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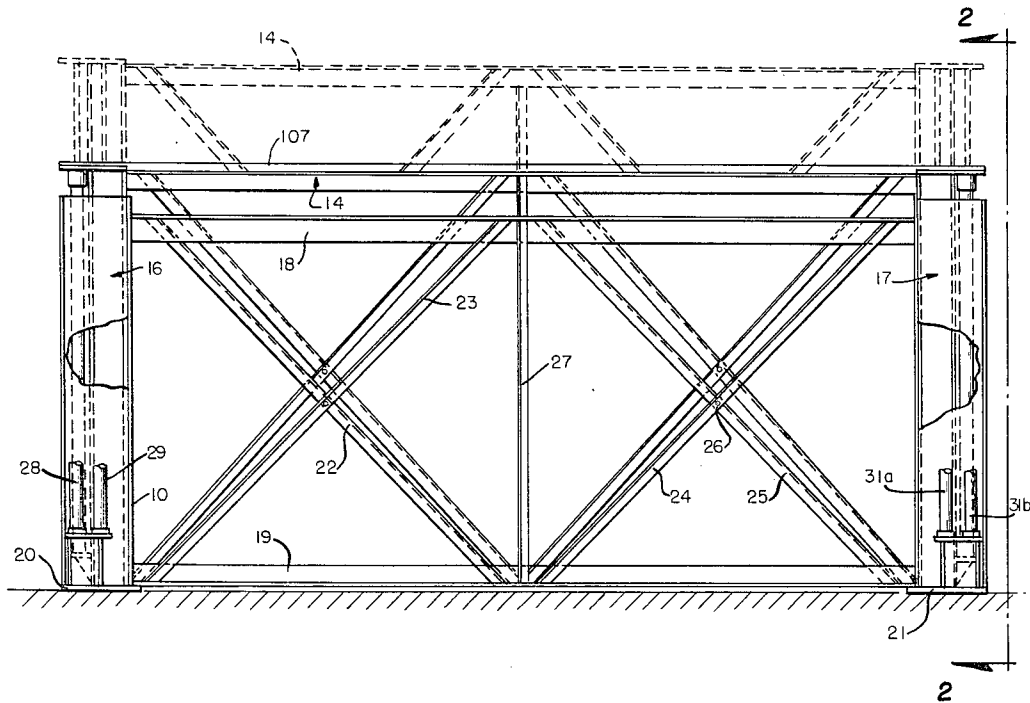
[54] MEANS FOR RAISING BUILDING OF MODULAR
CONSTRUCTION
24 Claims, 15 Drawing Figs.

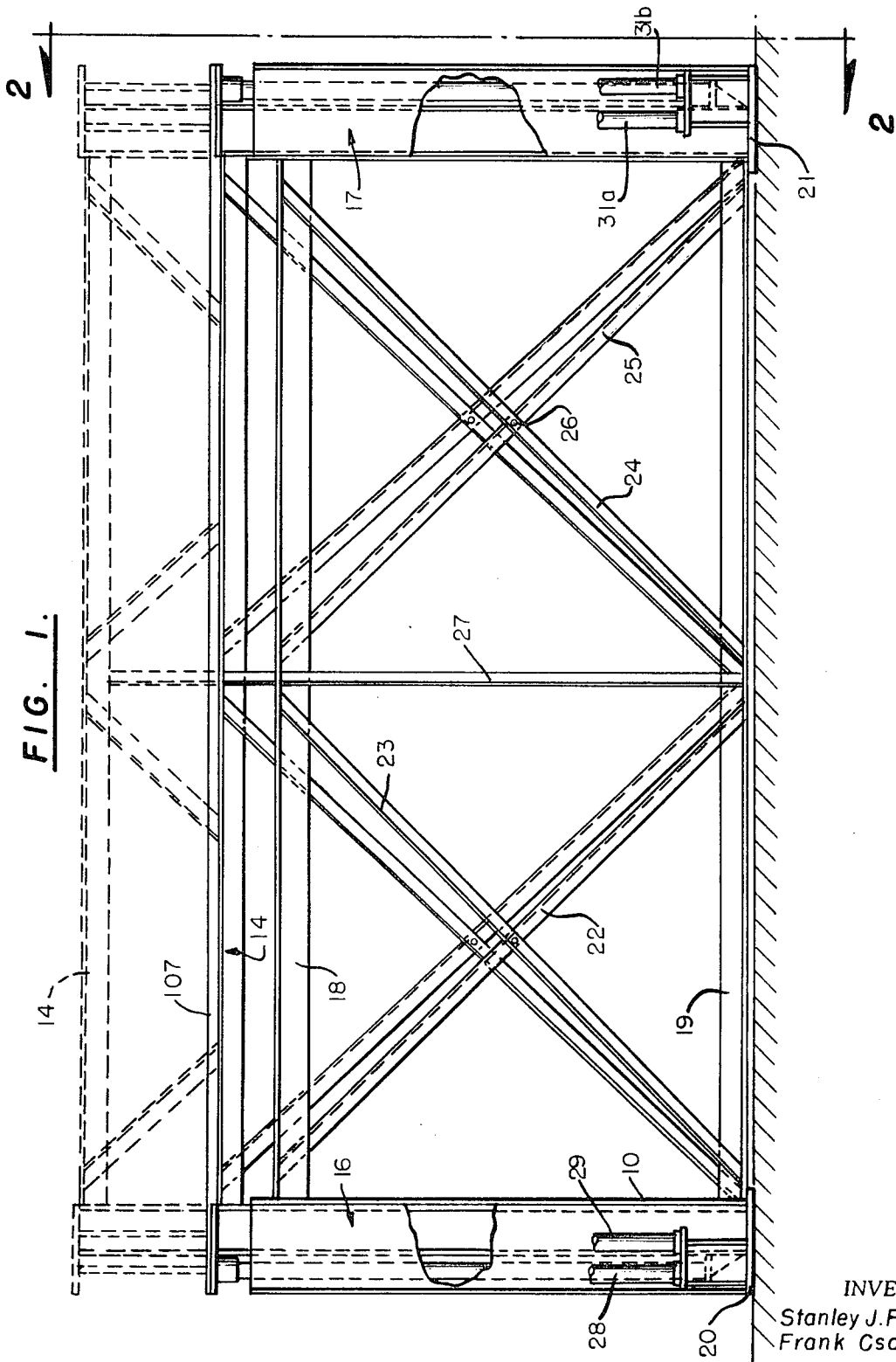
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254/105
[51] Int. Cl. B66f 7/12,
B66f 1/00
[50] Field of Search 254/89 H,
93, 105, 106, 107; 52/115, 123, 126

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ABSTRACT: Apparatus for raising a building formed of a plurality of modular units. Each module raising unit comprises a rigid, stationary framework supporting a plurality of movable trusses which are raised and lowered relative to the stationary framework by means of a plurality of jacks. The jacks act on the upper portions of the movable trusses, and a principal function of the stationary framework is to provide support for the movable trusses to guard against side forces resulting from wind thrust imposed upon the building during its erection. Preferably, a plurality of hydraulic jacks is employed, but an auxiliary system of mechanical, screw-type jacks is also provided together with an associated followup system to provide support in the event of any failure in the hydraulic system. A supporting structure which includes a plurality of rails is also provided and may be mechanically coupled to each module raising apparatus. Each module may then be equipped with a plurality of flanged wheels which are adapted to ride on the aforementioned rails so that each module may be placed on the supporting structure with the wheels thereof resting upon the rails and with the module then being rolled into place upon the jacking apparatus.





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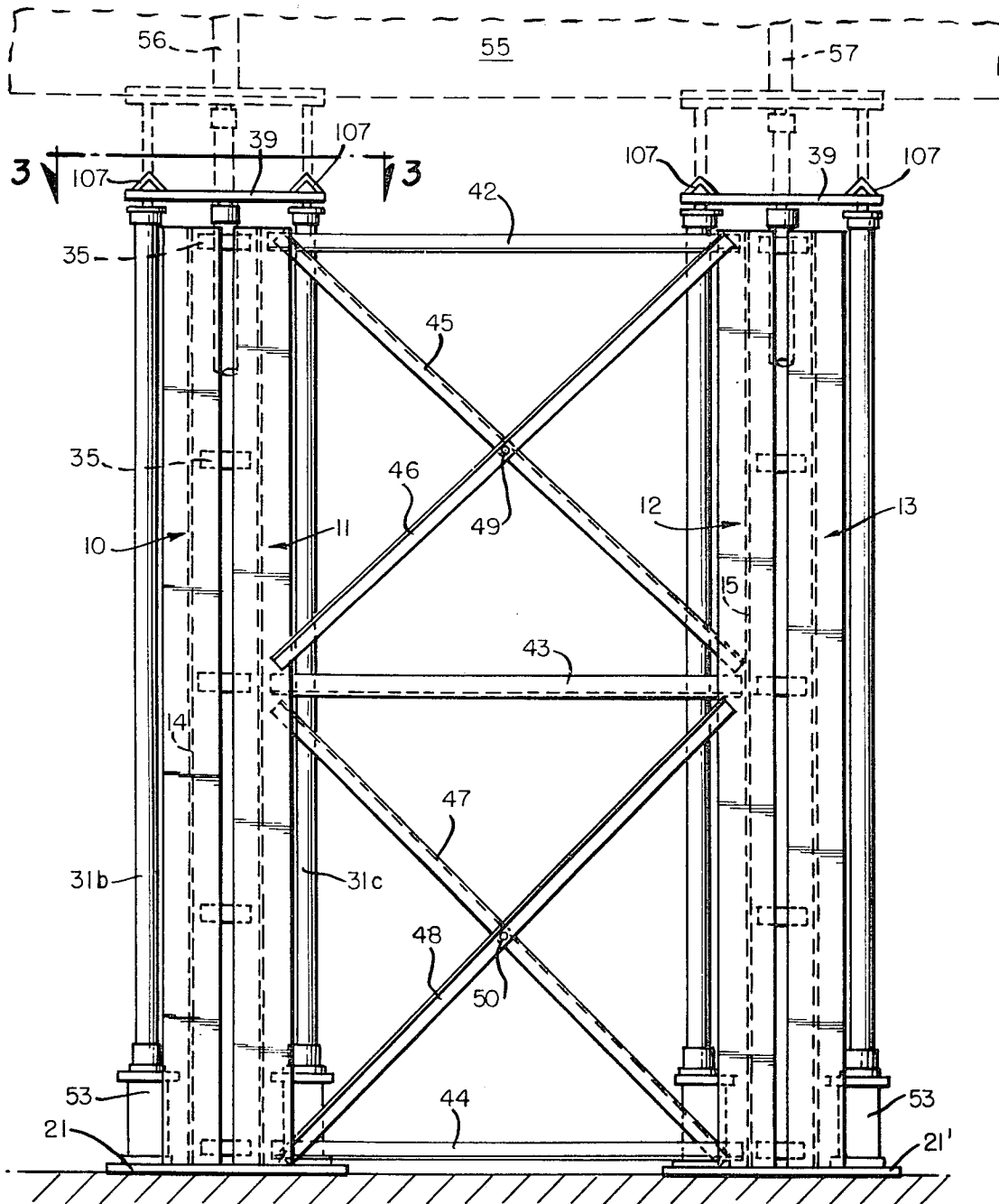


FIG. 2.

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FIG. 3.

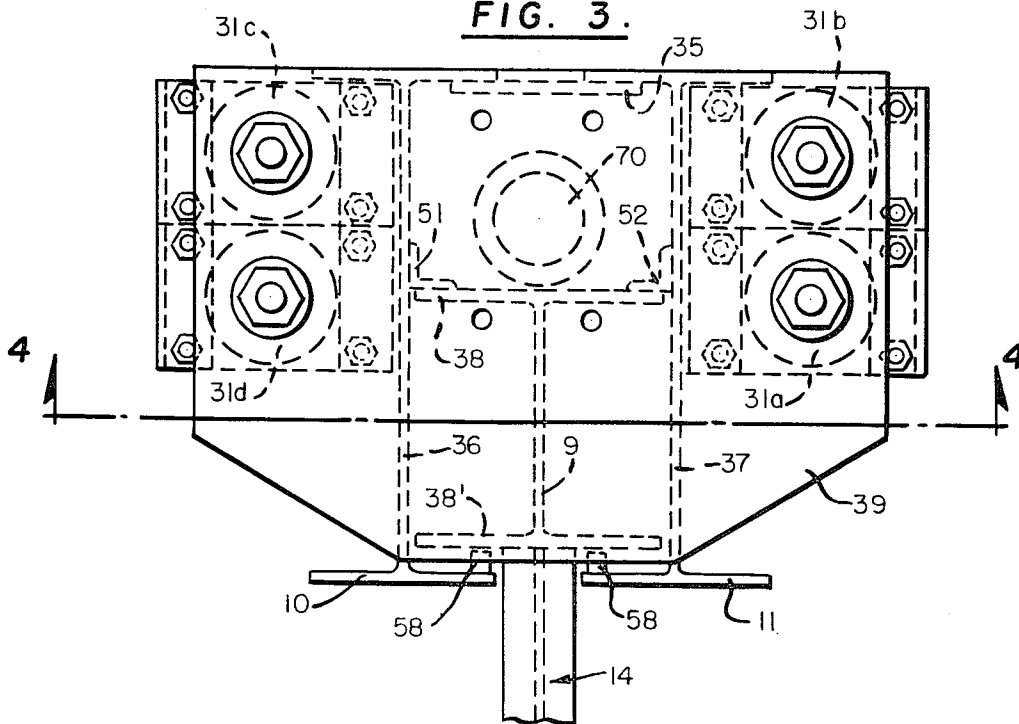
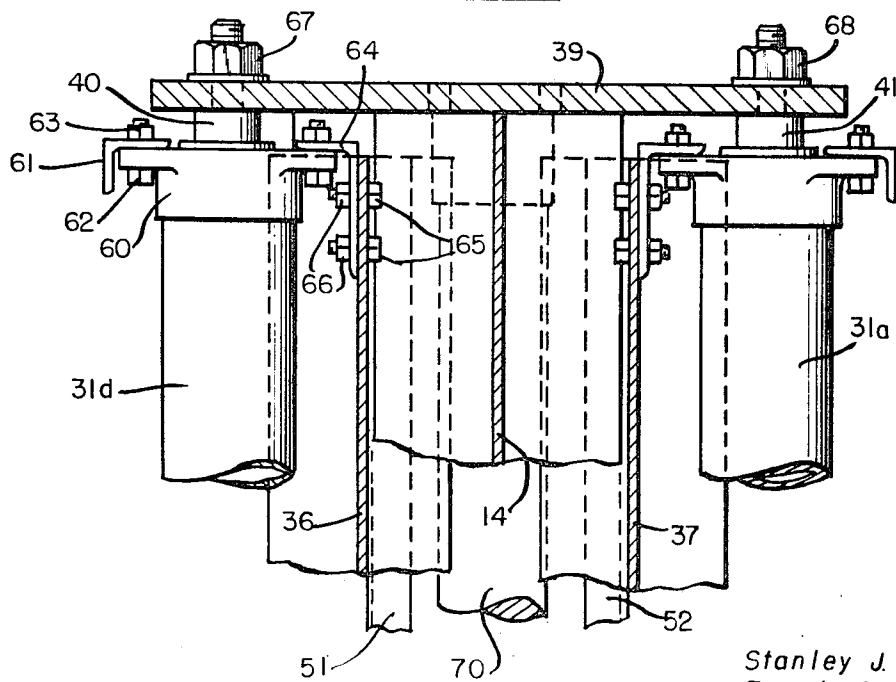


FIG. 4.



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FIG. 5.

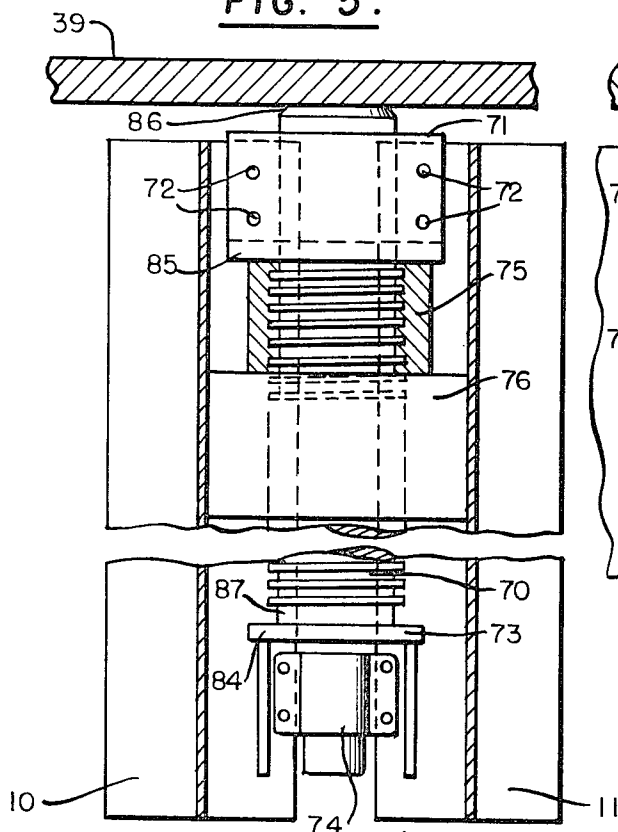


FIG. 5A.

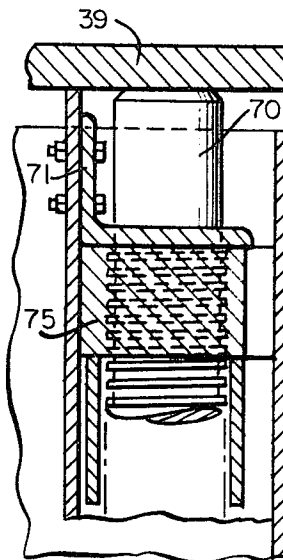
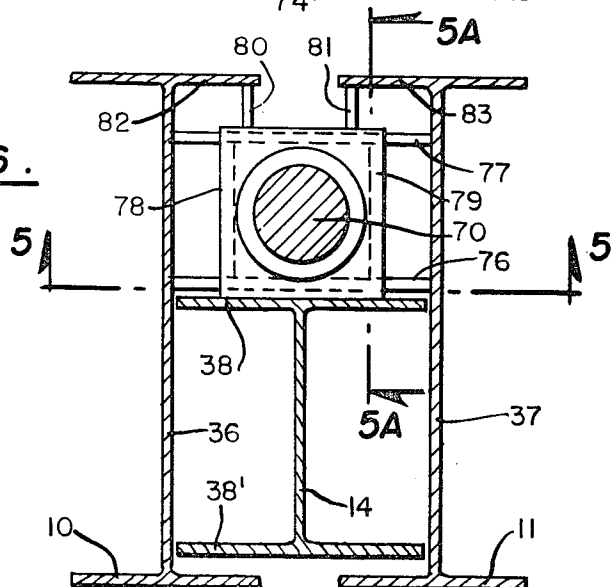


FIG. 6.



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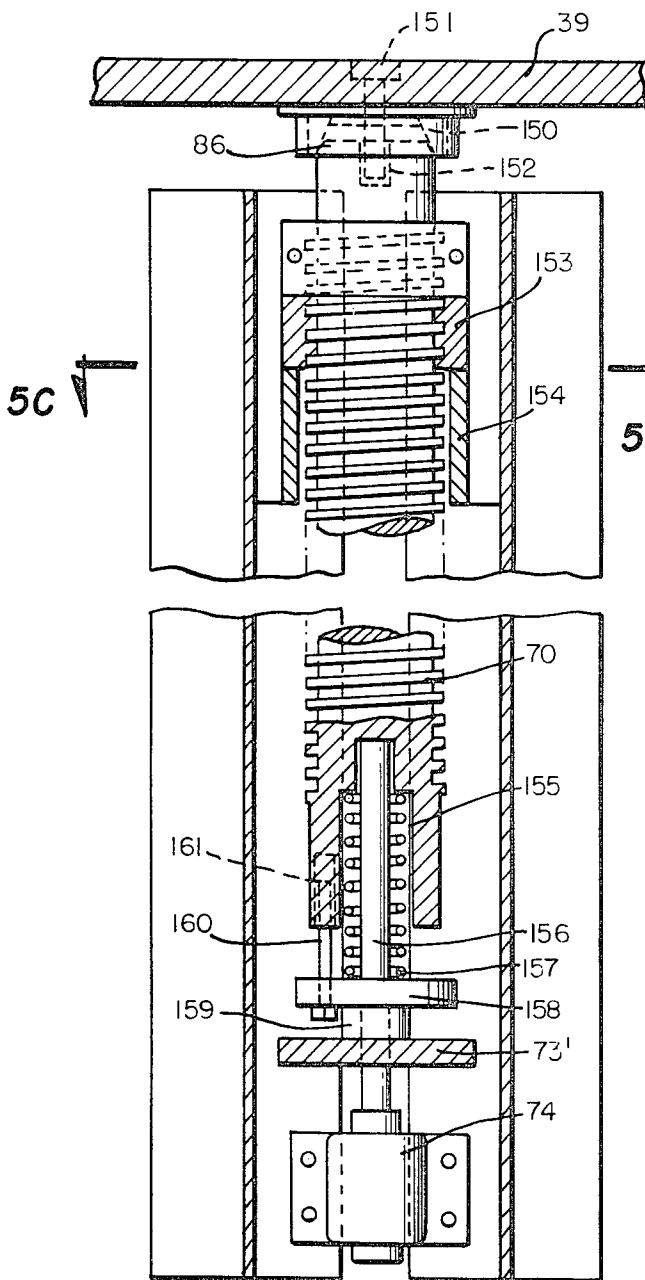


FIG. 5B.

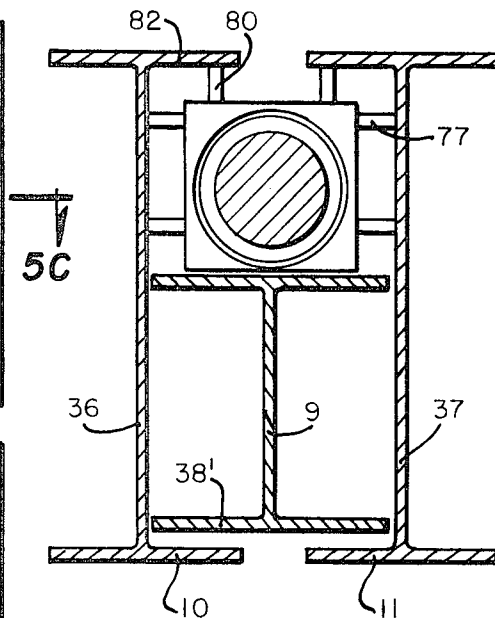


FIG. 5C.

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FIG. 7.

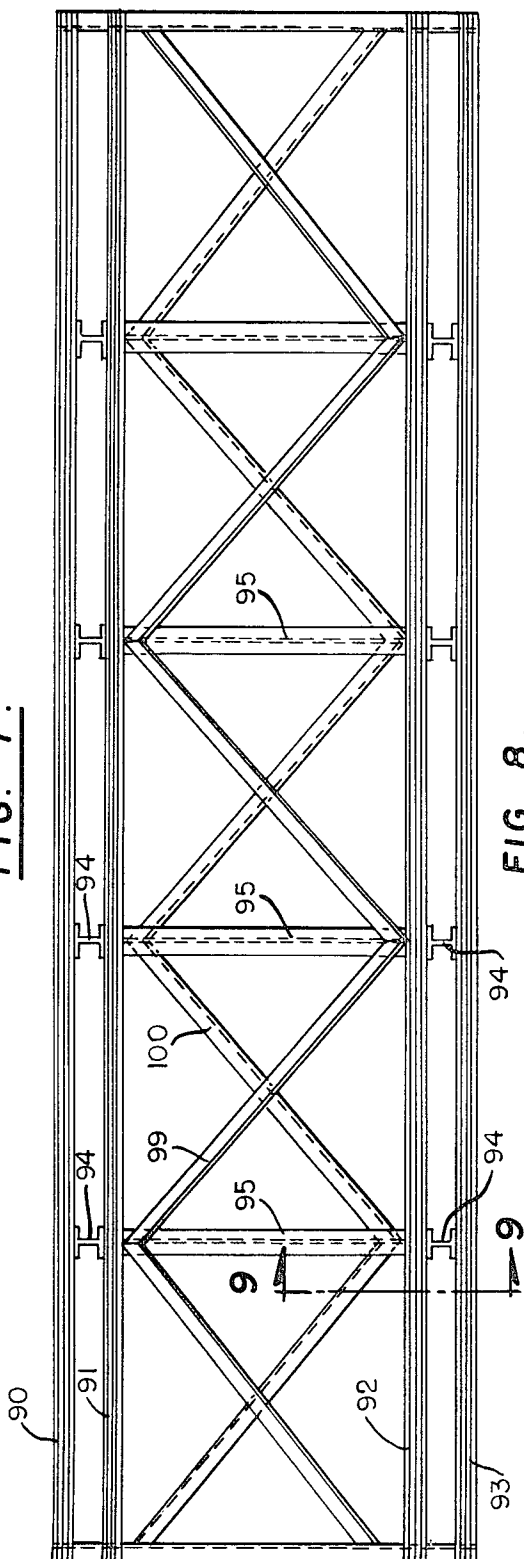


FIG. 8.



FIG. 9.

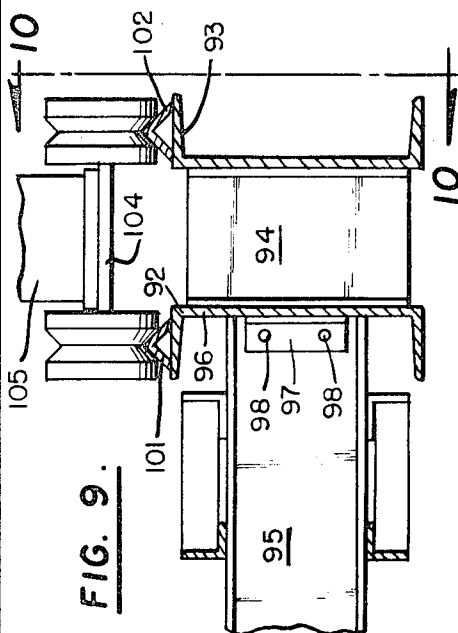
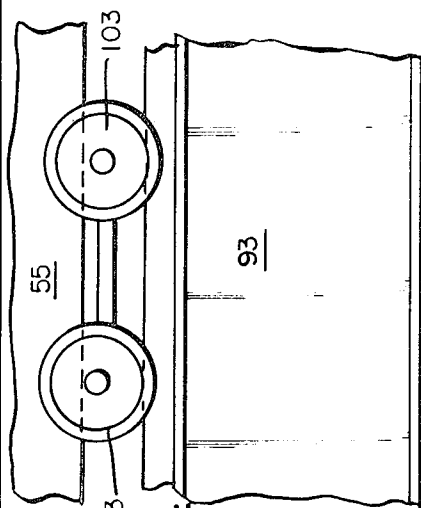


FIG. 10.



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FIG. 11.

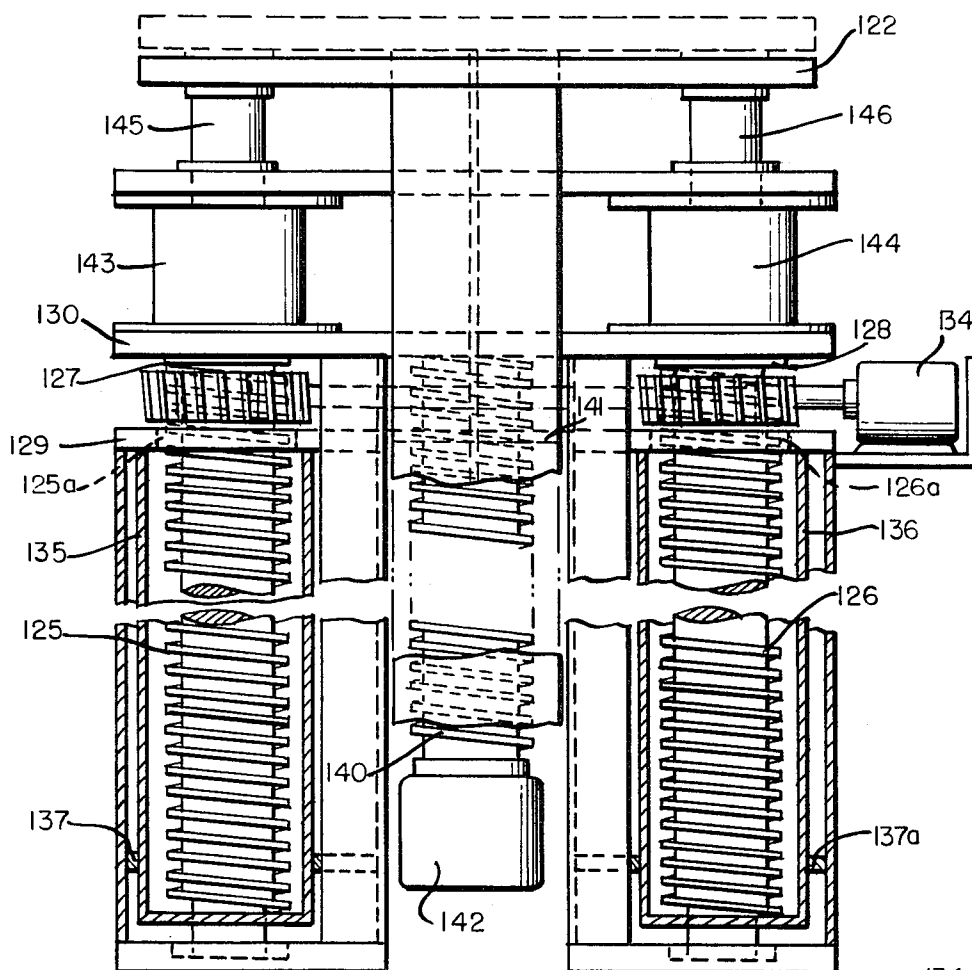
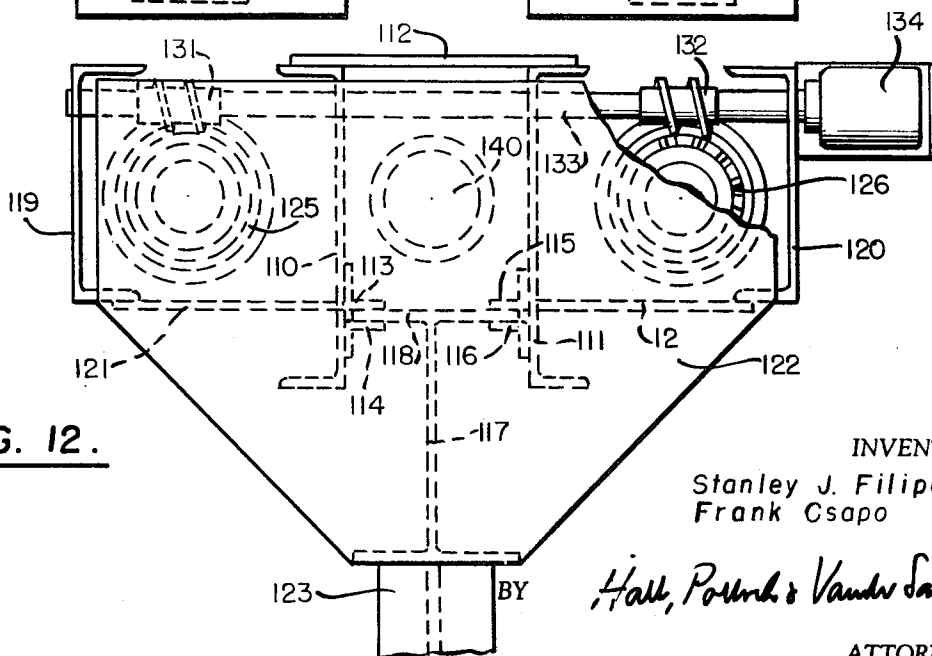


FIG. 12.



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MEANS FOR RAISING BUILDING OF MODULAR CONSTRUCTION

BACKGROUND OF THE INVENTION

In our copending application Ser. No. 5,296, filed Jan. 23, 1970, for Method of Erection of High-Rise Building Structures Formed of Modular Units, we have set forth some of the factors demonstrating the necessity of evolving improved methods of building construction. We have set forth therein the inefficiencies of constructing buildings by essentially the same methods as were used 50 and more years ago and have pointed out that most of the disadvantages of the present methods of building construction can be overcome by factory construction of modules which are quickly assembled into completed units on the building site. In the prior application, we have also pointed out that for various reasons the modular type of construction has heretofore been limited to completed buildings of only a very few stories in height but that there is a real need to be able to adapt the basic concept of modular construction of buildings to high-rise units as well, and in the aforesaid pending application, we have disclosed a novel method of erecting high-rise buildings of numerous stories, i.e., as much as 20 or more stories if desired. In the method disclosed there, the building is constructed by assembling first the modules which form the top story of the building, after which this entire top story is raised to the second-story level, at which time additional modules are inserted at spaced intervals underneath those constituting the top story, and with the two top stories then raised by the height of another story, and so on until the building is complete.

In our copending application Ser. No. 5,281, filed Jan. 23, 1970, for Modular Unit for High-Rise Building, we have disclosed a typical modular unit for use in constructing a building according to the method of the aforesaid application Ser. No. 5,296.

In both of the aforesaid pending patent applications, reference has been made to a combination supporting structure and jacking means which is capable of raising a module placed thereon and, as will be evident from the specification of the first-mentioned copending application Ser. No. 5,296, the jacking means must have a lifting capacity of sufficient magnitude so as to be able, in fact, to support and lift the weight of a number of modules rather than merely one, i.e., the weight of twice as many modules as there are stories in the building. The present application is concerned particularly with the construction and arrangement of parts of the combined supporting means and jacking means.

SUMMARY OF THE INVENTION

The present invention discloses a combination of supporting means and jacking means for raising one or more building modules by at least the height of a single story of the building. The jacking means comprises a rigid and suitably braced supporting means together with a plurality of movable trusses parts of which actually support the load of the modules placed thereon. A plurality of jacks is included in the combination, and each of these jacks has one portion thereof secured to the fixed structure and another portion thereof which is secured preferably to the top of one of the movable trusses. As a consequence of this arrangement, the opposing loads formed, respectively, by the weight of the modules on top of the movable trusses and the upwardly exerted forces of the jacking means are all concentrated along the upper portions of the movable supports and there is substantially little stress placed upon the various supporting and bracing members which comprise the rest of the movable trusses. Consequently, the various cross braces and supports forming the remainder of each of the movable trusses are readily capable of withstanding the quite considerable loads which may be imposed upon the supporting and jacking means as a result of wind forces.

The combined supporting and jacking means of this invention further includes a means to provide a fail-safe support of the load being carried and raised thereby in the event of any

failure in the hydraulic system. Thus, as will be described, a screwjack followup system is employed which carries no significant portion of the load of any module but is always available to support the load in the event that there is any failure of any of the jacks.

It will be appreciated that the modules used in the construction of a high-rise building are each of considerable size and weight, and therefore one of the problems involved in building a high-rise building of such modules is that of placing each module in its desired position relative to the other modules so that they can be coupled together to form an integral assembly comprising a floor of the building. The present invention contemplates the provision of a supporting structure which can be positioned exteriorly of the building foundation and which will support a plurality of track rails upon which each module can be placed. Preferably, each module is provided with a plurality of supporting wheels, thereby making it possible for the module, when placed upon the aforesaid supporting unit, to be rolled in place on top of one of the combined supporting and jacking means.

BRIEF DESCRIPTION OF THE DRAWINGS

In describing the invention, reference will be made to the accompanying drawings in which:

FIG. 1 is a side elevation view of a combined supporting and jacking means of the invention showing the movable trusses partially elevated with reference to the fixed support;

FIG. 2 is an end view of the apparatus of FIG. 1;

FIG. 3 is a plan view taken along the line 3—3 of FIG. 2;

FIG. 4 is a cross-sectional view taken along the section line 4—4 of FIG. 3;

FIG. 5 is a detailed cross-sectional view illustrating the arrangement of the parts of the followup screwjack system of the invention and is taken along the section line 5—5 of FIG. 6;

FIG. 5A is a detailed cross-sectional view taken along the section line 5A—5A of FIG. 6;

FIG. 5B is a detailed cross section of an alternative embodiment of the invention;

FIG. 5C is a detailed cross-sectional view taken along the section line 5C—5C of FIG. 5B;

FIG. 6 is a detailed cross-sectional view illustrating the manner of connection of the sleeve of the auxiliary or followup jacking arrangement to the jackscrew;

FIG. 7 is a plan view of a movable supporting structure adapted to facilitate the placement of a module in the desired position on top of a respective one of the supporting and jacking means of this invention;

FIG. 8 is a side view of the movable supporting structure of FIG. 7;

FIG. 9 is an end view of the apparatus of FIG. 7 illustrating the manner of support of a typical module on the movable supporting structure;

FIG. 10 is a side view of the apparatus of FIG. 9 illustrating the module and the wheels attached thereto supported on the rails of the supporting structure of FIG. 7;

FIG. 11 is a cross-sectional elevational view of an alternative jacking arrangement such as might be used at each corner of the module supporting and jacking apparatus; and

FIG. 12 is a plan view of the alternative embodiment shown in FIG. 11.

DETAILED DESCRIPTION OF A FIRST EMBODIMENT

FIG. 1 is a side elevational view of a typical one of the module-supporting and jacking means of the present invention, and FIG. 2 illustrates a side elevational view of the same apparatus. From FIGS. 1 and 2 it will be apparent that the apparatus is generally in the form of a rectangular parallel piped, comprising in effect two pairs of fixed and rigid support trusses 10, 11 and 12, 13. Between each of these pairs of trusses there is located a movable truss, with the movable truss 14, for example, being located between the pair of stationary trusses 10 and 11, and with the movable truss 15 being

similarly located between the stationary trusses 12 and 13. Each pair of stationary trusses acts as a guiding and supporting means for the associated movable truss as will be more fully described hereinafter.

Each stationary truss comprises a columnar I-beam at each end as exemplified by the I-beams 16 and 17 in FIG. 1 for the stationary truss 10. The I-beams 16 and 17 are interconnected by a top chord member 18 and by a bottom chord member 19, with the top and bottom chord members being bolted or welded to the respective I-beams 16 and 17. Each I-beam 16 and 17 is also welded to a bottom supporting plate designated as plate 20 for beam 16 and plate 21 for beam 17. These plates aid in coupling together the I-beams included in the stationary trusses at the respective corner and also provide a means for rigidly securing the entire structure to the foundation diagrammatically illustrated in FIG. 1. To provide a rigid structure, each truss is provided with a plurality of diagonal bracing members. Thus, the diagonal bracing members 22 and 23 interconnect the top and bottom chord members 18 and 19 over the left half of the stationary truss 10 shown in FIG. 1, and similarly diagonal bracing members 24 and 25 provide diagonal bracing between the same top and bottom chord members 18 and 19 over the right-hand half of the stationary truss 10. Each pair of diagonal bracing members is joined at their intersection by a suitable fastening means such as, for example, the bolt or rivet 26 which interconnects the bracing members 24 and 25 at their intersection. The top and bottom chord members 18 and 19 are additionally interconnected by the vertical bracing member 27 situated along the midlength of the stationary truss 10.

FIG. 1 shows the movable truss 14 in its fully retracted position in solid line and also shows the movable truss 14 in a partially raised position in dotted line. FIG. 1 also shows that there are a plurality of jacks at each corner of the supporting and jacking means, and two of these jacks 28 and 29 are shown at the left-hand end of the structure of FIG. 1, and two similar jacks 31a and 31b are shown at the right-hand end.

FIGS. 2 and 3 particularly illustrate the manner in which the various structural components forming a corner support of the combined supporting and jacking means of the present invention are assembled. Thus, the columnar I-beams 10 and 11 shown in FIG. 2 are also shown in cross-sectional plan view in FIG. 3 and are, moreover, shown as being coupled together at intervals along their length by spaced straps 35, each of which is either bolted on or welded to the flanges of the respective I-beams. The spacing between the respective webs 36 and 37 of I-beams 10 and 11 is chosen to be only very slightly greater than the width of the flanges 38, 38' of the I-beam 9 forming a part of the movable truss 14. Welded to the top of I-beam 9 is a supporting plate 39 which is directly coupled to the rods 40 and 41 forming an extension of the pistons of the hydraulic jacks 31a and 31d shown in both FIGS. 3 and 4. The upper end of each rod 40 and 41 is of reduced diameter and threaded, and the threaded portion passes through a corresponding aperture in plate 39 so that plate 39 is supported by the shoulders formed on the rods 40, 41. Nuts 67 and 68 threadably engage with the threaded ends of rods 40, 41.

FIG. 2 illustrates also the manner in which the respective pairs of stationary trusses are coupled together by means of horizontally extending cross braces 42, 43, and 44 and also by means of diagonal cross-bracing members, a pair of which, 45 and 46, is connected by welding to the opposed I-beam members 11 and 12 over the upper half of such members, and with similar diagonal cross-bracing members 47 and 48 being coupled between the same I-beams 11 and 12 over the lower half of such members. Preferably, the cross-bracing members 45 and 46 are secured together at their intersection by a suitable bolt 49 or rivet, and a similar connection is provided by a bolt 50 or the like to couple together the two crossmembers 47 and 48.

Referring to FIG. 3, the two I-beams 10 and 11 have angle plates 51 and 52, each of which has a flange thereof welded to a respective one of the I-beam webs 36 and 37, and with the

other flange of each member providing a sliding support for the flange 38 of I-beam 9 included in the movable truss 14. Sliding supports for the other flange 38' of I-beam 9 is provided by members 58 which are preferably welded to the inside of the flange of I-beams 10 and 11.

Referring again to FIG. 2, it will be noted that the various hydraulic jack members are all supported upon suitable platforms such as the platform 53 provided for hydraulic jack 31b. Such a platform may be provided where the length of an available jack in its retracted state does not exactly equal the intended height of the stationary truss.

In the above-mentioned copending application Ser. No. 5,281, we have illustrated a typical building module for a high-rise building and have shown that such module preferably is provided at each end with a pair of columnar I-beams which extend the full height of the module. Dimensionally, the supporting and jacking apparatus of this invention is so related to the module that each supporting plate 39 is disposed so as to exactly underlie a respective one of the columnar I-beams on the module when the module is suitably positioned upon the supporting and jacking means of the invention. This concept is clearly illustrated in FIG. 2 wherein the module is shown diagrammatically at 55, and two of the columnar I-beams 56 and 57 of such module are shown as being positioned directly atop the respective supporting plates 39 and 39'. It is to be understood that the length of the supporting jacking means of the present invention as shown in FIG. 1 is also so arranged relative to the length of the module that the two other columnar I-beams at the remote end of the module will similarly be positioned directly atop the supporting plates 39 at the far end as well.

It is, of course, possible to provide a single hydraulic jack at each corner of the supporting and jacking apparatus of this invention. However, it must be remembered that the loads to be lifted are of a high order and it is for this reason believed preferable, from the standpoint of economy, to provide a plurality of hydraulic jacks at each corner of the structure rather than a single one. It is for this reason that four hydraulic jacks 31a-31 are shown in FIG. 3.

FIGS. 3 and 4 also illustrate the manner in which the jacks are interconnected and secured to the stationary and movable trusses. More specifically, each jack is provided with a collar 60 at its upper end which collar is secured to the jack cylinder, and the collars of the two jacks on each side of the movable truss are rigidly interconnected by means of angles 61 which are joined by bolts 62 and mating nuts 63. A similar bracket 64 is provided along the inner edge of the two adjacent hydraulic jacks, i.e., adjacent the web 36 of I-beam 10 to thereby facilitate the intercoupling of the two jacks 31c and 31d and also provide for their rigid connection to flange 36 by means of bolts 65 and nuts 66.

It should be particularly noted that the lower ends of the various jacks bear directly upon the base plates 20, 21, etc., (see FIG. 1) and that the upper end of the extensible portion of each jack is directly coupled to plate 39 which is welded to the upper end of I-beam 9 included in the movable truss 14. By reason of this arrangement, when a module is being lifted by the apparatus of the invention, it will be apparent that the downward force resulting from the weight of the module is transmitted directly to the various plates 39 and that the upward force of various jacks is also directed onto the plates 39 in the opposite direction with the result that substantially no portion of the load of the module is borne by the columnar I-beams 9 included in the movable truss 14 nor by the various components constituting the supporting members for the stationary trusses. As a result, the various supporting members of both the stationary and movable trusses are relatively unstressed by reason of the downward weight of the module and are therefore capable of fulfilling their primary function which is to resist bending moments which may particularly result from the exertion of wind forces against the building as it is being constructed. Only a relatively small dimensional tolerance is provided between the I-beam 9 and the space pro-

vided for such I-beam between the stationary trusses so that effective sliding movement is readily permitted between the movable truss and the stationary trusses but with exception supporting strength being provided to counteract any laterally imposed forces tending to result in bending moments being applied to the supporting and jacking apparatus.

In the raising of a heavy load by an appreciable height, it is of course most important to ensure that even in the case of failure of any part of the system, the load will still be adequately supported. It is for this reason that the supporting and jacking apparatus of this invention includes a mechanical followup system which, although not capable of raising a heavy load such as a module, is nevertheless fully capable of supporting the full load imposed on the supporting and jacking apparatus in the event of a failure of any one or combination of jacks. This followup apparatus is disclosed in FIGS. 3 and 4 diagrammatically and represented by the reference character 70 which denotes a screw support for the load. Such screw support, it will be noted, is located directly at the center of the supporting system at one corner of the supporting and jacking apparatus of the invention. Thus, the screw support 70 is located in line with the web of I-beam 9 of the movable truss and is also symmetrically disposed relative to the four hydraulic jacks 31a-31d. By reason of the centralized support thus made possible, the single screw support 70 is able to support the load fully in the event of failure of the hydraulic jacking apparatus without having any significant bending moments applied to the component parts of the corner load-supporting structure in the event that the screw support 70 is called upon to carry the full load. Such central positioning of the screw supports 70 is possible because it is comparatively easy to position the columnar I-beam 9 in a position where it is displaced from the center of the system. Thus, it will be seen in FIG. 3 that the I-beam 9 has its center of gravity well forward of even the innermost of the hydraulic jacks 31a and 31d; of course, the reason why this can be done is that the I-beam 9 does not, in any event, carry the load of the building modules as has already been described.

The auxiliary supporting means is particularly disclosed in FIGS. 5 and 6. The screw 70 which extends substantially along the full height of the movable truss 14 is secured at its top and bottom ends to the movable truss. Bracket 71 supports the screw 70 at its upper end and with the unthreaded upper end of screw 70 being freely rotatable in bracket 71. Bracket 71 is secured to the movable truss by means of bolts passing through apertures 72 into the flange of columnar I-beam 9.

Similarly, screw 70 is freely rotatable in a bracket 73 which is also secured to I-beam 9 of the movable truss 14. A relatively low-powered motor 74 engages with the lower end of screw 70, and motor 74 exerts a slight turning torque on screw 70 at all times during a jacking operation. The torque exerted on screw 70 is merely sufficient to turn the screw in brackets 71 and 73 and is by no means sufficient to exert any appreciable lifting force to any load supported upon upper plate 39.

The upper threaded portion of screw 70 engages with the interior threads on a socket 75 which may be of generally annular cross section. Sleeve 75 is supported upon a framework of members which are rigidly secured to the columnar I-beams 10 and 11 which are included in the stationary trusses. Thus, plate 76 is positioned between the webs 36 and 37 of I-beams 10 and 11 and welded thereto, and a similar plate 77 is also welded between the webs 36 and 37 but spaced from the plate 76. A pair of additional plates 78 and 79 is welded between the cross plates 76 and 77, and together these four plates 76-79 provide a strong and rigid support for the socket 75, thereby providing the capability of handling a very substantial downward load exerted by screw 70, through socket 75, to the aforementioned members 76-79. Additional support is provided by means of a pair of short connecting plates 80 and 81 which are welded between the flanges 82 and 83 of I-beams 10 and 11 to the cross plate 77.

The threaded portion of screw 70 has a length which is very slightly less than the distance between the upper edge 84 of

bracket 73 and the lower edge 85 of bracket 71. As the various hydraulic jacking members raise the load by exerting upward forces against the bottom surfaces of the various plates 39, the constant torque exerted by motor 74 on screw 70 causes the screw 70 to turn in socket 75 thereby changing the axial position of the screw 70 relative to socket 75 and thereby permitting the upper end of 86 of screw 70 to bear continuously against the lower surface of plate 39. The speed of rotation of screw 70 in socket 75 is sufficient to ensure that, for the maximum speed of elevation of plate 39 in response to the operation of the hydraulic jack, the upper end 86 of screw 70 can adequately follow and thus remain in contact with lower surface of plate 39. Accordingly, in the event of any failure in the hydraulic jacking system, the load being supported by the various plates 39 is then exerted through the screws 70 to socket 75 and thence through the various supporting plates 76-81 to the fixed truss I-beams 10 and 11.

Under the conditions described, and assuming that the hydraulic jacking arrangement is inoperative, it will be apparent that the torque continually exerted on screw 70 by motor 74 has attempted to rotate screw 70 so that its upper surface 86 is in contact with the lower surface of plate 39 and accordingly there will be a slight gap between the lower threaded portion 87 of screw 70 and the upper surface of bracket member 73 since, as mentioned previously, the threaded portion of screw 70 is slightly less in length than the distance between the bearing surfaces on the upper and lower surfaces 73 and 85 of brackets 73 and 71. If now, however, the hydraulic jacking system again become inoperative to raise plate 39, it must be remembered that bracket 73 will rise also since both bracket 73 and plate 39 are rigidly secured to the movable truss. Bracket 73 is now free to move upwardly before coming into contact with the lower surface 87 of the threads on screw 70 because of the aforementioned gap, and with this upward movement of the movable truss, all load is removed from the screw 70 and a slight gap then appears between the upper surface 86 of screw 70 and the lower surface of plate 39 so that the screw can now again rotate relative to socket 75 in response to the torque exerted on screw 70 by motor 74. Screw 70 thus again follows the upward movement of plate 39 and stops as soon as contact is made between the upper end of screw 70 and the bottom surface of plate 39 since the resulting axial force against the screw will prevent the screw from being turned by the low-powered motor 74. It will, of course, be readily appreciated by one skilled in the art that the pitch of the threads on screw 70 is purposely selected to be only slightly inclined so that any large axial loads on the screw 70 will not induce rotation of screw 70 relative to sleeve 75.

Detailed Description of Alternative Jacking Apparatus— FIGS. 5B-5C

The previously described apparatus has proved to be entirely satisfactory, particularly in those instances where the various parts can economically be made to relatively close tolerances. More specifically, if a quite close tolerance can be provided for the I-beam 9 of movable truss 14 within the space provided therefor by the fixed truss members, then these members can remain accurately aligned vertically during the raising of the load and no problems result. However, in using structural steel members, it often happens that there are variations in dimensions of such members, and for this reason it is often more practical to provided for a somewhat looser fit between the members. When this is done, a wind load on the modules being raised may, for example, cause some slight misalignment of the members during the lifting operation and, when this occurs, it has been found that there may be some restrictions to easy rotation of the supporting screws 70, thereby resulting in an inability of the supporting screw to follow the upward movement of the movable truss relative to the fixed truss and thereby maintain support for the plate 39.

Referring to FIG. 5, if the screw 70, for example, is caused to assume a slightly skew position, one result may be that the upper end 86 of screw 70 will contact the bottom surface plate 39 along a peripheral portion rather than bear directly and firmly over its entire upper surface against plate 39. When this happens, there is then a tendency for the screw 70 to rotate eccentrically about its point of initial contact with the under-surface of plate 39. Also, although normally the weight of screw 70 is supported by socket 75, it must be remembered that screw 70 will have a considerable weight and may, for example, weigh as much as 1000 pounds or more. Because of this, there is considerable frictional force developed between the threads of screw 70 and the interior threads on socket 75, and this frictional resistance of course also inhibits rotation of screw 70 in response to operation of motor 74.

It is therefore an object of this alternate embodiment of the invention to provide apparatus which overcomes the aforementioned drawbacks so as to make it readily possible for the screw 70 to be rotated by motor 74 and thereby always maintain its upper end closely adjacent or in contact with the undersurface of plate 39.

It will be noted in FIG. 5B that, first of all, a thrust bearing 150 is provided between the upper end of screw 70 and the lower surface of plate 39. A positioning pin 151 passes through an aperture in plate 39 and extends with a sliding fit into a hole 152 bored into the upper end of screw 70. A close fit is provided between pin 150 and hole 152 so as to provide accurate positioning of the upper end of screw 70 relative to plate 39 and yet permit relative motion of these two members in the direction of the axis of screw 70. By this means, the screw 70 is laterally fixed in position relative to plate 39 and is thus not free to wander laterally as it is rotated by motor 74.

Instead of providing a single socket member corresponding to socket 75 of FIG. 5, the alternative embodiment of FIG. 5B employs two socket members 153 and 154, which may both be of rectangular cross section, placed in juxtaposition with the socket 153 on top of socket 154 and being readily movable laterally relative to the lower socket member. The upper socket member 153 threadably engages with the screw 70 in the same manner as does the single socket member 75 of FIG. 5. However, it will be noted that the upper socket 153 of this FIG. 5B is not rigidly secured to the fixed truss but is instead free to move laterally in response to lateral movement of the screw 70. The lower socket member 154 has a loose fit about screw 70 and therefore does not threadably engage with the screw 70. The lower socket member 154 is rigidly secured to the fixed truss in the same manner as is provided for the single socket member 75 of FIG. 5, and is thus supported by the plates 76-79 which are welded or otherwise fastened to the I-beams 36 and 37 comprising portions of the fixed trusses. By means of this arrangement, it will be apparent that the upper socket 153 is free to move laterally in response to lateral motion of screw 70, which lateral motion is permitted by reason of the loose fit of the lower socket member 154 relative to screw 70. The upper socket 153 is prevented from rotating in response to rotation of screw 70 by reason of the fact that its generally rectangular cross section and its dimensions prevent rotation thereof within the rectangular space provided for it between the webs and flanges of I-beams 36 and 37. At the same time, the axial load exerted by the screw 70 upon upper socket member 153 is borne by the fixed socket member 154. This arrangement tends to prohibit binding of the screw relative to the socket as may occur with the embodiment of FIG. 5.

A further modification involves the supporting of the weight of the screw 70 by means of a coiled spring. This is accomplished in order to minimize frictional forces between the screw 70 and the socket member 153. To accomplish this, a longitudinal bore 155 is provided in the lower end of screw 70, and into this bore 155 is inserted a pipe member 156 about which is placed a coiled compression spring 157. Pipe member 156 is welded or otherwise secured to a circular plate 158. Plate 158 is rotatably mounted upon a lower supporting plate

73' which otherwise generally corresponds with the lower support member 73 of FIG. 5 through a thrust bearing 159.

Spring 157 is so selected that the upward force which it exerts upon screw 70 is reasonably close to the weight of the screw itself so that, under normal conditions, there is only a minimal amount of force exerted between the threads of screw 70 and the threads of the upper socket member 153. For this reason, rotation of the screw 70 in response to operation of motor 74 will readily permit rotation of the screw relative to socket 153.

Frictional forces between plate 158 and plate 73 are minimized by the thrust bearing 159. Motor 74 has its output shaft keyed to plate 158. In order to ensure that rotation of plate 158 will also result in rotation of screw 70, one or more keying pins 160 are provided, and each such pin threadably engages with an aperture in plate 150 and extends into a hole 161 drilled into the bottom of screw 70. The pin 160 preferably has a close sliding fit in the hole 161 to thereby ensure that there can be limited axial movement of the screw 70 relative to plate 158 while still positively keying together these two elements.

Module Positioning Apparatus—FIGS. 7 and 8

The accurate positioning of a large and heavy module very accurately so that it can be coupled to other modules already in place can ordinarily be expected to present problems. It is accordingly an aspect of this invention to provide apparatus which will greatly facilitate the solution to this problem. FIGS. 7 and 8 illustrate plan and elevational views respectively of a supporting means which is intended to be positioned exteriorly of the building foundation and in line with one of the already described supporting and jacking means. A module is placed on the supporting means of FIGS. 7 and 8 and then rolled therealong and onto the top of the supporting and jacking means.

The apparatus of FIG. 7 comprises a plurality of beams situated in pairs with, for example, the channel-beams 90 and 91 being situated on one side of the supporting apparatus and the channel-beams 92 and 93 on the other side. Each pair of channel-beams is supported and kept properly spaced by means of short sections of I-beam 94 which have their respective flanges welded to the opposing webs of the channel beams. Suitable support for the structure is provided by means of lateral bracing members 95 which are preferably secured to the web 96 of channel-beam 92 by means of angles 97 which may be bolted to the web of cross I-beam members 95 by suitable bolts 98 and may be welded also to the web 96 of channel-beam 92. In addition, diagonal cross-bracing members may be employed as shown in FIG. 7 as illustrated, for example, by the diagonal bracing members 99 and 100.

As shown in FIG. 9, there is secured to the upper flange of each of the channel-members 92 and 93 a rail member 101 and 102, respectively, which rail member has a generally V-shaped cross section. Secured to the bottom of each module 55 is a plurality of wheels 103 which may be interconnected by a rigid axle 104 upon which rests a longitudinally extending beam 105 which forms a part of the module as shown, for example, in our copending application Ser. No. 5,281 referred to above.

In use, it is contemplated that the structure of FIGS. 7 and 8 will be mechanically coupled to the supporting and jacking apparatus earlier described in such manner that the various rails mounted thereon will align with corresponding rails 107 which may be welded on the top of the plate 39 forming a part of the supporting and jacking means. It is also contemplated that the apparatus of FIGS. 7 and 8 will be so positioned as to provide a slight downward grade with the lower level being at the end where the supporting structure is coupled to the supporting and jacking means. In this way, when a module provided with suitable wheel supports as in FIG. 10 is placed on the apparatus of FIGS. 7 and 8, it will then be readily possible for the module to roll slowly by gravity down the supporting structure and onto the jacking and supporting means as shown, for example, in FIGS. 1 and 2. The apparatus of FIGS. 7 and 8 can

then be readily moved to a different position so as to enable a further module to be positioned in place on a different jacking and supporting means.

Detailed Description of an Alternative Embodiment—FIGS. 11 and 12

The embodiment of the invention which has just been described employs a plurality of jacks, each of which is required to have a stroke at least equal to the overall height of a building module. Because of the long stroke of all of the jacks, it is only practical that all of the various jacks be operated concurrently in raising one or more modules. Obviously where the building is quite large, so that a rather substantial number of modules needs to be raised at one time, it is apparent that the very large number of jacks required will, when all operating, require substantial amounts of power. The previously described embodiment, although entirely practical in most instances, may therefore under certain special conditions not be entirely feasible, and it is for this reason that the alternative embodiment now to be described has been developed.

The alternative embodiment, as illustrated in FIGS. 11 and 12, shows the arrangement of the columnar I-beams for the fixed and movable trusses and the various jacks and supporting screws which may be provided at each corner of the generally parallelepiped supporting and jacking means. This alternative embodiment of the invention is characterized by its use of jacks whose stroke is only a fraction of the desired maximum load-lifting height of the jacking system.

FIG. 12 illustrates the columnar beams forming a portion of the stationary truss as being in the form of channel-beams 110 and 111 which have their respective flanges secured together at one end by a connecting plate 112 which may be bolted to the flanges. Welded to the web of a channel-beam 110 is a pair of angles 113 and 114, and a similar pair of angles 115 and 116 is welded to the web of channel-beam 111. Spacing is provided between the two angles of each pair to provide clearance for the web of a columnar I-beam 117 forming a part of the movable truss. Thus, it will be noted that the flange 118 of I-beam 117 fits with a sliding engagement between the angles 113, 114 and the similarly disposed angles 115 and 116. The flanges and web of columnar I-beam 117 forming a part of the movable truss are welded to a top connecting plate 122 which provides a support for the module being supported and raised. FIG. 12 shows a portion of an I-beam 123 which may be attached to the flange of I-beam 117 and form a part of the movable truss.

The stationary truss is also formed in part by channel-beams 119 and 120 and each of these members is coupled to the respective opposite channel-beam 110, 111 by a plurality of connecting members 121, 121a which are positioned at intervals along the length of the columnar channel-beam members and welded thereto. For example, each of the several longitudinally spaced connecting members 121 is secured to a flange of channel-beam 119 and secured also to the web of channel beam 110.

The apparatus of FIGS. 11 and 12 further includes a pair of externally threaded screws 125 and 126, each of which is freely rotatable within a respective aperture 125a, 126a defined in the plate 129 which is secured to the fixed truss member 110, 111, 119, 120. The portion of each screw 125, 126 extending below plate 129 is supported within an enclosed pipe 135, 136 which provides lateral support for the screw.

Each pipe 135, 136 may contain a suitable quantity of lubricant in its bottom portion for lubricating the respective screw 125, 126 when such screw is moved downwardly into the associated pipe. Each pipe 135, 136 is laterally supported at its bottom end by an apertured plate 137, 137a each of which is secured to the columnar member forming parts of the fixed trusses. Each screw 125 and 126 threadably engages with a respective socket member 127 and 128 which rests upon plate 29. Each of these sockets 127 and 128 is also provided with external threads which engage with a respective worm gear 131 and 132, which worm gears are keyed to a shaft 133

rotated by a motor 134. Preferably, the motor 134 is a torque motor which exerts a predetermined amount of torque upon shaft 133, with the motor stopping when the resistance to further rotation of shaft 133 is such as to exceed the predetermined torque rating of the motor. As will later be described, at times during a module-lifting operation, the motor 134 is energized and the resulting rotation of worm gears 131 and 132 causes the sockets 127 and 128 to revolve with respect to the screws 125 and 126. Since the sockets 127 and 128 are axially fixed in position upon plate 129, rotation of these sockets relative to the screw must necessarily result in axial movement of the screws 125 and 126. Rotation of the screws 125, 126 is prevented by keying each screw to either plate 129 or to the respective pipe 135, 136 to ensure thereby that rotation of the sockets will necessarily result in axial movement of the screws.

A support screw 140 is also provided, and the function of this screw is comparable to that of screw 70 in the previously described embodiment of the invention. Thus, screw 140 is secured at its upper and lower ends to the columnar I-beam 117 forming a part of the movable truss, and screw 140 is freely rotatable in brackets (not shown) which secure the screw to such I-beam 117. Also, as with the previous embodiment, the screw 140 threadably engages with a fixed, nonrotatable socket 141 which is supported relative to the fixed trusses in the same manner as disclosed in connection with FIGS. 5 and 6 of the previously disclosed embodiment. Threaded shaft 140 is coupled also to a torque motor 142 which exerts a predetermined small torque on shaft 140 during a module lifting operation, and the amount of torque exerted is sufficient to rotate screw 140 relative to socket 141 but is by no means sufficient to exert any significant lifting force on plate 122 and any module or other heavy load supported thereon.

On the plate 130 are two hydraulic jacks 143 and 144 having pistons 145 and 146 shown in the extended position. These jacks 143 and 144 are constructed to provide a predetermined stroke of the respective piston.

The embodiment of FIGS. 11 and 12 operates as follows:

It is assumed, first of all, that the jacks 143 and 144 are retracted and that the upper end of screw 140 is level with the tops of the two jacks as well. The first step in the lifting operation is to raise both of the jacks simultaneously, and when each jack 145, 146 has been raised by the amount of its full stroke, each jack ceases further operation. Throughout this lifting operation, motor 142 has been exerting a small torque upon screw 140 and thereby rotating screw 140 relative to fixed socket 141. As a result, screw 140, which is axially fixed relative to the movable truss, has moved relative to socket 141 which is fixed relative to the stationary trusses so that the upper end of screw 140 is maintained in contact with the undersurface of supporting plate 122. In this connection, the speed of rotation of shaft 140 is sufficiently great relative to the rate of extension of the jacks 143, 144 to ensure that the upper end of screw 140 will remain in contact with the lower surface of plate 122; however, as will be remembered, screw 140 cannot exert any appreciable lifting force on plate 122 because of the limited torque exerted by motor 142.

The apparatus is now in the condition where the jacks are fully extended and the load is capable of being supported by screw 140. At this time, the pistons 145, 146 of jacks 143 and 144 are fully retracted. The next step is for the motor 134 to be energized so as to rotate worm gears 131 and 132. This results in rotation of the rotatable sockets 127 and 128, thereby raising screws 125 and 126 to a level where the upper end of the pistons 145 and 146 of the two jacks come into firm contact with the under surface of plate 122. When this occurs, the predetermined torque of motor 134 is exceeded so that this motor becomes deenergized. It will now be apparent that the previously described sequence of steps can again take place with the load being raised by another increment equal to the stroke of the two jacks 143 and 144.

It will also be apparent that this embodiment offers several significant advantages. Thus, it is possible to raise the load by only a small increment for each cycle of operation, and this

makes it possible to raise each corner of the supporting and jacking means of the invention individually rather than requiring that all four corners of each and every supporting and jacking means be operated concurrently. More specifically, when a number of long stroke jacks is used, it is necessary that the jacks be all synchronized during any lifting operation so that no excessive stresses will be applied to any module. However, by using short stroke jacks, e.g., jacks having a stroke of only a fraction of an inch, it is possible to neglect the lack of synchronization among the various jacks during each lifting cycle and then compensate for any discrepancies when the cycle is completed and before the next successive cycle is started. For this embodiment, therefore, the length of the stroke of each jack is preferably selected so that no excessive stress will be imposed upon any module even under the most unfavorable conditions as, for example, when all the jacks but one raise the modules by the full amount of their stroke but with the one jack not being operated at all. Of course, the principles of this invention apply equally well to systems where jacks of longer stroke are used and means is employed to ensure that the action of the various jacks in the system is properly synchronized.

Also, although the apparatus of FIGS. 11 and 12 is shown as including torque motors 134 and 142, it will be apparent that where power sources are limited, it is readily possible to provide the required rotation of the various screws manually instead of by motors, and it is also possible to operate the hydraulic jacks 143 and 144 manually. Thus, this embodiment of the invention particularly renders itself to use in areas where power sources are unavailable.

This alternative embodiment also has an advantage over the use of an electrical jacking means. Thus, electrical jacks employing threaded screws must necessarily be constructed to extremely close tolerances in order that friction will be minimized, and this requirement necessarily increases very substantially the cost of electrically operated jacks. With the present invention, in contrast, there is no need to construct the screws 125, 126 to exceptionally close tolerances since these are raised by operation of motor 134 only at such time that there is no significant load thereon. Consequently, the matter of frictional losses is of minor significance and for this reason it is of no great importance that the screws 125 and 126 and particularly the threads thereon be constructed to close tolerances.

What we claim is:

1. Apparatus for supporting and elevating at least one building module by a height at least equaling the overall height of the module comprising in combination,

said apparatus having a generally rectangular parallelepiped configuration and including at each corner thereof a load carrying and raising means,

said means comprising a rigid vertical fixed support structure securely fastened to a base support and a rigid movable support which is vertically slidable relative to said fixed support structure,

at least one jacking means operatively connected to each said movable support in such manner that any upward force exerted thereon is exerted adjacent the upper end of said movable support,

each said fixed support structure providing lateral support for the associated movable support even when the movable support structure is in its fully extended position.

2. The apparatus of claim 1 wherein each said fixed support structure comprises a pair of longitudinally parallel vertical I-beams whose corresponding flanges are coplanar, the cross-sectional cavity formed at least in part by the opposed webs of said I-beams defining a cavity for slidably receiving said movable support structure.

3. The apparatus of claim 2 wherein said movable support comprises an I-beam.

4. The apparatus of claim 1 wherein at least one cross support member connects each fixed support structure with the corresponding fixed support structure at an adjacent corner.

5. The apparatus of claim 4 which further includes an auxiliary support means for supporting said modules in the event of failure of said jacking means, said auxiliary support means comprising for each corner of said apparatus a first part connected to said fixed support structure and a second part connected to said movable support, and means responsive to the movement of said movable support relative to said fixed support structure for varying the relative positions of said first and second parts, a portion of said second part of said auxiliary support means extending to a position substantially coplanar with the top of said movable support, whereby said second part is at all times in contact with the load supported by said movable support and is capable of supporting said load in event of a fault in said jacking means.

6. The apparatus of claim 5 wherein said second part comprises a threaded shaft rotatably secured at each end to said movable support and said first part comprises a socket rigidly secured to said fixed support structure and threadably engaging with said shaft, and means for exerting a torque on said shaft in a direction to raise said shaft relative to said socket as said movable member is raised by said jacking means.

7. The apparatus of claim 6 in which said shaft is provided with threads of sufficiently flat inclination relative to a plane perpendicular to its axis to prohibit turning of said shaft relative to said socket for any load expected to be raised by said movable support.

8. The apparatus of claim 6 wherein said threaded shaft is secured to said movable support at its opposite ends by first and second brackets, said shaft being fully rotatable in said brackets and being longitudinally movable a short distance between said brackets.

9. Apparatus for lifting a load comprising in combination,
at least one fixed vertical support member,
at least one vertically movable support member in sliding engagement with said fixed member,
at least one jacking member for raising said movable member relative to said fixed member,
auxiliary support means for supporting the load and including an extensible member normally in position to support the load,
and means responsive to the raising of said movable member for extending said extensible member to maintain it at all times in position to support the load.

10. The apparatus of claim 9 in which said auxiliary support means comprises a threaded screw and a fixed socket which engages with the threads on said screw, said socket being rigidly secured to said fixed support and said screw being rotatably secure to said movable support, and means for continuously applying a torque to said screw during the raising of said load by said jacking means.

11. The apparatus of claim 10 in which the torque exerted on said screw is sufficient to turn said screw only in the absence of any substantial axial loads between said screw and said socket.

12. The apparatus of claim 9 in which said jacking means comprises a jack having a maximum extension substantially less than the height over which said load is to be raised and an extensible member connected to said fixed support and providing a platform for said jack.

13. The apparatus of claim 12 in which said extensible member comprises a threaded screw in threaded engagement with an internally threaded rotatable socket, said rotatable socket being axially secured to said fixed support.

14. The apparatus of claim 13 wherein said rotatable socket is also provided with exterior threads, and gear means engaging said socket for at times rotating said rotatable socket to vary the axial position of said threaded screw relative to said rotatable socket.

15. The apparatus of claim 14 which also includes means for exerting a predetermined maximum torque on said gear means.

16. The apparatus of claim 9 in which said jacking means includes at least one jack having a maximum stroke which is

only a small fraction of the required load-lifting height of said jacking means,

means for securing each said jack to said fixed member, said securing means permitting adjustment of the vertical position of said jack relative to said fixed member.

17. The apparatus of claim 9 in which said jack is a hydraulic jack having a cylinder and a piston, said cylinder having external screw threads over at least a portion of its length,

said apparatus further including a socket rotatably mounted on said fixed member and having internal threads for threading engagement with said cylinder,

and means for at times rotating said socket to thereby move said cylinder axially relative to said fixed member.

18. The apparatus of claim 17 wherein said rotating means includes a gear which meshes external threads on said socket, whereby rotation of said gear revolves said socket and produces axial movement of said cylinder relative to said fixed member.

19. The apparatus of claim 18 which includes at least two jacks, and said gears meshing with the respective sockets for said jacks are all driven by a common shaft.

20. The apparatus of claim 1 which further includes module supporting means positioned exteriorly of the building confines and a plurality of rails on said supporting means adapted for engagement with a plurality of wheels mounted on each module.

21. The apparatus of claim 20 in which said rails are adapted for coupling with said movable support to permit each said module to be rolled along said rails onto said supporting and elevating apparatus.

22. The apparatus of claim 9 in which said auxiliary support means comprises a threaded screw and a fixed socket member which engages with the threads of said screw, a second fixed socket member immediately below and axially supporting said first socket member and having a loose fit relative to said screw, whereby said screw may adopt a nonperpendicular position relative to said second socket without binding and yet be axially supported by said first socket resting upon said second socket.

23. The apparatus of claim 9 in which said auxiliary support means comprises a threaded screw and socket means which threadably engages with said screw and is supported by said fixed support member, and spring means normally urging said screw upwardly to reduce frictional forces between the threads of said screw and the threads of said socket means.

24. The apparatus of claim 9 in which said auxiliary support means comprises a threaded screw and socket means which engages with the threads of said screw and is secured to said fixed support member, said apparatus further including a thrust bearing between the upper end of said screw and the load.

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