sectional parallelogram on the outer surfaces of the bar. The shape of the end of the bar is thus that of two equilateral triangles having said shorter diagonal as a common side, located on the two cutting planes.

All of the above described bars are tubular, hollow, and generally of uniform cross-sectional shape along all their length but the invention also envisages an elongated tubular member only the end part of which has the above-described shape characteristics. Moreover, it is also possible for the end part of the tubular member to be solid, for example in molded plastic material and joined to the end of a hollow tubular bar of any desired cross-sectional shape by any appropriate means.

The shaped ends of a plurality of bars can be assembled together in a particularly simple manner by suitable cooperation of the geometrical shapes. An example of the connection of six bars is shown in FIG. 6. The basic element consists of a set of three bars 20, 21, 22 joined as shown, for example, on the left hand side of FIG. 6 and in FIG. 6A. The extreme edges such as 4 (FIGS. 5 and 6A) of the three bars, represented by 24–25, 25–26, 26–27, 27–28, 28–29, and 29–24, lie along an equilateral triangle 25–27–29 the edges of which are thus twice as long as the edges 4. The shorter diagonals 24–26, 26–28, and 28–24 at the ends of the three bars 20, 21, 22 form an imaginary equilateral triangle 24–26–28, the inner edges such as 4*a* meeting at 23′ and defining on a regular tetrahedron 24–26–28–23 with this imaginary equilateral triangle 24–26–28 as base.

FIG. 6B shows a similar assembly of three bars 20′, 21′ and 22′, the ends of which are solid, and in which for the sake of simplicity the same elements and points are referred to by the same reference numerals with a prime designation. In this case, the said "imaginary" equilateral triangle 24′–26′–28′ is visible as is the regular tetrahedron 24′–26′–28′–23′. The cross-sectional view of FIG. 6C is taken along a plane through the longer diagonal 29′–23′ of bar 22′ and cutting said bar in two. It can be seen that the end part of bar 22′ terminates with a shape defined by two plane surfaces 24′–29′–28′ and 24′–23′–28′ (FIG. 6B) intersecting along the shorter diagonal 24′–28′ of the parallelogram of said bar, each of said plane surfaces making an angle of B/2 = 54° 44′ with a plane X–X through said shorter diagonal 24′–28′ and cutting said end part in two, said shape consisting of a pair of equilateral triangles 24′–28′–29′ and 24′–28′–23′ with said shorter diagonal 24′–28′ as common side. Of course, tubular bars such as 20, 21, 22 (FIG. 6A) have exactly the same end shape, but the shorter diagonals are not visible.

In FIG. 6, two such sets of three bars are shown disposed on two faces of a regular tetrahedron, each face being formed of an equilateral triangle the edges of which are twice as long as the sides 4. It can be seen that such sets could be disposed on three or on all four sides of the tetrahedron, so that up to twelve bars can be accomodated at one such joint.

Adjacent edges 4 of the bars are secured together by welding, sticking or any other means appropriate for the material of the bars. Alternatively, a connection piece to enable provision of a dismantlable structure can be provided, as will be described with reference to FIGS. 7 to 10.

When twelve bars are disposed about a joint on four faces of a tetrahedron, the space enclosed by the ends of the bars is in the shape of two juxtaposed regular tetrahedrons, one such tetrahedron being shown in FIG. 6 and the other tetrahedron being inverted and having its base in the plane of the upper surface of the horizontal bars.

For tetrahedral mounting, as shown in FIG. 6, a structure with a plurality of joints can be made using bars of equal length, the structure including two or more principal planes, such as the horizontal plane which includes four of the six bars shown.

An alternative mode of mounting sets of three bars is to dispose the large equilateral triangles formed by edges 4 of the bars about the faces of a regular octahedron or the trilateral faces of a regular semi-octahedron (square based pyramid). In this case, the shorter diagonals of the ends of the bars lie parallel to the principal planes of a structure so-formed.

FIGS. 7 to 10 show an example of assembling a plurality of the above described bars by means of a connection element 5 made in one piece by molding. Element 5 is shaped, geometrically, by the combination of a truncated regular tetrahedron 6 juxtaposed with a like-dimensioned regular tetrahedron 7. The base of one tetrahedron, for example base 7′, perpendicularly bisects three edges of the other tetrahedron 6, and vice versa. The part of truncated tetrahedron 6 above the base 7′ of the tetrahedron 7 is cut-away. These two tetrahedrons define nine housings 8 of a shape corresponding to that of the end of each bar 9 (FIGS. 9 and 10), of the type shown in FIG. 4.

The assembly of the bars 9 to the connecting element 5 is achieved by means of a mouthpiece 10 with a shape corresponding to that of the ends of the bars screwed at 11 and 12 into the end of the bar 9 and having a threaded hole in alignment with one of nine holes 13 of the connecting element 5 in which a bolt 14 is screwed. The connecting element 5 has a cavity 15 enabling placing of the bolts 14. As soon as all of the bars are fixed, nine being the maximum number of bars which can be accomodated by this joint, the cavity is advantageously closed by a cover 16 fixed by a screw engaging in a threaded hole 17.

The fixing could be of course be provided by any other means such as welding or sticking, the most adequate method being chosen in relation to the material of the bars.

What is claimed is:

1. An elongated member for use in a three dimensional structure, comprising at least one end part having a cross-section in the shape of an equal sided parallelogram two of the angles of which are substantially 70°32′, said end part terminating with a shape defined by two plane surfaces intersecting along a shorter protruding diagonal of said parallelogram, each plane surface making an angle of substantially 54°44′ with a plane through said shorter diagonal and bisecting the end part, said shape consisting of a pair of equilateral triangles with said shorter diagonal as a common side.

2. A three dimensional structure comprising three elongated members having like end parts, each of said end parts having a cross-section in the shape of an equal sided parallelogram two of the angles of which are substantially 70°32′, said end part terminating with a shape defined by two plane surfaces intersecting along a shorter protruding diagonal of said parallelogram, each plane surface making an angle of substantially 54°44′ with a plane through said shorter diagonal and bisecting the end part, said shape consisting of a pair of equilateral triangles with said shorter diagonal as a common side, and means for joining said three members in an angular array in which said members converge together with their end parts adjacent one another, wherein said shorter diagonals of the three end parts are arranged to define an imaginary equilateral triangle, one of each pair of equilateral triangles lying in the plane of said imaginary equilateral triangle, and the other of each pair of equilateral triangles forming, with said imaginary equilateral triangle, a regular tetrahedron.

3. A three dimensional structure as claimed in claim 2, including at least one joint comprising at least two and at most four sets of three members each set being joined together as defined in claim 2, in which said imaginary equilateral triangle of each set and said ones of said pairs of equilateral triangle are located on a respective face of a regular tetrahedron on the edges of which are of a length double that of said shorter diagonal of each member.

4. A three-dimensional structure as claimed in claim 3, in which said joining means comprise a body having an outer surface the shape of at least a part of which is defined by two juxtaposed regular tetrahedrons, the length of the edges of said tetrahedrons being substantially double that of said shorter diagonal of each member, the edges of the base of one tetrahedron perpendicularly bisecting three edges of the other tetrahedron and vice-versa.

5. A three-dimensional structure as claimed in claim 4, in which the shape of the outer surface of said body is defined by two juxtaposed regular tetrahedrons, an apex of one of said tetrahedrons being truncated by a base of the other tetrahedron, said body having means defining a cavity which is accesible through said base of said other tetrahedron, means defining a plurality of holes in said body communicating said cavity with the outer surface of the body, each hole being adapted to receive securing means for securing one member to said body.

6. A three-dimensional structure as claimed in claim 5, in which said member are tubular and hollow, said end parts each comprising a piece having an outer surface conforming to said shape, said piece comprising means for cooperating with said securing means for securing said member to said body.

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