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BUILDING CONSTRUCTION

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FIG. 1

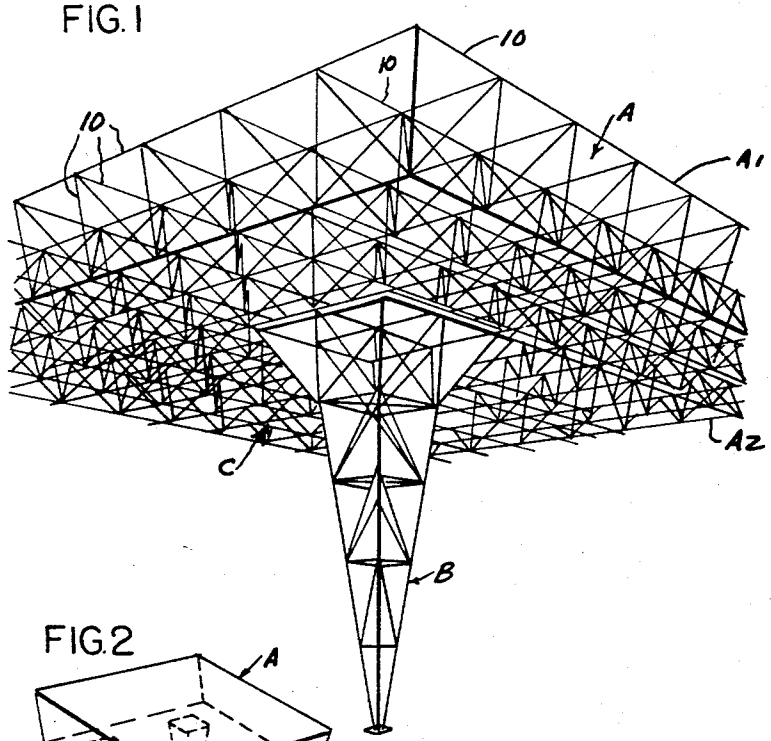

FIG. 2

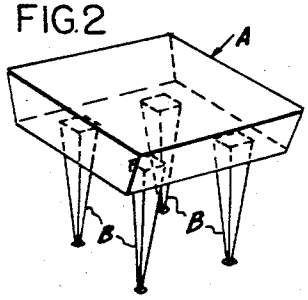

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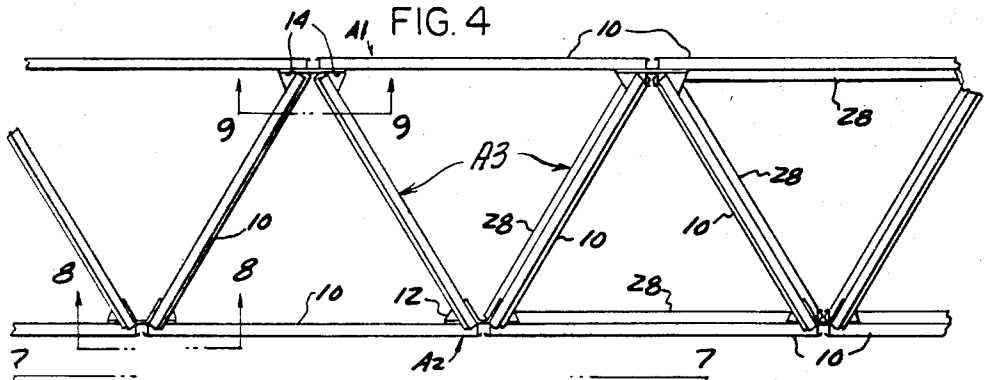
FIG. 4



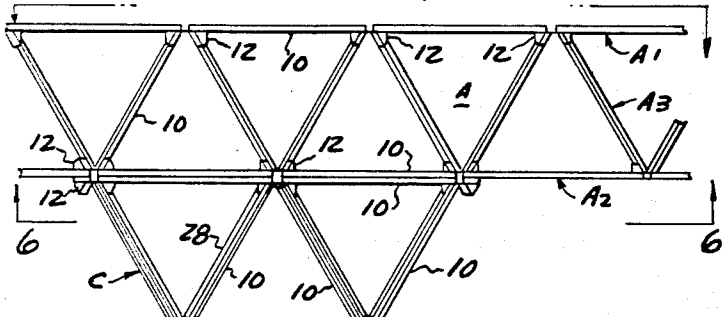


FIG. 3

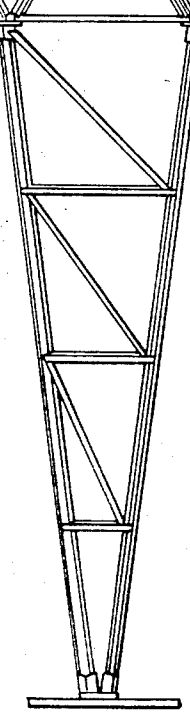
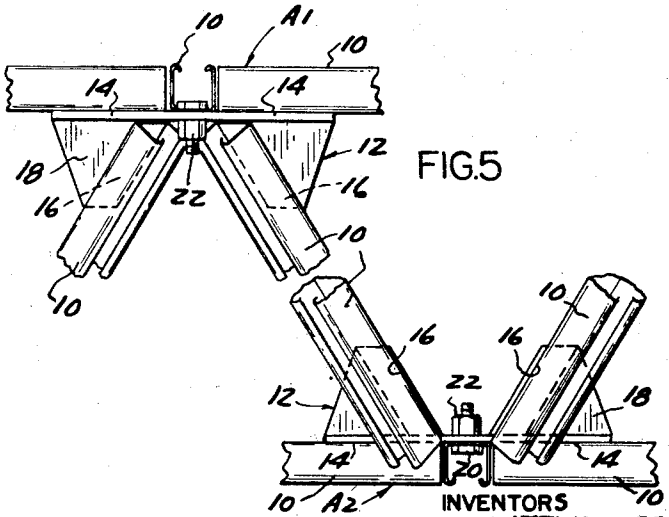


FIG. 5



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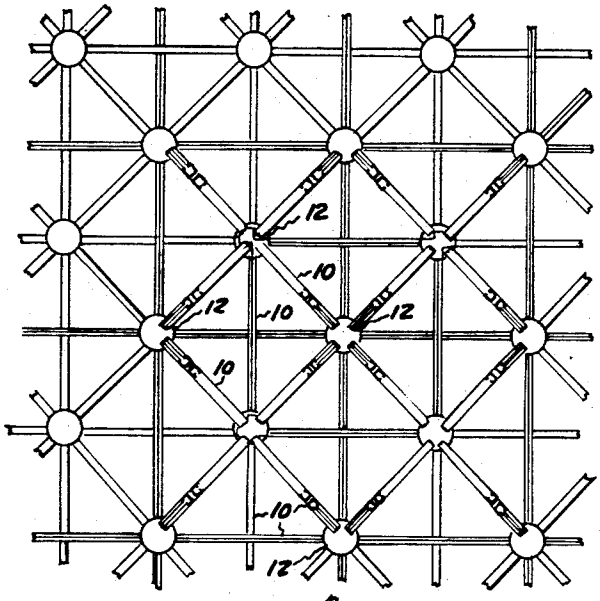

FIG.6

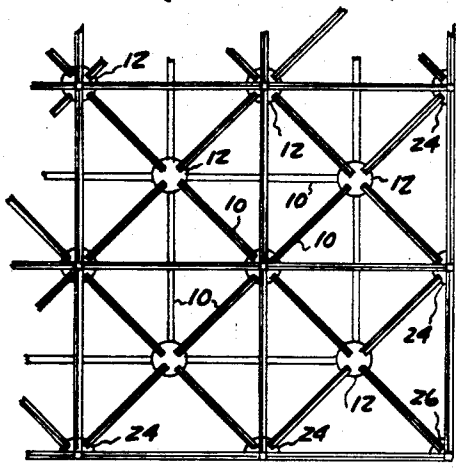

FIG.7

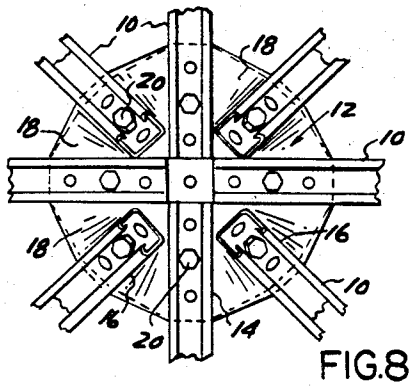

FIG.8

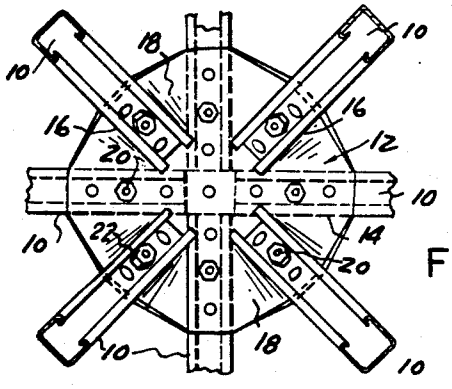

FIG.9

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FIG. 10

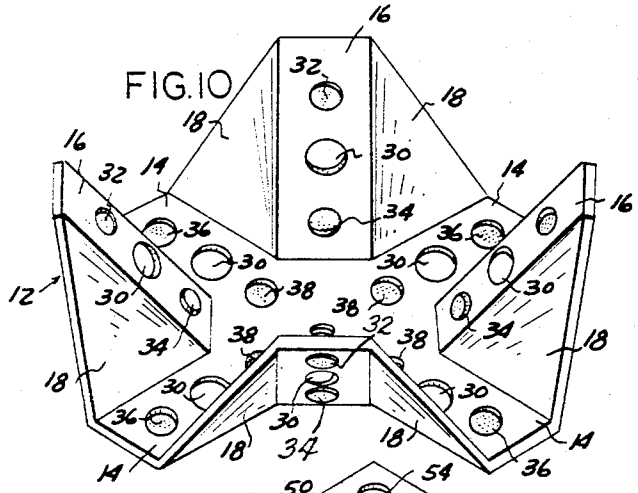

FIG. 11

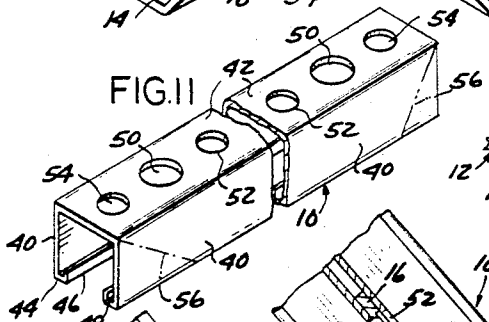

FIG. 13

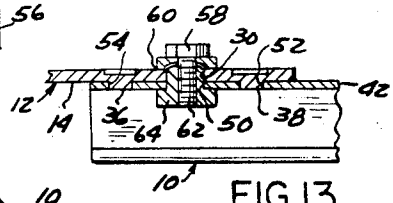

FIG. 15

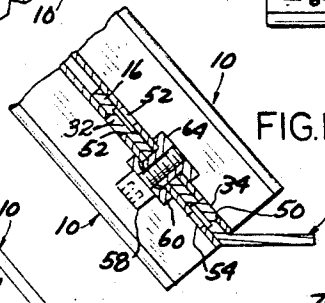

FIG. 14

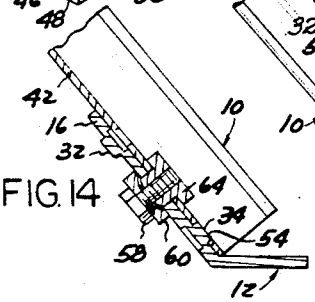

FIG. 16

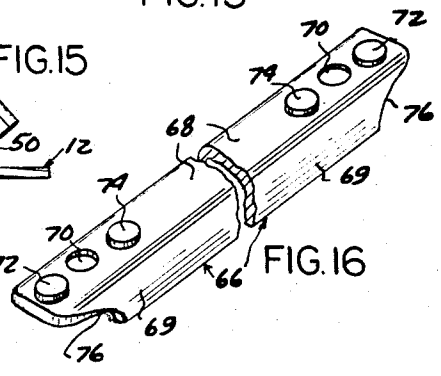

FIG. 12

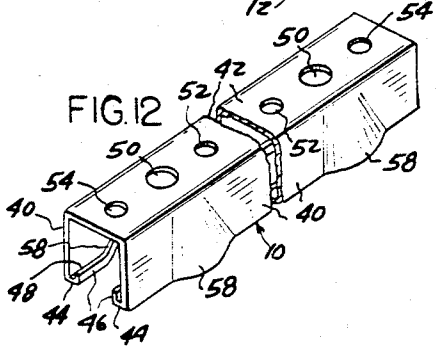

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FIG. 17

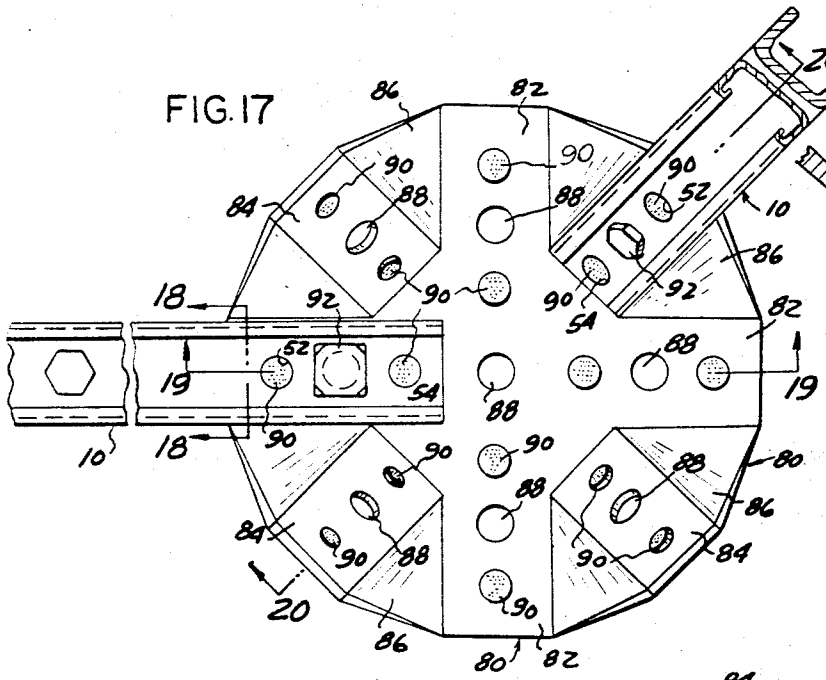


FIG. 18

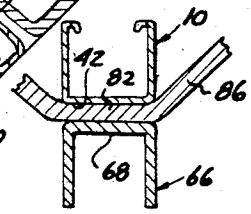


FIG. 19

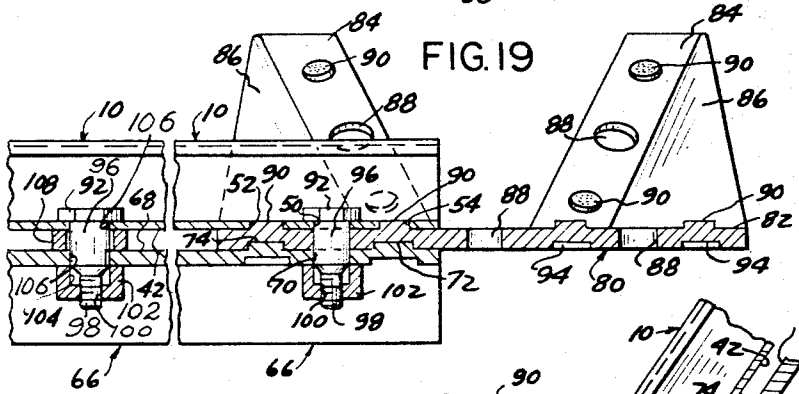


FIG. 20

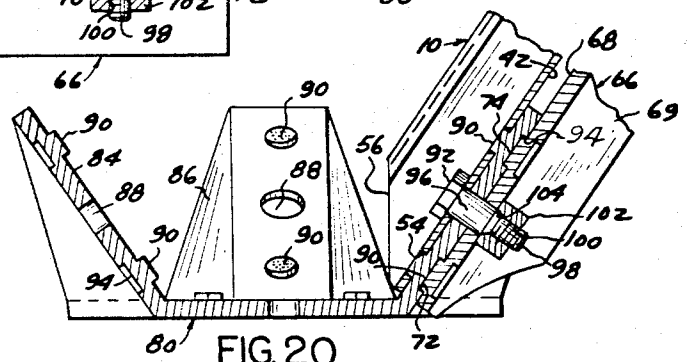
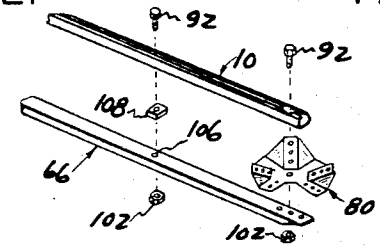


FIG. 21



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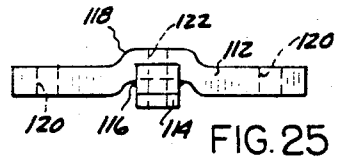

FIG. 25

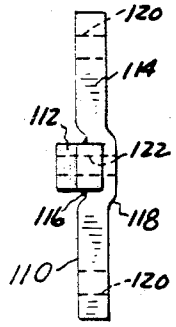

FIG. 26

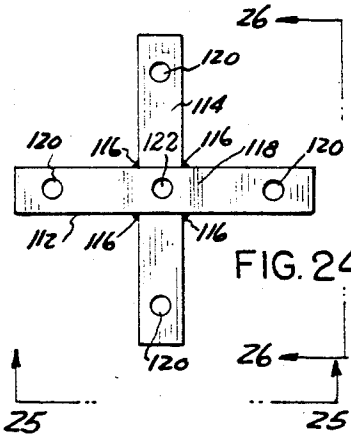

FIG. 24

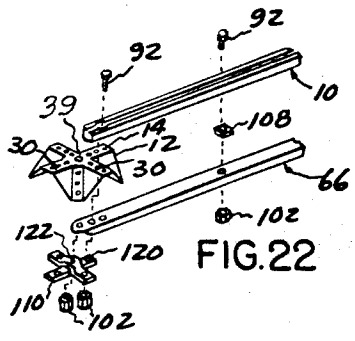

FIG. 22

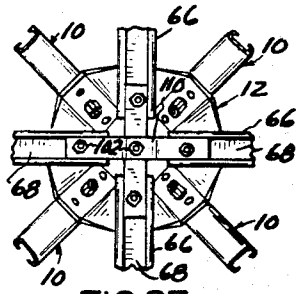

FIG. 23

FIG. 27

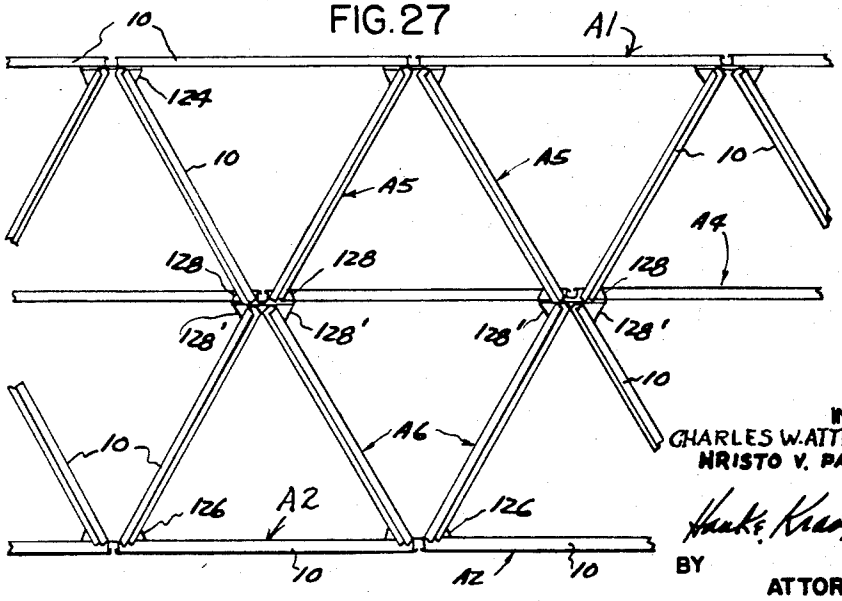

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FIG. 28

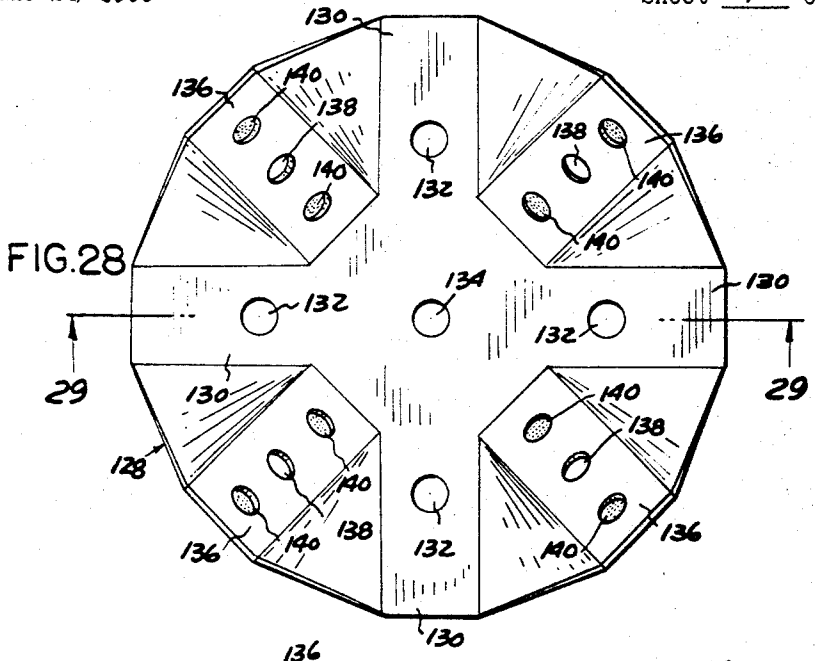


FIG. 29

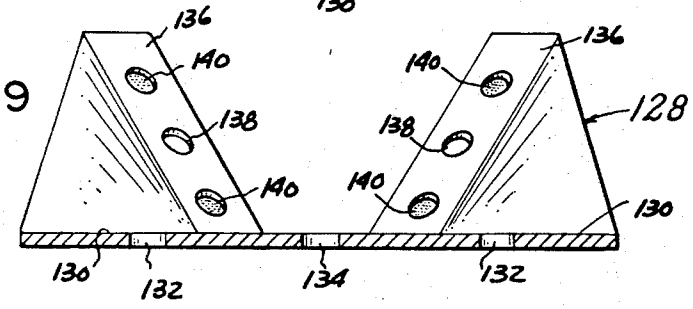
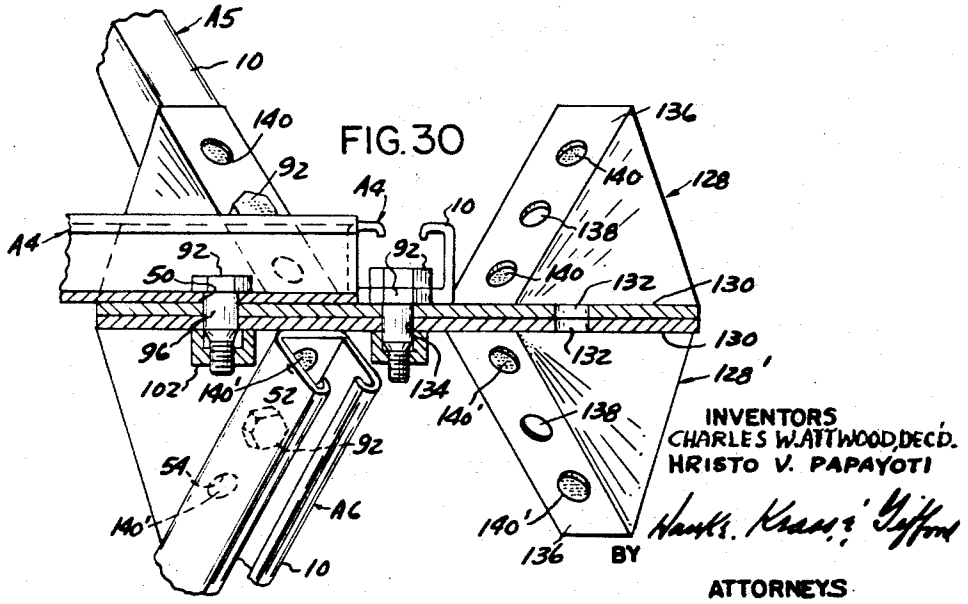


FIG. 30



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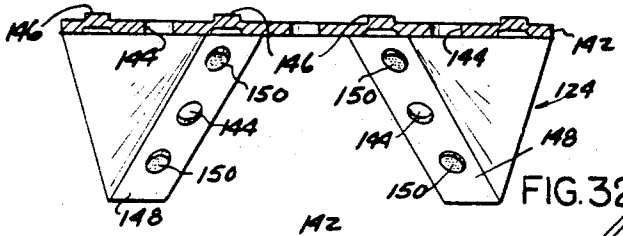


FIG. 32

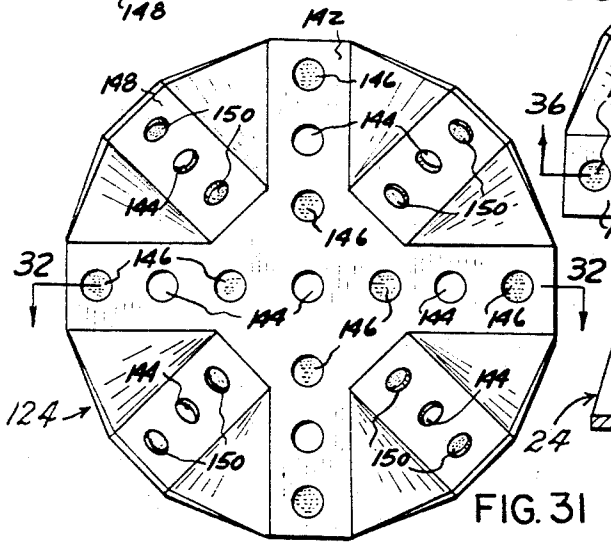
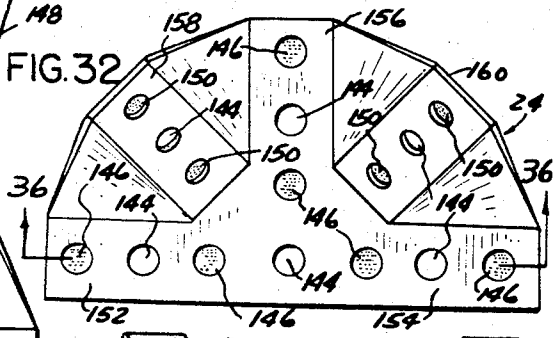


FIG. 31

FIG. 35



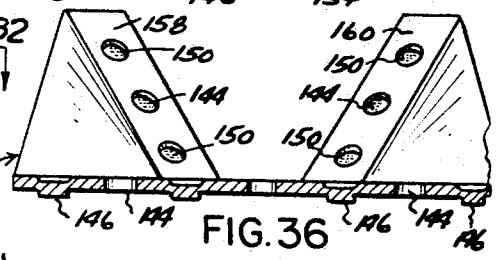


FIG. 36

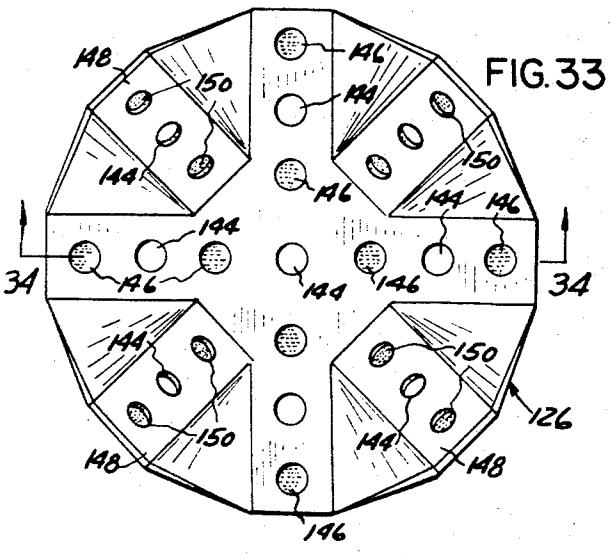


FIG. 33

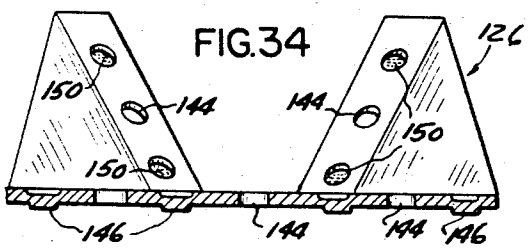


FIG. 34

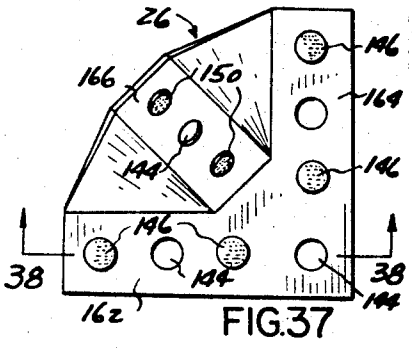


FIG. 37

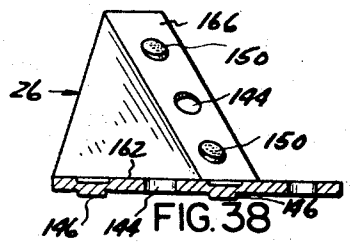


FIG. 38

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United States Patent Office 3,421,280 Patented Jan. 14, 1969

3,421,280

BUILDING CONSTRUCTION

Charles W. Attwood, deceased, late of Wayne, Mich., by James W. Attwood and Warren R. Attwood, executors, 4113 S. Wayne Road, Wayne, Mich. 48184, and Hristo V. Papayoti, Ann Arbor, Mich.; said Papayoti assignor to estate of Charles W. Attwood

Continuation-in-part of application Ser. No. 58,874, Sept. 20, 1960. This application June 24, 1966, Ser. No. 560,929

U.S. Cl. 52—648 15 Claims

Int. Cl. E04h *12/00*; F16b *1/00*

ABSTRACT OF THE DISCLOSURE

A space frame metallic structure consisting of standardized preformed and prefinished main strut members, reinforcing strut members, interconnected by means of standardized connectors, half-connectors, quarter-connectors and connector reinforcing members. The diverse elements forming the space frame structure are held in assembly by means of standardized nuts and bolts, all the elements being provided with corresponding mounting holes, projecting lugs and lug receiving recesses adapted to interlock the elements in appropriate structural and spatial relationship.

The present application is a continuation-in-part of copending application Ser. No. 58,874, filed Sept. 20, 1960 now Patent No. 3,270,478.

The present invention relates to building construction and more particularly to a new metallic space frame construction system having load carrying structural capacity.

In Patent No. 3,270,478, there is disclosed a standardized system of space frame construction involving the use of lightweight, interchangeable parts of high quality, manufactured to close tolerances, and that can be assembled at very low cost even by relatively inexperienced workmen to form structures varying greatly in design and capable of being readily disassembled, altered or expanded to meet the changing needs of the owner or user. Such a flexible type of structural framework is well suited for many different types of buildings, pavilions, trusses, structural spans and the like. In addition, such structural framework meets not only requirements of flexibility, standardization and high quality, but it is capable of carrying large loads and can be engineered to form spaces of varying sizes and shapes instead of being limited to certain overall fixed dimensions as is the case with conventional structures.

As disclosed in Patent No. 3,270,478, a "space frame" is a structure in which forces act in three or more directions in space. The structure uses four substantially standardized basic parts, namely, connection fixtures, struts, bolts and nuts. The heart of these four basic parts is a preformed universal connecting fixture having accurately located seats with accurate locating and securing means.

The space frame system as disclosed in the said patent and as herein shown and described can be applied to roof span construction as well as floor construction and other structures. Heretofore, trusses and the like used in such structures were either welded together and carried to the construction site, or were assembled by welding, riveting or bolting on the construction site from specified parts which individually were adapted for only one specialized use and had to be altered as necessary as construction progressed.

The present space frame system overcomes a shortcoming of previous art systems by utilizing lightweight, easily handled modular parts which, since they are manufactured in large quantities, are of such accurate dimensions that interchangeability is a rule rather than the exception. The precision with which parts are made in the factory insures speed and accuracy in assembly. The parts arrive on the site pre-finished and are readily joined together. Workmen do not have to use tapes or squares, and the simplicity of assembly even permits the employment of relatively unskilled labor.

Consequently, among the objects of the present invention is to advance the art of building construction by providing a new type of space frame structure capable of being erected by unskilled labor, using only a few simple tools of wide spread possession and use, the structure consisting of elements of relatively lightweight which are easily handled without machinery and comprising a minimum number of different elements.

Another object of the invention is to produce metallic frame structures by providing pre-formed universal strut connecting fixtures having strut seats connected by inclined and reinforcing gussets, and in which the strut seats are provided with accurately dimensioned and located lugs and apertures, said fixtures being connected to each other through a plurality of similar channels by means of nuts and bolts so that the entire structure may be, if desired, dismantled and again reassembled without the necessity of discarding or replacing a single piece.

Another object is to facilitate the assembly of metallic frame structures by providing a plurality of only a few different elements, none of which requires modification or adapatation in the process of construction.

A further object of the invention is to facilitate the construction of floors, roofs, trusses or arches and other structures by providing a new and simplified system of assembly utilizing precision manufactured parts adaptable for modularized and interchangeable construction.

Yet another object of the invention is to introduce new architectural principles in the development of space frames by providing simplified modularized factory-produced fabrication units pre-engineered with load supporting and stress meeting capabilities inherent in standardized parts, and capable of complete assembly on the construction site.

Yet a further object of the invention is to provide reinforcement means for an already existing structure so as to greatly increase the load capacity of the structure without dismantling the structure.

Another object of the invention is to provide a space frame structure having a "double-decker" structure for increased rigidity and increased load carrying capability.

Other objects and advantages of the invention will become apparent when the following description is considered with reference to the accompanying drawings illustrating preferred embodiments of the invention and wherein like reference numerals refer to like parts throughout the several views, and in which:

FIG. 1 is a general diagrammatic perspective view of a portion of a space frame structure according to the present invention;

FIG. 2 is another diagrammatic view showing a completely laterally stable space frame;

FIG. 3 is an enlarged view in elevation of a portion of the structure of FIG. 1;

FIG. 4 is an enlarged view in elevation of a portion of the structure of FIG. 3, showing a part thereof provided with reinforcing elements for increased load carrying capacity;

FIG. 5 is a partial view of some of the components of the structure of FIGS. 1–4;

FIG. 6 is a fragmentary view taken substantially on the line 6—6 of FIG. 3;

FIG. 7 is a fragmentary plan view from the top of

FIG. 3, substantially from line 7—7, but showing one of the corners of the structure;

FIG. 8 is a partial view as seen substantially from line 8—8 of FIG. 4;

FIG. 9 is another partial view as seen substantially from line 9—9 of FIG. 4;

FIG. 10 is a perspective view of an example of connecting fixture utilized in the present invention;

FIG. 11 is a perspective view of an example of channel member;

FIG. 12 is a perspective view of another example of channel member;

FIG. 13 is a longitudinal fragmentary section showing a connection between the elements of FIGS. 10 and 11 when the channel member acts as a chord;

FIG. 14 is a longitudinal fragmentary section showing a connection between the elements of FIG. 10 and FIG. 11 when the channel member acts as a single strut;

FIG. 15 is a longitudinal fragmentary section showing a joint between the elements of FIGS. 10 and 11, but illustrating a double strut reinforced modification;

FIG. 16 is a perspective view of an example of a preferred reinforcing channel member;

FIG. 17 is a top plan view of a modification of the connecting fixture of FIG. 10, with one chord and one web double strut mounted thereon;

FIG. 18 is a fragmentary cross-sectional view taken substantially on line 18—18 of FIG. 17;

FIG. 19 is a cross sectional view taken substantially on line 19—19 of FIG. 17;

FIG. 20 is a cross sectional view taken substantially on line 20—20 of FIG. 17;

FIG. 21 is an exploded view of the chord portion of the assembly of FIGS. 17–19;

FIG. 22 is an exploded view showing an example of means according to the invention for reinforcing a connecting fixture;

FIG. 23 is a plan view of a reinforced connecting fixture;

FIG. 24 is a plan view of the reinforcing element of FIGS. 22 and 23;

FIG. 25 is a side elevation view thereof, as seen from line 25—25 of FIG. 24;

FIG. 26 is a side elevation thereof, as seen from line 26—26 of FIG. 24;

FIG. 27 is a partial elevation view of an example of a "double-decker" space frame assembly;

FIG. 28 is a plan view of another example of connecting fixture according to the invention, adapted for back-to-back mounting on the intermediary chord frame of the assembly of FIG. 27;

FIG. 29 is a cross sectional view taken on line 29—29 of FIG. 28;

FIG. 30 is a fragmentary cross-sectional detail view of an assembly comprising two back-to-back connecting fixtures with some chord and web struts mounted thereon;

FIG. 31 is a plan view of another example of a connecting fixture according to the invention;

FIG. 32 is a cross-sectional view taken substantially on the line 32—32 of FIG. 31;

FIG. 33 is another example of a connecting fixture according to the invention;

FIG. 34 is a cross-sectional view taken along the line 34—34 of FIG. 33;

FIG. 35 is an example of a connecting fixture according to the invention for use on a peripheral or marginal chord frame;

FIG. 36 is a cross sectional view taken along line 36—36 of FIG. 35;

FIG. 37 is a plan view of an example of a modification of a connecting fixture according to the invention for use at the corner of a chord frame; and

FIG. 38 is a cross sectional view taken along line 38—38 of FIG. 37.

Referring now to the drawings, and more particularly

to FIGS. 1–4 thereof, an example of practical application of the principle of the present invention comprises a space frame structure, generally designated by reference character A, which, in the example illustrated, is supported by a column structure B, generally known as a "nine point" column. The space frame structure A is attached to the top of the column structure B by way of a column cap assembly C. The space frame structure A may extend in any direction and be of any appropriate size and shape, and may, for example, be supported as schematically indicated at FIG. 2 by a plurality of column structures B', or any other adequate supporting structure. It is evident that any column or pillar may be used to support the space frame structure A.

The space frame structure A comprises, as best seen in FIGS. 3–4, an upper chord frame structure A1 and a lower chord frame structure A2, held in spatial relationship by means of an intermediate web structure A3. Each chord frame structure and the web structure are assembled from a plurality of struts 10 which are preferably channel shaped and which are marketed under the trade name of "Unistrut." Examples of such channel struts will be described hereinafter in further detail.

The upper and lower chord frame structures A1 and A2 also comprise a plurality of junction plates or connecting fixtures. Examples of such connecting fixtures will also be described in detail hereinafter. It is sufficient, for the present purpose, to indicate that each connecting fixture is provided with a horizontal or plane portion having a plurality of spaced coplanar seat surfaces 14, see FIGS. 4–5 and FIGS. 8–9, and a plurality of equidistant angled seats 16 joined to the coplanar seats 14 by way of inclined gussets 18. Means are provided on each seat surface for attaching the end of the struts, such means consisting primarily of a bolt 20 and a nut 22, the bolt 20 having a body adapted to pass through alined apertures in the connecting fixture seats and the end of the channel struts 10, locating means also being provided as will be hereinafter explained in further details.

As shown in FIGS. 6 and 7 the channels of the struts of the lower chord frame structure are open downwardly and those of the upper chord frame structure are open upwardly. As shown in FIGS. 4 and 5 and FIGS. 8 and 9, the web struts are preferably attached to the inside surface of the inclined seats 16 of the connecting fixtures 12 of the upper chord frame structure A1, while the web struts are preferably attached to the outer surfaces of the angled seats 16 of the connecting fixtures 12 forming part of lower chord frame structure A2, although it is evident that such an arrangement is a matter of choice and that the whole structure can be assembled so that the upper chord frame just described becomes the lower chord frame and vice-versa.

All the struts 10 and all of the connecting fixtures 12 are preferably the same, with the result that no selection of parts or pieces need be made, since any strut or any connecting fixture may be used for any joint and requires no measuring or squaring since all dimensions are accurate and uniform. Attaching such elements together as indicated produces a space frame span in which the chord frame structures are in parallel planes and the struts are all arranged in squares with the intersections in one plane being vertically opposite the centers of squares in the other plane, as best shown in FIGS. 6 and 7. As the intersections in one plane are joined to those in the other plane by the diagonally arranged web struts, as best seen in FIGS. 3–4, the resulting structure consists of a plurality of four sided pyramids set together right side up and upside down with all edges of the same length.

In the preferred space frame arrangement disclosed herein, a single connecting fixture accommodates eight struts, with each strut being secured to the appropriate seat of the connecting fixtures by a single bolt and nut. In addition, by providing locating lugs or projections, as hereinafter described in further details, on the seats of

the connecting fixtures, a single bolt nut assembly insures perfect alignment and full strength, and eliminates the necessity for a plurality of bolts, although if desired, more than one bolt could be used instead of using the aligning and locating lugs or projections.

As shown particularly in FIG. 7, the edge of the upper chord frame assembly and, also, the edge of the lower chord frame assembly may preferably include modified connecting fixtures **24** having three coplanar strut seats and two angled seats, as hereinafter explained in further detail. The corners of the chord frame structures preferably include connecting fixtures such as shown at **26**, having two coplanar seats and one angled seat, as will also be explained hereinafter in further detail.

When it is desired to provide a space frame structure having increased load carrying capacity, an arrangement such as illustrated in the right hand side of FIG. 4, and also with respect to the column cap assembly seat of FIG. 3, and having reinforcing struts such as shown at **28** may be attached to and incorporated into the upper and/or lower chord frame structures and also, if so desired, may be incorporated into the web strut structure. The same connecting fixtures are generally used, whether the structure consists of a non-reinforced structure or whether it consists of a reinforced structure, the usual channel struts **10** and the reinforcing struts **28** being mounted upon the seats of the connecting fixtures **12** as will be hereinafter explained in further details.

FIG. 10 represents an example of a connecting fixture **12** having a plane portion providing a plurality of spaced equidistant coplanar seats **14** and having spaced angled seats **16** equidistant from each other and equidistant from two consecutive coplanar seats **14**, the angled seats **16** being joined to the edge of the coplanar seats **14** by way of inclined integral gussets **18**. In each of the seats **14** and **16** there is a mounting opening or hole **30** of a predetermined diameter, and substantially symmetrically disposed in alignment are circular coined projections or lugs **32** and **34**, symmetrically disposed relatively to each mounting opening **30** of the angled seats **16**. All the peripheral coined projections or lugs **32** project outwardly, and all the coined projections or lugs **34** project inwardly, as seen in the drawing.

Circular coined projections or lugs **36** and **38** are symmetrically disposed in alignment on both sides of each mounting opening or hole **30** of the coplanar seats **14**. In the example of connecting fixture illustrated, both coined projections **36** and **38** project outwardly, i.e. downwardly as seen in the drawing. A centrally disposed opening or hole **39** is also provided for a purpose to be explained hereinafter.

An example of channel strut **10** is shown in FIG. 11. The strut **10** is channel shaped, its sidewalls **40** being turned at a right angle relatively to the body **42** of the strut, the edge of each sidewall **40** being in turned inwardly at a right angle as shown at **44**, and the edge portions being again turned at right angle as shown at **46** so as to define a longitudinal slot **48** between each turned-in edge **46** and the corresponding sidewall **40**. The body portion **42** of the strut **10** is provided on both ends thereof with an opening or hole **50**, of a diameter substantially equal to the diameter of the openings **30** in the connection fixture **12** of FIG. 10. Longitudinally aligned, and symmetrically disposed on both sides of each opening **50**, are openings **52** and **54** of an equal diameter substantially the same as the outer diameter of projections or lugs **32**, **34**, **36** and **38** of connecting fixture **12** of FIG. 10. The strut of FIG. 11 may be modified by having a triangular portion removed from each side wall on one or both ends thereof as indicated at dot-and-dash lines **56**, so as to provide a metered end for the strut in applications where clearance is required on one or both ends in view of the particular mounting of the strut upon the connecting fixture which may otherwise lead to interference between diverse struts.

FIG. 12 represents another modification of the strut **10** which is substantially identical to the strut of FIG. 11, but which is provided with an outwardly bulging portion **58** on each sidewall **40**, proximate to opening or hole **50**. The outwardly bulging portion **58** of the sidewalls thus affords clearance for a tool to be introduced between the sidewalls for the purpose of holding and tightening a bolt or a nut for a bolt passing through opening **50** for the purpose of attaching each end of the strut to the appropriate connecting fixture.

FIG. 13 shows a connection wherein the strut member **10** acts as a chord member in the upper or the lower chord frame structure of FIGS. 1–5. As shown in FIG. 13, the bottom surface of one of the coplanar seats **14** of a junction plate **12** acts as a seat for a channel strut **10** with the opening **50** on one end of the strut being aligned with opening **30** in the seat and with opening **54** in the end of the strut fitting over and around the coined projection or lug **36** in the seat and with the opening **52** of the strut **10** fitting around projection **38** of the seat. In this manner, with the opening **50** in the channel strut registering with opening **30** in the seat of the connecting fixture, the channel strut is held in position by means such as a bolt **53** passing through washer **60** and having a threaded portion **62** engaging the threaded bore of sleeve-like nut **64**. The outer diameter of sleeve-like nut **64** is adapted to fit, by having a diameter substantially equal thereto, both openings **50** and **30** of substantially equal diameters.

It can thus be seen that the channel **10** is held in position below seat **14** of the connecting fixture **12** and is properly and automatically aligned by having its openings **52** and **54** engaging respectively coined projections or lugs **38** and **36** in the seat.

FIG. 14 shows a single web channel strut secured to an angled seat **16** of a connecting fixture **12**. In this type of assembly, only one of the coined projections, projection **34**, on seat **16** is utilized for the alignment of the strut by engaging opening or hole **54** in the end of the strut. Where it is desired to utilize a reinforced structure for the web structure of the space frame, the arrangement of FIG. 15 is used by utilizing two web channel stuts **10** in parallel. In FIG. 15, the angled seat **16** of the connecting fixture **12** is sandwiched between two back-to-back arranged struts **10**, with the upper strut **10** having its opening **54** engaging coined projection or lug **34** of the seat and the lower strut **10** having its opening **32** engaging the coined projection **52** on the bottom of the seat. The two channel struts **10** are held together and held upon the seat **16** by means of a bolt **58** provided with a sleeve-like nut **64** with a length sufficient to project through the several parts.

The structures disclosed in FIGS. 13–15 are generally used for the lower chord frame structure, the fixture **12** being inverted, relatively to the orientation shown in FIG. 10, when used in the upper chord frame structure. Such arrangements are also shown in FIG. 5 and FIG. 8, FIG. 8 showing the arrangement relatively to the lower chord frame structure as seen from below and FIG. 9 showing the arrangement relatively to the upper chord frame structure as seen also from below.

FIG. 16 represents a perspective view of a typical reinforcing strut which may be used in a frame structure according to the invention instead of the channel strut of FIGS. 11 and 12 in applications where a reinforced structure is desired. Reinforcing strut **66** of FIG. 16 is generally U-shaped with a body portion **68** provided with right angled sidewalls, one of which is seen in FIG. 16 at **69**. Both ends of reinforcing strut **66** are provided with an opening or hole **70** for attachment to the connecting fixtures, as hereinbefore explained in relation to the mounting of channel struts **10**, coined projections or lugs such as shown at **72** and **74** being provided for engagement in appropriate recesses in the seat of the connecting fixture, as will be hereinafter explained in further details. It is evident, at this point, that the channel struts **10** of

FIGS. 11 and 12 could also be provided with projections instead of being provided with holes or openings **52** and **54**, for use with a different embodiment of connecting fixture from the one illustrated in FIG. 10. Similarly, the reinforcing strut of FIG. 16 could also be provided with openings instead of coined projections, and it is also evident that instead of being provided with coined projections, the strut **66** of FIG. 16 can be provided with coined recesses to cooperate with connecting fixtures having seats provided with coined projections instead of recesses. Preferably, the ends of the reinforcing struts **66** have a cut-out portion which may be arcuate, as shown at **76**, or which could be straight as cut-out **56** of the hereinbefore described modification of channel strut **10** of FIG. 11.

FIGS. 17 through 20 illustrate the construction of a space frame structure using a modified connecting fixture **80** having the same general configuration as the connecting fixture **12** of FIG. 10, thus comprising a plurality of coplanar seats **82** and angled seats **84** connected to the coplanar seats by inclined gussets **86**. In each of the seats **82** and **84** is a bolt receiving opening or hole **88**, and spaced therefrom on both sides thereof are coined projections or lugs **90**. In this embodiment of a connecting fixture, however, both coined projections on each seat extend in the same direction, and in the example shown, the coined projections extend inwardly. Fixture **80** can be used in either the upper or lower chord frame structure, in combination with connecting fixtures in the other chord frame structure having coined projections or lugs all extending in the opposite direction, i.e. outwardly. Although it is evident that connecting fixtures such as connecting fixture **80** may be used for non-reinforced structures the following description will be made with the emphasis being placed on an example of use in a reinforced structure.

Channel struts **10**, such as have been hereinbefore described in relation to FIGS. 11 and 12, may be bolted to any seat of the connecting fixture **80** with the coined projections or lugs **90** thereof engaged in holes **52** and **54** on the end of the channel strut. The use of such connecting and aligning arrangement, in conjunction with a clamping bolt, provides for increased resistance to tension, compression and torque loads imposed on the channel struts **10**.

Where a reinforced structure is desired, another strut member is disposed back-to-back with channel strut **10**, the appropriate seat of the connecting fixture **80** being sandwiched between the two struts. For reinforcement, any of the struts **10** of FIGS. 11 and 12 may be used, but the drawings illustrate the use of a reinforcing struct such as strut **66** of FIG. 16. As shown in FIGS. 17–20, and also as shown in FIG. 21 illustrating an exploded view of the arrangement, a reinforcing strut **66** is connected below each seat of connecting fixture **80** so that projections **72** and **74** on the body portion **68** of the strut engage recesses **94** disposed on the opposite side of the seats from the side on which the coined projections **90** are situated. Opening or hole **70** in strut **66** is thereby automatically aligned with hole **50** in channel strut **10** and hole **88** in the seat. Bolt **92**, which is another example of bolt appropriate for use as the connecting means between the elements of a space frame structure according to the invention, has an enlarged body portion **96** adapted to pass through and just fit the aligned openings **50**, **88** and **70**, respectively in the channel strut **10**, the connecting fixture **58** and the reinforcing strut **66**. The enlarged body portion **96** of a bolt **92** is provided with a reduced diameter threaded portion **98** engaging the threaded bore **100** of a sleeve-like nut **102** having a smooth inner enlarged diameter portion **104** disposed toward the enlarged body portion **96** of the bolt. Consequently, bolt-nut combinations such as formed by bolt **92** with nut **102** are capable of tightening and clamping together parts having a total thickness comprised within predetermined limits in view of sleeve-like nut **102** being adapted for partial engagement around the enlarged body portion **96** of the bolt, the longitudinal travel of the nut being not limited strictly to the length of the threaded portion of the bolt.

Struts **10** and **16** preferably have openings, such as shown at **106** in FIGS. 19 and 21, at least one such opening being provided along the length of each strut, and opening **106** is normally filled with a knock-out disc, not shown, which may be easily removed, so that at least at one point along their length both both struts may be joined, as shown more clearly in FIGS. 19 and 21, by means of a bolt **92** engaging aligned openings or holes **106** in both struts, the two struts being held apart by a washer or spacer **108** having a thickness substantially equal to the thickness of the seats **82** and **84** of the connecting fixture. Such construction, of course, offers better structural rigidity and increased resistance to tension, compression and torque loads.

In the hereinbefore referred to patent, there is disclosed a connecting fixture provided with coplanar seats of a greater thickness of material than the material forming the angled seats. Such a modification of connecting fixtures has usefulness for incorporation into reinforced structures. However it requires that special connecting fixtures be manufactured for such purpose, and it is much simpler to make connecting fixtures having a thickness of material which is the same all over. The arrangement illustrated in FIGS. 22–26 permits the use of standard connecting fixtures even in structures subjected to heavy loads.

As shown in the exploded view of FIG. 22 and the plan view of FIG. 23, a standard connecting fixture, such as the connecting fixture **12** of FIG. 10, or the modified connecting fixture **80** of FIG. 17, is used in combination with a channel strut **10** and a reinforcing strut **66** fastened upon the coplanar seat **14** thereof by means such as bolt **92** and nut **102**. A cross-shaped reinforcing member **110** is placed below the coplanar seats **14** and is provided with two members or arms **112** and **114** disposed at right angles to each other and being connected together at a portion equidistant from both ends by any convenient means such as welding, for example, as shown at **116**. The connected portions of the arms are bent over, as shown at **118**, so that the two ends of arms **112** and **114** are normally disposed in coplanar relationship. Proximate the ends of each arm is an opening **120** of a diameter substantially the same as the diameter of the mounting openings in the connecting fixtures and the channel struts, the distance between two openings in one given arm, **112** or **114**, being substantially equal to the distance separating two openings, such as the openings **30** in the connecting fixture **12** of FIG. 10 being situated in aligned coplanar seats. A hole **122** is disposed substantially at mid distance between the two openings **120** in any given arm of the reinforcing member **110** so that the reinforcing member can be mounted on the coplanar seats, or below the coplanar seats, of a connecting fixture by means of a bolt passing through hole **122** and through the center hole, such as hole **39** in the connecting fixture of FIG. 10. When the reinforcing member **110** is mounted in a connecting fixture, as shown in FIG. 23, the rigidity and strength of the connecting fixture **12** is thus greatly increased and, as the distance separating the top and bottom surfaces of the bent over portions **118** is such that when the appropriate surface of the bent over portion engages the surface of the coplanar seats of the connecting fixture with centrally disposed bolt **92** properly tightened, substantially the exact clearance is provided between the surface of each end of the arms, **112** or **114**, to permit engagement between the surface of the connecting plate and of the body portion, such as **68**, of a reinforcing strut **66**, the use of the reinforcing member **110** substantially increases the solidity of the mounting of the struts upon the connecting fixture.

Referring now to FIG. 27, there is shown a side view of a "double-decker" space frame structure. It can be seen that such a space frame structure consists actually of two "single-decker" structures such as described in conjunction with FIGS. 1–7, disposed on top of each other, so that the total structure comprises an upper chord frame structure A1, a lower chord frame structure A2, and an intermediary chord frame structure A4, connected to each other by first intermeditae web structure A5 and second intermediate web structure A6. In such a structure, the struts forming the upper chord frame structure and designated by reference numeral **10** are preferably mounted on the top of "in-strut" connecting fixtures **124**, similar generally to the connecting fixtures **12** and possessing the general characteristics of the assembly shown in FIG. 5 and hereinbefore explained in detail. The lower chord frame structure A2 includes channel struts **10** mounted on the bottom of "out-strut" connecting fixtures **126**, according to the manner shown in details also in FIG. 5. The channels **10** forming the intermediate chord structure A5 are preferably mounted on the top of "out-strut" connecting fixtures **128**, such intermediate web struts **10** of the intermediate web structure A5 being mounted below the inclined angled seats of the "in-strut" connecting fixtures **124** of the upper chord frame structure. Mounted back to back with the "out-strut" connecting fixtures **128** of the intermediary chord frame structure A4 are disposed back to back with "in-strut" connecting fixture **128'**, in the manner hereinafter explained in further details. The channel struts **10** of the lower intermediate web structure A6 are disposed with one end thereof attached below the angled seats of the "in-strut" connecting fixtures **128'** and their other end attached below the angled seat of the "out-strut" connecting fixture **126** of the lower chord frame structure A2.

As shown in FIGS. 28–29, the connecting fixture designated generally by numeral **128**, which is modified for back-to-back mounting, has generally the same overall configuration as previously illustrated and described with regard to connecting fixtures according to the present invention. The principal difference, however, resides in the fact that the coplanar seats **130** are deprived of coined projections and are provided with only one opening or hole **132** per seat and with a centrally disposed hole **134**. The angled seats **136** are also provided with a mounting hole **138**, but, in addition, they are also provided with coined projections or lugs, such as **140**, which in the example of connecting fixture illustrated are directly outwardly, i.e. downwardly as seen in FIG. 29. It is evident that the coined projection may be such that one projection on each end of seats **136** is directed inwardly, while the other coined projection is directed outwardly, substantially like the arrangement previously shown in FIG. 10. The coined projections of the angled seats of an "in-strut" connecting fixture, such as connecting fixture **128'** of FIG. 27 preferably project inwardly, as clearly shown in FIG. 30, although it is evident that an arrangement similar to the one of FIG. 10 could also be adopted, with coined projections projecting alternately outwardly and inwardly.

In FIG. 30, a connecting fixture such as connecting fixture **128** of FIGS. 28–29, is mounted back-to-back with a substantially similar connecting fixture **128'** but which has coined projections **140'** directed inwardly. The holes or openings **132** and hole **134** on the coplanar seats **130** of both connecting fixtures **128** and **128'** are aligned, and intermediary chord channel struts **10** are mounted on the coplanar seats **138** by means of bolts **92** having their enlarged body portion **96** disposed through openings **50** in the channel struts and aligned holes **132** in the connecting fixture, in cooperation with appropriate sleeve nuts **102**.

The upwardly directed intermediary web structure A5 comprises struts such as channel strut **10** attached below upwardly directed angled seat **136** of connecting fixture **128** by means of bolts **92**, the aligning openings, not shown, on the end of the channel strut engaging the outwardly projecting coined projections **140**. The downwardly directed channel struts **10**, forming the downwardly directed intermediary web structure A6, are attached in a same manner as the upwardly directed channel struts, with the difference that the downwardly directed channel struts are attached above the angled seats **136** of connecting fixture **128'**.

It is evident that the openings **52** and **54** on the end of the channel struts **10** forming the downwardly directed intermediary web structure A6 are engaged upon the inwardly projecting coined projections **140'** of the angled seats **136** of the connecting fixtures **138'**. It is also evident that a pair of connecting fixtures such as connecting fixture **80** of FIGS. 17–20 may be also disposed back-to-back because their coined projections **90** project inwardly and that a fixture such as fixture **80** may be disposed back to back with a fixture such as connecting fixture **12** of FIG. 10, outwardly projecting projections **36** and **38** thereof engaging recesses **94** of the connecting fixture **80** of FIGS. 17–20.

FIGS. 31–32 represent respectively a plan view and a cross-sectional view of a typical "in-strut" connecting fixture **124**, which is an example of the "in-strut" connecting fixtures **124** as used as part of the upper chord frame structure A1 of FIG. 27. "In-strut" connecting fixture **124** of FIGS. 31–32 is substantially similar to the connecting fixtures previously described, see FIGS. 10 and 17–20, and is provided with coplanar seats **142** having the usual mounting apertures **144** and having outwardly projecting coined projections or lugs **146**. The angled seats **148** are also provided with a mounting hole or aperture **144**, with longitudinally and axially aligned inwardly projecting lugs or coined projections **150**.

FIGS. 33–34 represent a typical "out-strut" connecting fixture such as the "out-strut" connecting fixtures **126** forming part of the lower chord frame structure A2 of FIG. 27. "Out-strut" connecting fixture **126** of FIGS. 33–34 is substantially similar to the "in-strut" connecting fixture **124** of FIGS. 31–32, with the difference that the coined projections or lugs **150** on the angled seats **148** are projecting outwardly.

Referring now to FIGS. 35–36, there is shown a typical "in-strut" connecting half-fixture, such as fixture **24** of FIG. 7 forming part of an edge of the lower chord frame structure, such as the structure of FIG. 3. The "in-strut" connecting half-fixture **24** of FIGS. 35–36 comprises only three coplanar seats **152**, **154** and **156**. Coplanar seats **152** and **154** are longitudinally aligned with each other, and coplanar seat **156** is directed substantially at right angle relatively to the orientation of seats **152** and **154**. The three coplanar seats are provided with the usual mounting holes or openings **144**, and outwardly projecting coined projections or lugs **146**. Connecting fixture **24** has only two angled seats **158** and **160**, angled seat **158** being equidistant between coplanar seats **152** and **156**, and angled seats **160** being equidistant between coplanar seats **156** and **154**. The angled seats **158** and **160** are provided with the usual mounting hole or opening **154** and have inwardly projecting coined projections or lugs **150**. It is evident that the angled seats **158** and **160** could be provided with outwardly projecting coined projections or lugs in order to obtain an "out-strut" connecting half-fixture.

FIGS. 37–38 represent a corner connecting fixture such as shown at **26** on FIG. 7. Corner connecting fixture, or connecting quarter-fixture, **26** of FIGS. 37–38 comprises only two coplanar seats **162** and **164** disposed at right angle to each other and provided with the usual mounting holes or openings **144** and having outwardly projecting coined projections or lugs **146**. Connecting fixture **26** has only one angled seat **166**, equidistant from both coplanar seats **162** and **164** and provided with the usual

mounting hole or opening 144 with aligned inwardly projecting lugs, projections or lugs 150. Connecting fixture 26 is thus an "in-strut" corner connecting fixture and it is evident that where the coined projections or lugs 150 extend outwardly, the connecting fixture is an "out-strut" connecting fixture.

Having thus described the invention by way of examples, and being obvious to those skilled in the art that many changes, omissions in the disclosed space frame structure and components herein described may be made without departing from the scope and spirit of the invention, what is claimed as new and useful and desired to be secured by Letters Patent is:

1. In a load carrying construction system, a connecting fixture having a substantially flat seat and at least another seat being angular with respect to said flat seat, a pair of channels disposed in back to back relationship, said angular seat being sandwiched between said channels, means securing said channels to said angular seat, a spacer element of a thickness substantially equal to the thickness of said flat seat, said spacer element being disposed between said channels a predetermined distance away from said seat and means for clamping said channels with said spacer element sandwiched therebetween.

2. In a load carrying construction system, a connecting fixture having at least one substantially flat seat and at least another seat being angular with respect to said flat seat, at least a first pair of channels disposed in back to back relationship, said flat seats being sandwiched between said channels, at least a second pair of channels disposed in back to back relationship, said angular seat being sandwiched between said channels, means securing said channels to said seats, a spacer element of a thickness substantially equal to the thickness of each said seat, said spacer element being disposed between said channels a predetermined distance away from said seat and means for clamping said channels with said spacer element sandwiched therebetween.

3. In a load carrying construction system, a connecting fixture having a substantially flat seat, a pair of channels disposed in back to back relationship, said flat seat being sandwiched between said channels, means securing said channels to said flat seat comprising a removable connector element selectively operable to clamp said channels to said seat, locating means cooperating with said connector element to prevent angular, lateral and longitudinal shifting of said seat with respect to said channels, and a spacer of a thickness substantially equal to the thickness of said flat seat, said spacer element being disposed between said channels a predetermined distance away from said seat, and means for clamping said channels with said spacer element sandwiched therebetween.

4. In a load carrying construction system, a connecting fixture having a substantially flat seat, a pair of channels disposed in back to back relationship, said flat seat being sandwiched between said channels, means securing said channels to said flat seat comprising a removable connector element selectively operable to clamp said channels to said seat, locating means cooperating with said connector element to prevent angular, lateral and longitudinal shifting of said seat with respect to said channels, at least two pairs of channels being disposed in back to back relationship, and a reinforcing member disposed within at least two channels disposed on the same side of said seat, said reinforcing member being secured by the means securing said channels to said seat.

5. The construction system of claim 4 wherein said means securing said channels and said reinforcing member to said seat is a bolt having a body portion of a diameter adapted to fit aligned holes in said seat, said channels and said reinforcing member, and a reduced threaded end portion, and a nut threading on said threaded end portion, said nut having an enlarged diameter unthreaded portion disposed toward said body portion of said bolt and having a diameter corresponding to the diameter of said body portion.

6. In a load carrying construction system, a connecting fixture having at least one substantially flat seat and at least another seat being angular with respect to said flat seat, at least a first pair of channels disposed in back to back relationship, said flat seat being sandwiched between said channels, at least a second pair of channels disposed in back to back relationship, said angular seat being sandwiched between said channels, means securing said channels to said seats, a reinforcing member being disposed within at least two channels disposed on the same side of said flat seat, said reinforcing member being secured by the means securing said channel to said flat seat.

7. The construction system of claim 6 wherein said means securing said channels and said reinforcing member to said seat is a bolt having a body portion of a diameter adapted to fit aligned holes in said seat, said channels and said reinforcing member, and a reduced threaded end portion, and a nut threading on said threaded end portion, said nut having an enlarged diameter unthreaded portion disposed toward said body portion of said bolt and having a diameter corresponding to the diameter of said body portion.

8. The construction system of claim 6 in which said connecting means comprises a removable connector element selectively operable to clamp said channels to each said seat.

9. The construction system of claim 8 wherein said removable connector element is a bolt having a body portion of a diameter adapted to fit aligned holes in said channels and said seat and a reduced threaded end portion, said nut having an enlarged diameter unthreaded portion disposed toward said body portion of said bolt and having a diameter corresponding to the diameter of said body portion.

10. The construction system of claim 8 wherein said removable connector element is a bolt having a body portion of a diameter adapted to fit aligned holes in said channels and said seats and a reduced threaded end portion, and a nut threading on said threaded end portion, said nut having an enlarged diameter unthreaded portion disposed toward said body portion of said bolt and having a diameter corresponding to the diameter of said body portion.

11. A connecting fixture for skeletonized structure comprising a plurality of regularly disposed equidistant angled flat surfaces extending radially from a central point, a plurality of equidistant flat surfaces alternating with said angled surfaces and being equidistant therewith, said surfaces being connected by inclined webs, each of said surfaces being provided with a pair of longitudinally spaced projections, the projections on the coplanar surfaces both extending above said surfaces and the projections on the angled surfaces extending above said surfaces, each of said surfaces being also provided with an opening between and equidistant from said projections, a pair of connecting fixtures being placed back to back with the bottom of their coplanar surfaces engaging one another.

12. In a load carrying space frame construction system, a space frame structure comprising a lower chord frame structure, an upper chord frame structure, an intermediary chord frame structure, and a stress-distributing web stucture spacing and connecting said chord frame structures, each of said lower and upper chord frame structures comprising a plurality of fixture elements disposed substantially in a plane and spaced along a plurality of longitudinal and lateral rows, said intermediary chord frame structure comprising a plurality of pairs of fixture elements attached back to back and elongated stress carrying channels extending between said fixture elements to form longitudinal and lateral rows of adjacent two-dimensional space modules, the modules of the upper chord frame structure being longitudinally and laterally offset from the

modules of the intermediary chord frame structure and the modules of the lower chord frame structure being similarly longitudinally and laterally offset from the modules of the intermediary chord frame structure, said web structure comprising elongated stress-carrying channels extending between the fixture elements of another chord frame structure, said channels of all three chord frame structures and of the web structure being of equal length and attached to the fixture elements whereby all space modules are similar and all channels are replaceable and interchangeable.

13. The construction system of claim **12** in which each of said fixture elements is provided with a plurality of seat portions inclined angularly inwardly with respect to said chord frame structures, the channels of said web structure being interchangeably seated on the seat portions of said fixture elements, and connecting means are provided for removably securing each end of each channel to the seat portion of a fixture element.

14. The construction system of claim **13**, in which each of said connecting means comprises a bolt and a nut clamping the base side of the end of each channel to the seat portion of a fixture element, and complementary coacting means carried by each of said fixture elements for locating said channels and operatively cooperating with said bolt are provided for transmitting substantially all compression tensile stresses.

15. The construction system of claim **14** in which each channel of said web structure is secured at one end to the outside surface of the angular seat portion of a fixture element in one chord frame structure and at the other end to the inside surface of the angular seat portion of a fixture element in the next chord frame structure.

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