An improved hoist system is provided comprising the usual vertical supporting tower, a hoist cage or lifting platform, and a counterweight trolley operatively connected to the cage in movable relation therewith for decreasing the power requirement of the cage lifting or drive motor. In accordance with the invention the drive motor and its associated components are directly mounted on and supported by the counterweight trolley and are adapted for driving a series of pinion gears cooperatively engaging a gear-toothed rack member vertically affixed to the tower adjacent to the path of travel of the counterweight trolley, the weight of the drive motor and its associated components thereby serving as the counterweight for the hoist system. The height of the hoist tower may selectively be increased by adding suitable sections thereto and a novel method of erecting the tower is disclosed wherein both the hoist cage and the counterweight support trolley may be positioned at the same height on the tower to provide dual working platforms for this purpose.
RACK AND PINION DRIVE COUNTERBALANCED HOIST SYSTEMS

The present invention relates generally to hoist systems and more particularly, to hoist systems employing a rack and pinion drive mechanism for effecting the ascent and descent of the hoist cage or lifting platform. It is well known to raise and lower hoist cages by means of a driven pinion gear or series of gears riding a vertically disposed rack affixed to a supporting mast or tower. Such a hoist system is disclosed, for example, in U.S. Pat. No. 3,415,343 to Svensson. In this prior system, the motor drive means for the pinion gear is carried by or supported directly on or in the hoist cage with the driven pinion gear(s) cooperatively engaging the vertically disposed rack member which latter is for obvious reasons disposed on the side of the hoist tower immediately adjacent to the path of travel of the cage. A significant disadvantage inherent in the foregoing arrangement is that if the hoist tower is to be constructed of any substantial height as, for example, when the hoist system is to be used in lifting personnel and/or material during the construction of a multi-story building or other structure, the payload lifting capacity and linear speed requirements are such as to dictate the use of a separate counterweighted trolley or carriage in order to economically conserve the horsepower requirement for the hoist cage drive motor. The use of such a counterweighted trolley, in turn, increases the dead weight loading on the tower necessitating stronger and heavier tower sections and therefore increased equipment and set up costs despite the savings achieved by using a lower horsepower drive motor.

In accordance with the present invention there is provided an improved rack and pinion drive hoist system employing counterweight means wherein instead of mounting the drive motor and its associated components directly on or in the hoist cage or platform, they are remotely mounted on or supported directly by the counterweight trolley itself. The weight of the drive motor and its associated components thus comprises the necessary counterweight for the hoist system thereby permitting the desired reduction in the horsepower requirement of the drive motor but at the same time reducing the dead weight loading on the hoist tower. This therefore permits use of tower sections of reduced strength and weight thereby achieving significant economies over the prior rack and pinion drive hoist system without sacrificing any of the latter's advantages.

Another disadvantage inhering to the prior art rack and pinion drive hoist system is that because the drive motor and the driven pinion gear assembly are supported directly on or by the hoist cage, loading of the cage with personnel and/or material creates a torque or reactive moment that is transmitted directly through the pinion gear to the rack member on the tower and thus causes excessive wear on these components as well as increased noise and vibration during ascent and descent of the cage. In accordance with the present invention however, the drive motor, driven pinion gear as well as the rack member are all remotely disposed with respect to the hoist cage, that is, the drive motor and pinion gear assembly is located on the counterweight trolley and together with the rack member are disposed on a portion of the tower other than the side or portion of the tower along which the cage travels. Accordingly, no torque loads can be transmitted directly from the hoist cage to these components. This results in reduced wear on the rack and gear assembly, and smoother and quieter operation of the hoist system.

Moreover, by remotely locating the motor drive components on the counterweight trolley and away from the hoist cage as contemplated by the present invention, any serious malfunction in these devices, e.g., a short circuit in the electrical power circuit of the drive motor system, or the spillage of hot oil due to a ruptured oil line in the hydraulic portion of the drive motor system, cannot cause serious injury to personnel in the hoist cage at the time of the malfunction. In the prior system, of course, the drive motor components are located directly on or adjacent to or sometimes even inside the elevator cage and their proximity therefore provides a serious safety hazard to personnel inside the cage in the event of a component failure.

Still yet another advantage over the prior system achieved by the improved hoist system of the present invention resides in the capability of utilizing both the hoist cage and the counterweight trolley as mobile work platforms which can be employed simultaneously during the erection of the hoist tower. This results in a significant cost saving in that the use of dual platforms on either side of the tower, respectively, facilitates more rapid raising of the tower and thus decreases the man-hours required for the raising operation.

From the foregoing, it will be appreciated that the primary object of the present invention is to provide an improved rack and pinion drive hoist system wherein the drive motor, driven pinion gear, and rack member are remotely disposed on the hoist tower with respect to the hoist cage or lifting platform.

It is another object of the present invention to provide an improved rack and pinion drive hoist system wherein the remotely disposed drive motor, driven pinion gear and associated components actually comprise the counterweight for the hoist cage.

It is yet another object of the present invention to provide an improved hoist system wherein the drive means for raising and lowering the hoist cage are remotely disposed with respect to the hoist cage, and both the hoist cage and the remotely disposed drive means may be employed as mobile work platforms to facilitate the erection of the hoist tower.

It is still another object of the present invention to provide an improved hoist system including a tower or mast that is built up of a plurality of individual tower sections and wherein novel means are provided for anchoring the individual tower sections together.

It is still yet another object of the present invention to provide an improved counterweighted rack and pinion drive hoist system that is safer to operate, less expensive to purchase, install and operate, smoother and quieter to run, and more reliable than prior art systems of the class described herein.

To the accomplishment of the foregoing objects and advantages, the present invention briefly comprises an erectable hoist tower defining on differently disposed portion thereof at least one pair of vertically disposed paths of travel. Adjacent to one of said paths of travel on one portion of the tower is provided a hoist cage and adjacent to the other of said paths of travel on the other differently disposed portion of the tower is provided a counterweight trolley or carriage carrying a drive
motor and driven pinion gear assembly. Affixed to said differently disposed portion of the tower is a vertically positioned rack member cooperatively engaged by the driven pinion gear assembly mounted on or carried by the counterweight trolley. The hoist cage is supported for ascent and descent along the path of travel defined on said one portion of the tower by a traveling lift cable or cables extending from the hoist cage upwards along the said one portion of the tower, over and through a conventional "cathead" sheave assembly positioned on the top of the tower and thence downwards along said other different disposed portion of the tower where they are eventually connected to the counterweight trolley, the latter being supported and guided for ascent and descent along the path of travel defined by said differently disposed portion of the tower by the cooperative engagement of the driven pinion gear assembly carried by the counterweight trolley with the vertically positioned rack member affixed to the tower along said differently disposed portion thereof.

The foregoing and still other objects and advantages of the present invention will be more apparent from the following detailed explanation of the invention in connection with the accompanying drawings wherein:

FIG. 1 is a perspective view partially broken away of a preferred embodiment of the improved hoist system according to the present invention;

FIG. 1A is an enlarged detail view in perspective of a portion of the hoist system of FIG. 1;

FIG. 2 is a side elevation schematically showing a modified embodiment of the hoist system of FIG. 1;

FIG. 2A is an enlarged detail of a portion of the control cable schematically indicated in FIG. 2;

FIG. 3 is an exploded view in perspective showing a preferred embodiment of an individual tower section according to the present invention;

FIG. 3A is an elevation of a portion of the hoist tower of the present invention showing an alternate preferred means for anchoring two individual tower sections together;

FIG. 3B is sectional view taken along line B—B in FIG. 3A;

FIG. 3C is a perspective view of a portion of an alternate preferred embodiment of an individual tower section of the present invention;

FIG. 4 is a front elevation of the preferred embodiment of the counterweight trolley according to the present invention;

FIG. 5 is a sectional view of the counterweight trolley taken along line 5—5 of FIG. 4;

FIG. 5A is an elevation showing an enlarged detail of a portion of the counterweight trolley shown in FIG. 5;

FIG. 6 is a top view of the counterweight trolley according to the present invention, taken along line 6—6 of FIG. 4;

FIG. 7 is a sectional view of another portion of the counterweight trolley taken along line 7—7 of FIG. 4; and

FIG. 8 is an enlarged detail view in perspective of a portion of the counterweight trolley of the present invention showing the engagement between one of the trolley's guide roller units and one of the guide rails on the hoist tower.

Turning now to the drawings wherein like reference numerals represent similar parts, there is schematically shown in FIG. 1 a perspective rendering of a preferred embodiment of the improved hoist system according to the present invention. Speaking generally, the hoist system comprises a tower or mast 10, a hoist cage or lifting platform 12, and a "counterweight" or counterbalancing trolley 14. The tower which is built up of a plurality of similar tower sections 16 as will be more fully explained below, is vertically supported on a steel or concrete foundation 18 by means of a foundation frame member 20 integral with the lowermost tower section 22, the frame member 20 in turn being bolted or otherwise securely fastened to the foundation in a manner well known in art. In order to provide additional lateral support for the tower a plurality of tie rods 24 may be disposed between the side of the tower adjacent to the side of the building or other structure with which the hoist is being used, the tie rods extending laterally and being fixed respectively at one end to a section of the tower and at their respective other ends to the building or other structure. Similar tie rods (not shown) may be used at various selected heights upwards along the tower (e.g., every 25 feet) to provide firm lateral support for the tower.

Affixed to the tower and extending vertically along one side thereof are a pair of parallel spaced guide rails 26, 28 (see FIG. 7) for defining the path of travel for the hoist cage 12. Similarly, on the oppositely disposed side or face of the tower as depicted in FIG. 1 there are affixed another pair of vertically extending parallel spaced guide rails 30, 32 for defining the path of travel for the counterweight trolley 14.

Also affixed to said oppositely disposed side or face of the tower is a vertically extending gear-toothed rack member 34 spaced between and parallel to the guide rails 30, 32.

In accordance with one of the important features of the present invention, the motor drive means for effecting movement of the hoist cage is mounted on and directly supported by the counterweight trolley 14. Thus as schematically indicated in FIG. 1, the trolley 14 carries a pair of drive motor units 36, 38 each one of which is adapted to drive a pinion gear 39 cooperatively engaging the gear-toothed rack member 34 as shown in FIG. 1A and as will be explained in still further detail below. The counterweight trolley 14 thus is capable of controlled powered movement upwards and downwards along the guide rails 30, 32 by the action of the drive motor units 36, 38 driving their respective pinion gears which in turn ride on the vertically disposed gear-toothed rack member 34 fixed to and supported by the tower. A pair of cranking lifting cables 40, 42 are connected to a corresponding pair of hitch members 44, 46 integrally fixed to the counterweight trolley and extend upward toward the top of the tower whereupon they are guided over the top of the tower's uppermost section through a cathead assembly comprising a pair of pulley wheels or sheaves 48, 50. The cathead is removably supported on the uppermost portion of the upper tower section by a pair of disconnectable yoke members 52 or the like so that the cathead assembly can be dismounted and raised when the tower height is being increased by adding more sections thereto as will be described more fully in the ensuing discussion. The lifting cables 40, 42 are guided through sheaves 48, 50 respectively, and extend downward along the other side of the tower where they are firmly and securely connected by suitable known means to a hitch member 53 integrally located on the hoist cage 12 and then to a pair of conventional storage drums or
3,878,916

reels 54, 56 affixed to the cage's roof as shown. The cable drums 54, 56 are normally locked in position, but as is known in the hoisting art, can be unlocked to let out more lifting cable when the hoist tower height is increased by adding more sections thereto. By virtue of the connection provided between the hoist cage 12 and the counterweight trolley 14 via the lifting cables 40, 42, it will be appreciated that when the counterweight trolley is caused to travel upwardly and downwardly along the guide rails 30, 32 by means of the driven pinion gears 39 supported on the counterweight trolley riding on the gear-toothed rack member 34, the hoist cage 12 will accordingly be driven downwardly and upwardly in corresponding fashion along the guide rails 26, 28 on the side of the tower oppositely and remotely disposed with respect to the other side or face of the tower along which the counterweight trolley is traveling.

As indicated in FIG. 1 a pair of the usual limit stop or buffer members 58, 60 may be connected to foundation frame members 20 on either side of tower 10 directly underneath the hoist cage 12 and counterweight trolley 14, respectively, to limit the travel of the cage and trolley when either are at their bottom-most positions on the tower. Also, the cage 12 may include a chain link guard rail 61 for defining a work area on the roof of the cage and the usual vertically sliding gates 62 for permitting free and easy ingress and egress to the cage from either a ground platform (not shown) or from any prescribed height on the tower, e.g., from the upper floors of a building under construction; however, as will be appreciated by those skilled in the art, a wide variety of other cage contraptions, or lifting platforms capable of carrying personnel and/or material may be employed with the hoist system of the present invention. Suffice it to say that whatever form of cage 12 or other platform is employed with the present invention, the motor drive means used to effect controlled movement of the cage upwardly and downwardly along the tower rather than being mounted on or supported directly by the cage itself is mounted on and directly supported by the counterweight trolley 14. In this regard, it will be necessary to mount a manually operable actuator or control means 63 (see FIG. 2) within the cage so that personnel therein may operate and control the movement of the cage by selectively and remotely controlling or activating the motor drive means on the counterweight trolley.

In the preferred embodiment of FIG. 1, one end of a traveling control cable 64 is operatively coupled to the drive motor units on the trolley 14 through suitable control devices and switches located in a central control station 65 mounted on the trolley. The traveling control cable 64 extends upwardly from the control station 65 and is guided through the cat-head sheave 48 rotatably supported on the top of the tower thence downwardly to the hitch member 53 located on the cage 12. Since the cathead sheave 48 also serves to guide the lifting cable 40, the sheave or pulley wheel 48 advantageously may be of the parallel double-grooved type well known in the art. Alternatively, a pair of separate single-groove sheaves to carry the lifting cable and the control cable, respectively, and which are mounted in a generally parallel side-by-side manner may be used as well. The control cable 64, which is preferably loop-connected about the hitch 53 in a known manner is then wound on a storage reel or drum 66 located on the cage roof in generally the same manner as the lifting cable storage reels 54, 56. Finally, the other end of the control cable 64 extends from the storage drum 66 into the hoist cage where it is connected to the manual control station 64. It is thus apparent that by means of the traveling control cable 64 extending between the cage 12 and the trolley 14 via the cathead assembly mounted on top of the hoist tower a direct connection for transmitting control or actuation signals between the control station in the cage and the pinion gear drive apparatus on the trolley will be maintained during corresponding motion of the cage and trolley on the tower. It will be noted that as in the case of the lifting cables 40, 42, the control cable 64 may selectively be lengthened when the tower height is increased by simply unlocking the storage drum 66 and letting out the necessary length of cable.

An alternate preferred method of providing a direct control connection between the hoist cage 12 and the trolley 14 is schematically depicted in FIG. 2 where instead of guiding the control cable up over the top of the tower through the cathead assembly (e.g., sheave 48) the control cable is shown in the form of a traveling coaxial cable 67 extending from the manual control station 63 within the cage downward from the cage to a pulley or sheave 68 rotatably mounted on the tower near the bottom thereof and then upward to the drive motor mechanism mounted on and supported by the trolley. Preferably, as shown in FIG. 2A, cable 67 comprises a control cable 64 coaxially mounted within a flexible sheath or conduit 69 of suitable material which latter serves the dual function of (1) protecting the control cable, and (2) because of its weight serving as an automatic counterweight compensator for the lifting cables 40, 42. The latter function is desirable because of the appreciable weight of the lifting cables which if not compensated for would place undesirable stresses on the drive mechanism of the trolley when the latter is at its extreme rest position, i.e., the bottom or top of the tower, and begins to accelerate either upwardly or downwardly on the tower as the case may be. To illustrate the manner in which such compensation is automatically achieved in accordance with the present invention consider FIG. 2 wherein the hoist cage 12 is shown near its uppermost position on the tower 10 and, consequently, the counterweight trolley is depicted near its lowestmost position on the opposite side facing the face of the tower. Now at the moment the counterweight trolley is caused to travel upwardly on the tower and the hoist cage begins its concomitant motion downwardly on the tower, the lifting cables 40, 42 being predominately on the trolley side of the tower will gradually be guided through the cathead assembly to the other side of the tower as they follow the cage down that side of the tower. This will rapidly add to the weight or force acting in the direction of the counterweight trolley's upward motion, tending to accelerate the trolley toward the top of the tower. However, by the same token (and as indicated in FIG. 2) the control cable 64 and its outer protective conduit or sheath 69, which are predominately located on the cage side of the tower when the cage begins its downward travel, are gradually guided through pulley 68 to the trolley side of the tower as they follow the motion of the trolley during the latter's upward movement. Hence, the weight of the control cable 64' and its outer protective sheath 69 tends to balance or counter the transferring
weight of the lifting cables 40, 42 thereby preventing upward acceleration of the trolley as it travels upwardly on the tower. As the cage progresses in its movement downwardly on the tower, the foregoing compensation is automatically maintained since the cable 64 and its protective outer sheath 69 being connected to the trolley will follow the latter through the guiding pulley 68 as it travels upwardly on the tower at the same rate the lifting cables 40, 42 are following the hoist cage through the cathead assembly on the top of the tower and downwardly along the tower behind the cage. Hence, at any given moment during the corresponding motion of the cage and trolley, the force due to the weight of the lifting cables which initially opposes the upward motion of the trolley and then gradually is transferred to the side of the tower opposite the trolley and thus gradually tends to accelerate the trolley’s upward movement is balanced or countered by an opposite force due to the weight of the control cable 64 and its outer protective sheath 69 which initially aids the downward movement of the hoist cage, but gradually is transferred to the trolley side of the tower (through guide pulley 68) behind the trolley and thus opposes the upward acceleration of the trolley. The same automatic compensation process occurs in reverse fashion, i.e., when the counterweight trolley is at the rest position at the top of the tower and begins its downward motion and the hoist cage is at the bottom of the tower and begins its upward motion on the tower. It will be appreciated that when the alternate preferred form of control cable 64 is employed, the storage reel 66 may more conveniently be mounted on the underside of the hoist cage 12 rather than on the roof thereof as is the situation when the control cable 64 of FIG. 1 is employed.

Although use of a direct connection via control cable 64 (FIG. 1) or control cable 64' (FIG. 2) are the preferred methods of remotely controlling the actuation of the drive means on the counterweight trolley from the hoist cage 12, it will be understood that other methods of remote control may be employed instead, such as radio telemetry, for example, without departing from the present invention. Likewise, a control station 70 located on the ground near the base of the hoist tower and connected to the motor drive mechanism on the counterweight trolley via cable 72 as schematically depicted in FIG. 2 may be used to remotely control the movement of the hoist cage from the ground rather than from the hoist cage, and furthermore, to serve as a redundant or back-up control means for the controller 63 and control cables 64 or 64' in the event of failure of the latter. Finally, as is also indicated in FIG. 2, the electrical power for the drive means on the counterweight trolley will normally be supplied from a ground power supply station 74, coupled to the trolley via a power cable 76, the latter being stored on a conventional take-up or storage reel 78 which has the capability of permitting the power cable 76 to pay out and follow the counterweight trolley upwardly along the tower, but which contains a driven drum mechanism which will automatically wind up and store the power cable when the trolley travels downwardly on the tower. Alternatively, since the power cable may add to the dead weight loading on the trolley 14, particularly as the latter approaches the upper portion of the tower, it may be desirable especially when significant tower heights are employed to run the power cable vertically up through the interior of the tower as shown in FIG. 2 and to statically connect the power cable to the tower structure proper at a position 77 located approximately at the one-half point with reference to the tower's height with the remainder of the power cable being free to follow the motion of the trolley 14 either upwardly or downwardly as the situation dictates. By this arrangement, at least one-half the weight of the power cable 76 will be supported at all times directly by the tower itself and accordingly, will lessen the dead weight loading on the trolley due to the weight of the power cable by the same amount. Obviously, conventional storage reel means similar to that at 78 may be used in conjunction with the control cable 72 and ground controller 70.

As mentioned above, the tower or mast 10 may be constructed from a plurality of similar individual tower sections 16. Turning now to FIG. 3, each individual tower section 16 in one preferred form comprises a structurally rigid rectangularly shaped box or frame member including four hollow vertically disposed corner post members 80, four upper horizontal rib members 82, and a like plurality of lower horizontal rib members 84. As shown, the horizontally disposed rib members 82, 84 are in the form of rigid right-angle structural members whereas each corner post has a substantially square or rectangularly shaped cross-section, although it will be appreciated that other structural shapes for these parts may be used instead as will become more apparent below in connection with the discussion related to FIGS. 3A–3C. Each side or face of the frame member may also include a strengthening strut 86 extending diagonally between opposed corners of the frame member as indicated. The post members, horizontal rib members, and strengthening struts may be assembled in the configuration shown by any suitable and convenient method as by bolting or welding the various members to one another.

On the oppositely disposed sides or faces of the frame member, as indicated in FIG. 3, two pairs of vertically disposed essentially Z-shaped guide rail sections 88 are securely affixed in a known manner to the four corner post members, respectively, with each Z-shaped guide rail section 88 defining a plurality of guiding surfaces and edges forwardly and laterally offset with reference to the plane of the frame member's side or face to which the respective guide rail sections are attached. Thus, as shown in more detail in FIGS. 6 thru 8 the outermost or transverse extremity of each guide rail section defines a first vertically disposed guiding surface 96, a second vertically disposed guiding surface 98, and a third vertically disposed guiding edge 100 orthogonally related to the first and second guiding surfaces 96, 98, with the guiding surfaces 96, 98 being parallel to each other and facing away and toward the tower, respectively, while the guiding edges 100 common to each pair of Z-rail sections 88, respectively, are parallel to and face toward each other. At this juncture, it might be mentioned that the present invention is not to be limited to the use of a guide rail having a Z-shaped cross-section. Thus, for example, guide rails 28–32 may be built up from sections having a substantially U-shaped cross-section in which event the guiding surfaces 100 rather than face toward one another on the same side of the tower will extend in opposite directions with respect to each other. Obviously, other par-
ticular forms and shapes for the guide rails 28-32 will occur to the routineer. In any event, the forwardly and laterally offset guiding surfaces and edges 96, 98, 100 defined by the Z-shaped guide rail sections 83 (and consequently the Z-shaped guide rails vertically disposed on the tower) function as vertically disposed bearing surfaces for corresponding guide roller units which are located on the hoist cage and counterweight trolley respectively and are adapted for cooperative engagement with the guide rails 28-32 as will be more fully explained below with particular reference to FIG. 8.

On the front face or side of each frame member as viewed in FIG. 3, a section 102 of the gear-toothed rack member 34 is vertically disposed substantially intermediately between the Z-shaped guide rail sections 88 in parallel relation thereto and is securely fastened to the frame member through a pair of standoffs or spacers 103, 104 by a like plurality of bolt fasteners 105 and 106. Each rack member section 102 includes a gear-toothed portion 112 on one side thereof and a smooth, flat bearing surface 114 on the other side thereof. As will be made more apparent in connection with the following discussion of the gear-toothed portion 112 of each rack member section 102 on each tower frame member is adapted to be cooperatively engaged by a series of driven pinion gears supported on the counterweight trolley while the smooth, flat bearing surface 114 is adapted to be cooperatively engaged by a guide roller also mounted on and carried by the counterweight trolley.

During the raising or erection of the hoist tower 10, a plurality of tower sections 16 are sequentially lifted into position and assembled one on top of another until the desired tower height is achieved. As shown in FIG. 3 each tower section or frame member 16 includes eight gusset plates 116 located at the eight corners of the frame member respectively defined by the intersection of the upper and lower horizontal rib members 82, 84 with each of the four corner post members 80. Each gusset plate in turn includes an aperture 118 through which a suitable fastening element may be inserted. In order to facilitate the assembly of the tower sections the bottom end of each post member 80 terminates in a chamfered end-cap member 120 suitably sized so as to be receivably engaged within the bore 122 defined by each hollow corner post member. In addition, each gear-toothed rack section 102 carries on its bottom end surface a vertically downwardly extending dowel pin 124, and in its top end surface a locating aperture 126 suitably sized to receivably engage the dowel pin. With this construction the individual tower frame section being installed is lifted above the tower section previously installed and is lowered into position with the chamfered end-cap members 120 and the dowel pin 124 on the tower section about to be installed being inserted respectively into the corner post bores 122 and the rack locating aperture 126 on the section already installed. This automatically locates the two tower sections relative to each other so that the corresponding Z-shaped guide rail sections 88 and the rack member sections 102 are in proper vertical alignment, whereupon the two sections may firmly be bolted together by inserting appropriate bolt fasteners on the like through the corresponding apertures 118 in each pair of super-imposed gusset plates 116 located respectively on the bottom of the tower section being installed and on the top of the tower section already installed. The foregoing procedure is then repeated as often as necessary until the desired tower height is achieved.

Turning now to FIGS. 3A and 3B an alternate preferred form of the present invention will be described wherein a single fastening element in the form of a longitudinally extending hollow sleeve or insert member 128 is provided for anchoring the upper portion of a corner post member on one tower section to the lower portion of the corresponding corner post member on another tower section as well as for providing means for affixing each Z-rail section 88 to its respective corner post member 80. As shown in FIGS. 3A and 3B each hollow sleeve member 128 which preferably is chamfered at each end thereof has a cross-sectional shaped generally conforming to the cross-sectional shape of each corner post member 80 but is suitably sized so that it may be telescopically and snugly received within the bore 122 of each corner post member. A pair of diametrically opposed similarly sized apertures 129, 130 is disposed in the upper portion of the sleeve member whereas a similar pair of diametrically opposed similarly sized apertures 131, 132 is disposed in the lower portion of the sleeve member. Apertures 129-132 generally have their central axis horizontally disposed and substantially perpendicular to the central longitudinal axis of sleeve member 128. When utilizing the longitudinally extending hollow sleeve member of FIGS. 3A and 3B, each corner post member 80 is formed therein near its lower extremity a first pair of diametrically opposed apertures 133, 134 and near its upper extremity a second pair of diametrically opposed apertures 135, 136 as shown with apertures 133-136 being similarly sized with respect to the apertures 129-132 formed in the sleeve member 128. Likewise, each Z-rail section 88 has formed therein near its upper and lower extremities respectively first and second apertures 137, 138 extending through the laterally extending portion 139 of the Z-rail which laterally extending portion is juxtaposed and in contact with the corner post member 80 (see FIG. 3B). Apertures 137, 138 are also preferably similarly sized with respect to the apertures 129-132 formed in the hollow sleeve member 128. During the erection or raising of the tower 10, four such sleeve members 128 are respectively slid into each bore 122 at the bottom of each corner post member 80 until the apertures 129, 130 in the upper portion of the sleeve member 128 register with the apertures 133, 134 in the corner post member 80. Each Z-rail section 88 is then aligned relative to its corresponding corner post member until the aperture 137 formed therein registers with previously aligned apertures 129, 130 and 133, 134. A suitably sized bolt fastener 140 may then be inserted through the commonly aligned apertures in the Z-rail, the corner post member and the hollow sleeve member and fastened by means of nut 141. As in the case of the embodiment of the invention described above in regard to FIG. 3, the individual tower section being installed (section 16A, FIG. 3A) is then raised into position above the previously installed tower section (section 16B, FIG. 3A) and lowered into the position shown in FIG. 3A with the four downwardly projecting lower portions of the four sleeve members 128 serving as locating studs as the latter are telescopically receivably engaged within each bore 122 of each corresponding corner post member on the section previously installed. At this juncture, the
aperture 138 provided in the upper portion of each Z-rail will be aligned with apertures 135, 136 in the upper portion of each corresponding corner post member 80, as well as with apertures 131, 132 in the lower portion of each corresponding sleeve member 128. A second bolt fastener 142 may then be inserted through the aligned apertures and fastened by means of a nut 143.

It will be appreciated that the foregoing procedure may be repeated until the desired tower height is reached at which point the upper portion of each Z-rail will be fastened directly to the upper portion of each corresponding corner post member on the uppermost tower section 16 by use of a bolt fastener extending through apertures 138, 135, and 136, that is, no sleeve members 128 are necessary at the upper portion of the final individual tower section 16 installed on the tower. From the foregoing, it should also be apparent that by utilizing the sleeve member 128 only two bolt connections are necessary to anchor each Z-rail section to its corresponding corner post member and to anchor two corresponding corner post members on two different tower sections together whereas in the embodiment of FIG. 3 such would normally require three bolt connections.

In addition, the sleeve member 128 serves as a chamfered locating stud as mentioned above thereby obviating the chamfered end-cap members 120 required in connection with the embodiment of FIG. 3.

Although, in the alternate preferred embodiments of FIGS. 3 and 3A-B, each hollow corner post member 80 is of a square or rectangular cross-sectional shape it should be understood that other structural shapes for these parts are within the contemplation of the present invention. For example, each corner post member 80 may have a hollow cylindrical cross-section with the chamfered end caps 120 (FIG. 3) and the elongated hollow sleeve members 128 (FIGS. 3A and 3B) being similarly shaped.

In this same regard, it is not even necessary that separate guide rail sections (e.g., Z-rail sections 88) be affixed to each hollow corner post member. Thus, in accordance with still another alternatively preferred form of the invention, there is shown in FIG. 3C a substantially Z-shaped corner post member 146 having a guide rail section integral therewith. The Z-shaped corner post member 146 includes a first laterally extending portion 147, a web portion 148 integral with and substantially perpendicular to the portion 147, and a second laterally extending portion 149 integral with the web portion 148 and extending parallel to but in a direction opposite to that of the first laterally extending portion 147. Since the web portion 148 and the first laterally extending portion 147 are substantially perpendicular to one another they conveniently form a right-angle post member to which the end portions of the horizontally disposed right-angle rib members 82 of each individual tower section may suitably be connected. Likewise, at the lower extremity of each Z-shaped corner post member 146 (not shown) the end portions of the horizontally disposed right-angle rib members 84 may suitably be connected to the right-angle corner post member formed by the first laterally extending portion 147 and the substantially perpendicular web portion 148. It will be observed that since the second laterally extending portion 149 provides the same guiding surfaces 96, 98, 100 provided by each Z-shaped guiding rail 26-32 (compare FIG. 8) there is provided in the form of the Z-shaped corner post member 146 of FIG. 3C a unitary integral corner post member and guide rail construction. When individual tower sections are employed utilizing the latter construction, the tower sections preferably are anchored together using the gusset plate members 116 and through apertures 118 described above in connection with the preferred embodiment of FIG. 3.

It will be in relation to FIG. 3 that it is not necessary for the extreme laterally extending portions common to each pair of guide rail sections 88 on either side of the tower respectively to face one another, but alternatively, may face in opposite directions thus forming substantially U-shaped guide rail sections instead. Similarly, it will be understood that the integral corner post guide rail construction of FIG. 3C may be modified to have a substantially U-shaped cross-section in which case the second laterally extending portion 149 will extend in the same direction as the first laterally extending portion 147 and parallel thereto.

As mentioned previously in connection with FIG. 1, the primary feature of the present invention is the provision of a counterweight trolley 14 that is capable of carrying and directly supporting a pinion gear motor drive means for effecting upward and downward movement of the hoist cage 12 along a side or portion of the tower other than that along which the trolley itself travels upwardly and downwardly by means of the pinion gear or gears riding upon a gear-toothed rack member 34 vertically supported on said other side or portion of the tower. Thus, turning now to FIGS. 4-8 the preferred form of the counterweight trolley will now be described. A pair of spaced apart, parallel, longitudinally extending L-shaped frame members 150, 152 are connected at their upper extremities by an upper l-beam 153, and at their lower extremities by a lower l-beam 154 to form a rigid, substantially rectangularly shaped rear supporting frame for the trolley 14. As seen to best advantage in FIGS. 6 and 8 each end of upper l-beam 153 is suitably connected through a pair of angle irons 155 to each of the L-shaped frame members 150, 152 and to each one of a pair of laterally extending T-shaped hitch members 44, 46 respectively. Likewise, each end of lower l-beam 154 is suitably connected to the lower extremities of each of the frame members 150, 152 through a similar pair of angle irons 155, respectively. As most clearly shown in FIGS. 4 and 8 each laterally extending T-shaped hitch member 44, 46 includes an aperture 156 through which the terminal portions of lifting cables 40, 42 may be inserted respectively and securely fastened in a known manner as indicated at reference numeral 157. With the foregoing arrangement, any tension in the lifting cables occasioned by the load of the hoist cage 12 may be uniformly transmitted to and taken up by the rigid rectangular rear supporting frame of the trolley 14. Under heavy duty loading, as where a rather large lifting cage 12 is employed on a tower of relatively great height it may be desirable to strengthen the laterally extending T-shaped supporting members by providing a plurality of reinforcing webs 158 as depicted in FIGS. 4 and 8.

In accordance with another important feature of the present invention, and as shown in FIGS. 4 thru 6, the counter balancing trolley 14 includes near the upper portion thereof a horizontally disposed working platform 160 extending laterally and forwardly with respect to the rear support frame members 150, 152. The working platform 160 which is suitably connected to
each of the L-shaped frame members 150, 152 by means of a right-angle peripheral frame member 161 is further supported by a second pair of longitudinally extending spaced apart L-shaped frame members 162, 164 disposed parallel to each other and to each of the rear frame members 150, 152 respectively. In addition, a first horizontally disposed right-angle brace member 165 is suitably connected to the upper portions of the L-shaped frame members 162, 164 and to the underside of the working platform 160 as indicated in FIGS. 4-6, while a second horizontally disposed right-angle brace member 166 is suitably connected to the lower portions of frame members 162, 164 (FIG. 5). A series of struts 167 diagonally extending between L-shaped frame members 150, 152 on the one hand and between L-shaped frame members 162, 164 on the other hand give added structural support to the working platform in addition to providing further strength and rigidity to the trolley 14. The working platform 160 preferably includes the usual corner posts 168 and chain rail 169 to safely delineate the outer extremities of the platform. By virtue of the provision of working platform 160 it will be appreciated that the trolley 14 may be employed independently as a hoist or mobile work platform, say for example, to lift the various individual tower sections 16 during the initial raising or erection of the hoist tower 10. Moreover, as will be explained in greater detail below, the trolley 14 with its working platform 160 may be used in conjunction with hoist cage 12 to provide dual working platforms at any selected height on the tower 10. In both events it may be necessary to enable a workman situated on the platform 160 to selectively control the upward and downward movement of the trolley along the tower 10. In order to meet this requirement, a set of conventionally manually actuable motor and brake controls are provided in the central control station 65 mounted on the platform 160. Preferably the control station 65 will be protected by a weatherproof housing having a removable cover as will obviously occur to those skilled in the art. In connection with the preferred embodiment of the counterbalancing trolley 14 shown in FIGS. 4-8, it will be understood that the power cable 76 and all control cables such as the cables 64, 67, or 72 described above with reference to FIGS. 1 and 2 are eventually connected in a conventional manner to and through the control station 65 on the platform 160, however, these connections have not been shown in FIGS. 4-8 in the interest of brevity and to simplify the presentation hereof.

As emphasized above, the trolley 14 is adapted to directly carry and support the pinion gear drive apparatus for effecting controlled movement of the trolley and therefore of the hoist cage on the tower. Due to the weight of the pinion gear drive motors and their associated components the trolley is capable of functioning as the counterweight or counterbalancing means for the hoist cage thereby permitting use of a pinion gear drive motor system having less horsepower output than would be necessary in the absence of any counterweight means whatsoever. Moreover, by locating the pinion gear drive motor mechanism on the trolley rather than on the hoist cage as is the usual practice, the dead weight of the pinion gear drive motor mechanism need no longer be counterbalanced by an equivalent counterweight; hence, the total cumulative dead weight loading on the tower is substantially reduced by a factor equal to twice that of the weight of the pinion gear motor drive system. This results in the important advantage of permitting the use of tower sections of less size and weight for a given hoisting capacity thereby effecting a substantial reduction in the initial cost of the hoist system. Alternatively, for a tower having sections of given size and weight, this reduction of the dead weight loading on the tower through the expedient of employing the pinion gear drive means for the hoist cage as the counterbalancing means for the hoist cage as achieved by the present invention increases significantly the ability of the tower to withstand stresses and loading, and consequently, substantially increases the structural safety factor associated with the tower. It will be appreciated, therefore, that in its broadest aspects, the present invention relates to the use of the hoist cage pinion gear drive motor drive mechanism as the counterbalancing element in the hoist system, it being relatively unimportant what type or form of pinion gear drive motor system actually is used. By way of illustration, however, the pinion gear drive motor apparatus employed in the preferred embodiment of the invention may be of the electro-hydraulic type. Thus, as schematically indicated in FIGS. 4 and 5A the trolley 14 includes a pair of longitudinally displaced hydraulically actuable pinion drive motors 170, 38 (see also FIG. 1) an electric motor 170, an oil pump 171, a heat exchanger for cooling the oil 172, an oil filter 173, and an oil storage tank or reservoir 174. The electric motor 170 which is preferably of the squirrel cage type, is mounted on the trolley by means of an integral supporting plate 176 suitably connected to rear frame members 150, 152 and is adapted to coaxially drive the oil pump 171 which latter as best seen in FIG. 5 is supported on the trolley 14 via a yoke member 178 and a first pair of right-angle braces 180, 182 suitably connected to the yoke member and to rear frame members 150, 152, and a second pair of right-angle braces 184, 186 suitably connected to the yoke member and to the other pair of frame members 162, 164.

Each pinion drive motor unit 36, 38 which incidentally includes coaxially mounted therewith a hydraulically actuable brake unit 188, 190, respectively, is supported on a mounting plate member 192 through a bracket assembly 194 with each mounting plate member 192 in turn being suitably connected to rear frame members 150, 152. An upper right-angle brace 196 and a lower right-angle brace 198 are further provided to strengthen the connection between the mounting plate 192 and rear frame members 150, 152. The heat exchanger 172's suitably connected to a pair of right-angle braces 200, 202, each of which in turn is suitably connected to the trolley frame members 150, 162 and 152, 164, respectively; whereas oil filter 173 is supported by a suitable bracket member 204 affixed to frame member 152. Finally, the oil tank or reservoir 174 is supported on the trolley by a pair of right-angle braces 206, 208 suitably connected to frame members 150, 152 and 162, 164, respectively.

The electrical power connection to motor 170 (i.e., power cable 76, FIG. 2) and the various hydraulic connections between the oil pump 171, the pinion gear drive units 36, 38; heat exchanger 172; oil filter 173; and oil tank 174, have not been shown in order to avoid confusing the drawings. Suffice it to say that power cable 76 is suitably connected to the electric motor 170 the output shaft of which drives the oil pump 171. This causes the oil pump to feed high pressure oil through
suitable high pressure connections or lines to each of the pinion gear drive units 36, 38 and to each of the brake units 188, 190 coaxially mounted thereon. Low pressure connections then feed the oil exhausting from the pinion gear drive motors and/or brake units to and through the oil filter and thence to and through the heat exchanger. After being cooled in the heat exchanger the oil is then fed through suitable connections to the oil tank or reservoir from which a return line carries the cooled filtered oil back to the oil pump to begin the cycle again. Finally, it will be appreciated that suitable connections (not shown) are provided extending from the control on working platform 160 to the electrical motor 170, the pinion gear drive units 36, 38 and brake units 188, 190 for the purpose of carrying actuation or control signals to the actuating mechanisms or control devices (solenoids, relays, valves, etc.) located on or with these components.

In a typical hoist installation, say, where the tower height is approximately 500 feet, the average linear speed of the hoist cage is 500 fpm, the running payload or capacity of the hoist cage is 5,000 lbs. and the dead weight of the hoist cage (empty) is approximately 2,000 lbs., the amount of counterweight utilized will typically be equal to the dead weight of the hoist cage plus one-half the capacity or 4,500 lbs. Accordingly, enough power must be made available to the pinion gears to propel at 500 fpm the difference between the sum of the dead weight of the hoist cage and the cage capacity (i.e., 7,000 lbs.) and the sum of the dead weight of the counterweight trolley and the drive components mounted thereon (i.e., the total counterweight or 4,500 lbs.). Thus, in the example given above enough power output will be needed to propel 2,500 lbs. at 500 fpm. Once the power requirement is calculated the proper size drive components may be selected. This will normally determine the weight of the drive components which when added to the weight of the trolley itself should total 4,500 lbs. Obviously, when the weight of the drive components mounted on the trolley is insufficient to provide the correct amount of counterbalancing, additional counterweight may suitably be added to the trolley 14, as for example, by attaching dead weights to a convenient location on the trolley frame.

An alternative preferred method of adding the additional counterweight under such circumstances may be employed in the form of a separate auxiliary trolley having a series of dead-weights supported thereon in the conventional manner. The auxiliary trolley is adapted for up and down movement with the main trolley along the Z-shaped guide rails on the tower by a series of guide roller units similar to those used on the main trolley, and is connected to the main trolley by suitable attaching means. Preferably, the attaching means is readily disconnectable so that the auxiliary trolley may be removed from the main trolley when desired.

In any event, it will be noted in connection with the present invention that by mounting the drive components on the counterweight trolley instead of on the hoist cage as is the usual practice, the dead weight loading due to the drive components need no longer be counterbalanced by a separate and equivalent counterweight thus effectively reducing the total dead weight loading on the hoist tower by twice the dead weight of the drive components.

As mentioned above, each motor drive unit 36, 38 may be of the hydraulically actuated type and includes coaxially mounted therewith a hydraulically actuated brake unit 188, 190, respectively. Inasmuch as the details of the drive motors and their associated brake units form no part of the present invention, such details will not be discussed herein, it being sufficient for a complete understanding of the present invention to state only that these motor-brake units are responsive to the controlled flow of pressurized hydraulic fluid or electric current to either rotate or prevent the rotation of the pinion gears engaging the rack member on the hoist tower. Thus, as shown in greatest detail in FIG. 7, each motor-brake unit includes an output shaft 210 extending through a suitable aperture provided in each mounting plate 192. The output shaft 210 of each motor-brake unit has suitably affixed thereto a pinion gear 39 which cooperatively engages or meshes with the gear-toothed portion 112 of the rack member 34 vertically affixed to the tower as described above. Rotatably mounted on the rear side of each supporting plate 192 is a guide roller 216 cooperatively engaging the smooth flat portion 114 of the rack member 34 for the purpose of maintaining the pinion gear 39 in positive engagement with the gear-toothed portion 112 of the rack member as the pinion gears ride upon the gear-toothed portion.

In accordance with another important feature of the present invention, the two pinion gear motor-brake units 36, 38 are longitudinally displaced substantially along the axis or centerline of the trolley 14 load a distance "a" as shown in FIG. 5A. The distance a is purposely chosen to be greater than the length (or height) "h" of each individual tower section 16 so that at any given moment there is only one pinion gear cooperatively engaging the rack member section 102 of each individual tower section with the other pinion gear always engaging the rack member section 102 on another or neighboring tower section. By this arrangement the load on the bearings acting on the rack member caused by the engagement therewith of the driven pinion gears are distributed over at least two tower sections instead of one resulting in a smoother ride with less vibration, and less wear and tear on the pinion and rack assembly as would otherwise occur. In prior rack and pinion gear hoist systems, the driven pinion gears mounted on the hoist cage engage the rack member sections on a single individual tower section, and the reactive movement of the pinion gears acting on a single tower section tends after a while to loosen the connections between the individual tower sections. By longitudinally or axially displacing a plurality of pinion gear motor-drive assemblies on the counterweight trolley as contemplated by the present invention, the reactive moments produced by the pinion gears are always distributed over at least two individual tower sections and thus reduces the tendency to loosen the connections therebetween. Of course, it will be understood that more than two pinion gear motor-drive units may be employed on the counterweight trolley in which case the various motordrive units would preferably be positioned in the displaced longitudinal manner described above in connection with FIG. 5A.

It will further be observed especially in connection with FIGS. 4, 5, and 5A that the various components in the motor drive system are preferably mounted on the trolley 14 in a generally linearly spaced relation
(one on top of another so to speak) with the result that the center of gravity of the trolley is located only a short distance or moment arm from the plane of the pinion gears and rack member. This further minimizes the torque loads of reactive moments on the pinion gears which might otherwise tend to twist out the latter with respect to the rack member and accordingly, greatly reduces wear on these components and increases the reliability of the hoist system. Similarly, it will be noted that the various components mounted on the counterweight trolley 14 preferably have their center of gravity located near the latter's centerline or central longitudinal axis thereby minimizing any torques which might tend to rotate the carriage in the plane defined by the guide rails 30 and 32 during motion of the trolley on the tower. This in turn, further assures smooth and quiet operation and less wear and tear on the pinion gear and rack assemblies.

As mentioned above, and in addition to the guide rollers 216 acting to maintain positive engagement of pinion gears 39 with the rack member, there is further provided a series of four main guide roller units generally indicated by referenced numeral 217 mounted on each corner of the trolley 14 for the purpose of defining and maintaining a smooth vertical path of travel for the trolley on the tower. Preferably, each main guide roller unit 217 includes three pairs of rollers for cooperatively engaging the forward and laterally extending guiding surfaces respectively defined by each Z-shaped rail 30, 32 affixed to the trolley side of the tower. Thus, as shown schematically by way of example in FIG. 8, a main guide roller unit 217 is mounted on the left-most portion of the upper surface of the upper I-beam 153 of trolley 14 and includes a first pair of guide rollers 218, 220 engaging the outwardly facing surface 96 of Z-rail 32, a second pair of guide rollers (only one of which is shown, i.e., roller 219) engaging the oppositely facing surface 98 of the Z-rail 32, and a third pair of rollers 224, 226 engaging the freely extending vertically disposed edge 100 of the Z-rail 32. Each pair of rollers is carried by an arm 227 which in turn is mounted on a common bracket structure 228 affixed to the upper surface of the trolley's I-beam 153. The arm 227 carrying each pair of rollers preferably is connected to the supporting bracket 228 in such a manner as to allow limited pivotal displacement or rocking of the arm and therefore of the rollers about a horizontal axis parallel to the surface or edge being engaged by that pair of guide rollers. Guide roller units of the foregoing type are commercially available and the structural details of such roller guide units are more fully disclosed.

Inasmuch as the surfaces on each Z-rail engaged by the first, second, and third pair of rollers of each corresponding main guide roller unit 217 are at right angles to each other and are either parallel or perpendicular to the face of the tower immediately adjacent the trolley 14, it is apparent that the four main guide roller units located on each corner of the trolley, respectively, act to prevent lateral displacement of the trolley (either towards or away from) during the latter's travel upwardly and downwardly along the tower. Moreover, since each guide roller unit preferably has its separate pairs of guide rollers mounted on an arm and bracket assembly permitting limited rocking motion of each pair of rollers about a horizontal axis parallel to each engaged surface or edge on the Z-rail, the main guide roller units furthermore assure that the trolley's vertical motion on the tower will be smooth and relatively vibrationless and noisefree. As indicated in FIG. 7, similar Z-shaped guide rails 26, 28 may be provided on the hoist cage side of the tower. When this is done the hoist cage 12 preferably will be provided with similar main guide roller units 217 thereby affording the same smooth, vibrationless quiet-riding qualities to the hoist cage as it ascends and descends along one side or portion of the tower by the action of the trolley's pinion gears riding upon the rack member affixed to another side or portion of the tower.

It should be apparent also that in the event the substantially U-shaped guide rails are employed instead of the Z-shaped rails shown, the main guide roller units 217 will be mounted on the trolley and/or cage in an outboard manner with respect to each pair of guide rails on either side or portion of tower respectively, rather than being mounted inboard with respect to same as is the case when the Z-shaped guide rails are used.

Moreover, and independent of the particular form of the guide rails or main guide roller units employed it will be noted that the present invention effectively prevents torque loads due to the loading of heavy equipment in the hoist cage, or due to the dead weight of the hoist cage itself, from being transmitted to the pinion gears and rack member since these parts are located on a portion or side of the tower other than that along which the hoist cage travels.

In prior art systems where the pinion gear drive apparatus is supported directly on or by the hoist cage, the weight of the payload in the hoist cage acts along a relatively long moment arm and accordingly, a significant torque loading or reactive moment is directly transmitted to the rack and gear assembly adjacent the hoist cage resulting in a more rapid wearing of these parts. In the present invention, however, since the drive components are mounted on the counterweight trolley which, in turn, is located on a side or portion of the tower remotely disposed with respect to the hoist cage, the usual torque loads resulting from the payload in the hoist cage and which act along the relatively long moment arm produced by the generally substantial extension of the hoist cage outwardly from the tower, are effectively isolated from the rack member and pinion gears engaged therewith.

As mentioned above, a still further advantageous feature of the present invention resides in the capability of using both the trolley and the hoist cage as working platforms when it is desired to raise or increase the height of the mast or tower, as for example during the construction of a multistory building where the hoist tower is initially raised to a first level until construction is completed at that level, and then is raised again as construction proceeds to the next higher level, and so on. Thus, to illustrate, assume the hoist system of the present invention is being employed during the construction of a forty story building and that originally, the hoist tower was raised to the twenty story level. Now suppose construction is completed at this level and it is desired to raise the height of the tower to say the thirty story level in order to complete the next stage of construction of the building. In order to accomplish
this with the hoist system of the present invention, the trolley initially is driven to its uppermost position on the tower until the cage comes to rest at the bottom landing position of the tower. A number of individual tower sections 16 are loaded onto the roof of the hoist cage and the trolley is then propelled downwards on the tower until it comes to rest at the bottom landing position of the tower and the hoist cage carrying the individual tower sections is located at the uppermost position or twentieth story level on the tower. At this point, the hoist cage is temporarily anchored in place to the tower in a manner well known in art and the lifting cables 40, 42 are disconnected from the trolley’s hitch members 44, 46 by removing the fastening means at 157 (FIGS. 4 and 8). If needed, an additional plurality of individual tower sections may then be loaded onto the working platform 160 of the trolley and the latter subsequently is propelled upwards on the tower and brought to rest at the uppermost position on the tower opposite to the anchored hoist cage (i.e., the twentieth story level). The cathead assembly is then removed from the top of the tower by disconnecting the cathead yoke members 52 and is temporarily stored on the hoist cage roof. By using the trolley and its working platform 160 as a mobile lifting platform the individual tower sections 16 may then be installed in position on the tower one about the other as explained above in connection with FIGS. 3, or 3A and 3B, until the new thirty story tower height is achieved. When this occurs the cathead assembly is raised from the roof of the hoist cage (anchored at the twenty story level) to the newly raised top of the tower ten stories above, again through utilization of the trolley as a mobile work or lifting platform which is able to travel upwardly and downwardly on the newly installed tower sections 16 between the anchored hoist cage and the new top of the tower by virtue of the trolley’s pinion gears riding on the gear-toothed rack member 34 which, in turn, has also been raised an additional ten stories. It will be appreciated that before the cathead assembly has been securely repositioned in place at the top of the tower (now thirty stories high) the lifting cables 40, 42 and the control cable (e.g., cable 64) are sufficiently lengthened by an amount equal to the ten story rise as by suitably manipulating the cable storage reels 54, 56 and 66 on the roof of the hoist cage. Accordingly, the lifting cables and the control cable will extend upwardly from the hoist cage through the newly positioned cathead assembly and thence downwardly along the trolley side of the tower whereupon the free ends of these cables will be located at approximately the ten story level of the tower. The trolley is driven to the last mentioned level and the cables reconnected to the hitch members 44, 46 and the control station, respectively. When this has been accomplished the hoist cage may then be released from its anchored position on the twenty story level of the tower and normal operation of the hoist system commenced on a tower now having a height of 30 stories. Obviously, the foregoing procedure may be repeated until the final forty story height of the tower is realized. It is thus seen that the novel hoist system of the present invention enables the use of the hoist cage as an elevated stationary sub-platform or storage work area on the tower and the concomitant use of the trolley with its own platform as a mobile erection platform during the raising of the hoist tower and thereby permits such raises of the tower to be accomplished in a more efficient and less time-consuming manner than has heretofore been possible with prior art hoist systems of the rack and pinion type.

And although the present hoist system has been described in considerable detail by reference to particular preferred embodiments thereof, it will be understood that many modifications and variations of the invention may occur to those skilled in the art. For example, in situations where an extremely high lift capacity is desirable, a single four-sided tower or mast may be provided with two independently operable counterweight drive hoist systems, i.e., a first lifting cage and counterweight drive unit disposed on one side of the tower and a second lifting cage and counterweight drive unit disposed on the remaining two sides of the tower, respectively.

Accordingly, the present invention should be limited only by the spirit and scope of the appended claims.

What is claimed is:

1. A hoist system comprising, a substantially vertically disposed tower, lifting means adapted to be supported on said tower for conveying personnel and/or material vertically along a first path of movement defined by one portion of said tower, counterweight means supported on said tower and being adapted for controlled powered movement vertically along a second path of movement defined by another portion of said tower, means adapted to be connected between said lifting means and said counterweight means for causing related movement of said lifting means along said first path in response to powered movement of said counterweight means along said second path, said lifting means including control means thereon, said hoist system further including means coupled to said counterweight means and being responsive to actuation of said control means on said lifting means for effecting controlled powered movement of said counterweight means along said second path, said hoist system further including control means on said counterweight means, said means for effecting controlled powered movement of said counterweight means along said second path being responsive to said last-mentioned control means for effecting controlled powered movement of said counterweight means along said second path independent of actuation of said first-mentioned control means on said lifting means.

2. The hoist system of claim 1 further including a horizontally disposed work platform fixed to said counterweight member for movement therewith.

3. The hoist system of claim 1 wherein said tower comprises a plurality of individual tower sections affixed together one above the other, each of said individual tower sections including a vertically disposed rack member section affixed thereto, said rack member sections defining a unitary rack member affixed to said another portion of said tower when said plurality of individual tower sections are affixed together as aforesaid, said counterweight member having a horizontally disposed working platform, and at least one motor driven pinion gear assembly supported thereon, said motor driven pinion gear assembly cooperatively engaging said unitary rack member for effecting said controlled movement of said counterweight member along said second path.
4. The hoist system of claim 1 wherein said last-mentioned control means is manually actutable.

5. The hoist system of claim 4 further including control cable means extending from a position remote from said tower to said last-mentioned control means on said counterweight member for controlling powered movement of said counterweight member from said remote position.

6. The hoist system of claim 1 wherein said tower includes a vertically disposed rack member affixed to said another portion thereof, and said means coupled to said counterweight means includes at least one motor driven pinion gear cooperatively engaging said rack member for effecting said controlled powered movement of said counterweight means along said second path of movement.

7. The hoist system of claim 1 wherein said means adapted to be connected between said lifting means and said counterweight means includes cable means and means supported by said tower for guiding said cable means from said one portion of said tower to said another portion of said tower.

8. The hoist system of claim 1 wherein said tower includes a cable guiding assembly mounted on the upper portion thereof, said means adapted to be connected between said lifting means and said counterweight means including at least one lifting cable adapted to be directly connected between said lifting platform and said counterweight member, said at least one lifting cable extending upwardly from said lifting platform through said cable guiding assembly and downwardly to said counterweight member.

9. A hoist system comprising:
   a substantially vertically disposed tower;
   a lifting platform adapted for conveying personnel and/or material upwardly and downwardly along a first path of movement defined by one portion of said tower;
   a counterweight member adapted for controlled powered movement along a second path of movement defined by another portion of said tower; and
   means operatively coupling said lifting platform with said counterweight member such that powered movement of said counterweight member along said second path causes related movement of said lifting platform along said first path, said counterweight member simultaneously serving as a counterweight for said lifting platform during said related movement;
   said tower including a first cable guiding assembly mounted on the upper portion thereof, said operatively coupling means comprising at least one lifting cable directly connected between said lifting platform and said counterweight member, said at least one lifting cable extending upwardly from said lifting platform through said cable guiding assembly and downwardly to said counterweight member;
   said lifting platform including control means thereon, said hoist system further including means coupled to said counterweight member and being responsive to actuation of said control means on said lifting platform for effecting controlled powered movement of said counterweight member along said second path;
   said tower further including a second cable guiding assembly, said hoist system further including a control cable connected at one end thereof to said control means on said lifting platform and at the other end thereof to said means coupled to said counterweight member, said control cable extending from said lifting platform through said second cable guiding assembly to said means coupled to said counterweight member.

10. The hoist system of claim 9 wherein said second cable guiding assembly is mounted at the lower portion of said tower, said control cable extending downwardly from said lifting platform through said second cable guiding assembly and upwardly to said means coupled to said counterweight member, said control cable serving the dual function of counterbalancing the weight of said at least one lifting cable.

11. The hoist system of claim 9 wherein said second cable guiding assembly is mounted at the upper portion of said tower, said control cable extending upwardly from said lifting platform through said second cable guiding assembly and downwardly to said means coupled to said counterweight member.

12. The hoist system of claim 9 wherein said counterweight member includes a horizontally disposed work platform supported thereon.

13. A hoist system comprising:
   a substantially vertically disposed tower, means for conveying personnel and/or material upwardly and downwardly along a first path of movement defined by one portion of said tower, means adapted for controlled powered movement along a second path of movement defined by another portion of said tower, and means operatively coupling said first-mentioned means with said second-mentioned means such that powered movement of said second-mentioned means along said second path causes related movement of said first-mentioned means along said first path, said second-mentioned means simultaneously serving as a counterweight for said first-mentioned means during said related movement,
   wherein said tower comprises a plurality of individual tower sections affixed together one above the other, each of said individual tower sections including a vertically disposed rack member section affixed thereto, said rack member sections defining a unitary vertically disposed rack member affixed to said another portion of said tower when said plurality of individual tower sections are affixed together as aforesaid; said second-mentioned means comprising a frame member including means for guiding said frame member along said second path of movement, and a plurality of motor-driven pinion gear assemblies, said plurality of pinion gear assemblies being mounted on said frame member in substantially vertically disposed longitudinal displacement with respect to each other, said longitudinal displacement being at least greater than the height of each of said individual tower sections whereby each of said plurality of pinion gear assemblies is maintained at any given moment in cooperative engagement with the rack member section on a different one of said individual tower sections respectively.

14. The hoist system of claim 13 wherein said frame member includes a horizontally disposed work platform laterally extending therefrom.
15. In a hoist system comprising a substantially vertically disposed tower, said tower comprising, a plurality of individual tower sections affixed together one above the other, a lifting platform for conveying personnel and/or material upwardly and downwardly along a first path of movement defined by one portion of said tower, a counterweight member adapted for controlled powered movement along a second path of movement defined by another portion of said tower, said counterweight member having a substantially horizontally disposed work platform, means operatively coupling said lifting platform with said counterweight member such that powered movement of said counterweight member along said second path causes related movement of said lifting platform along said first path, said counterweight member simultaneously serving as a counterweight for said first-mentioned means during said related movement, said tower including a cable guiding assembly mounted on the upper portion thereof, said operatively coupling means comprising at least one lifting cable directly connected between said lifting platform and said counterweight member, said at least one lifting cable extending upwardly from said lifting platform through said cable guiding assembly and downwardly to said counterweight member, the method of raising the height of said tower comprising the steps of:

a. effecting controlled powered movement of said counterweight member to the upper portion of said second path whereby said lifting platform is positioned at the lower portion of said first path,
b. loading a plurality of said individual tower sections onto said lifting platform,
c. effecting controlled powered movement of said counterweight member to said lower portion of said second path whereby said lifting platform is positioned at the upper portion of said first path,
d. temporarily anchoring said lifting platform to said first guide means supported on said one portion of said tower,
e. disconnecting said at least one lifting cable from said counterweight member,
f. effecting controlled powered movement of said counterweight member to a position on said tower substantially equal in height to that of said anchored lifting platform,
g. removing said cable guiding means from the upper portion of said tower and temporarily storing same on said lifting platform, and
h. affixing said plurality of said individual tower section on said lifting platform on said tower one above the other by effecting controlled powered movement of said counterweight member upwardly along said second path as said individual tower sections are affixed together above one the other until the new height of said tower is reached, said counterweight member horizontally disposed work platform serving as a mobile work platform for raising each individual tower section as it is affixed in place on each previously installed tower section.

16. Apparatus for lifting personnel and/or material from a first position to a second position elevated with respect to said first position comprising:

a supporting mast, said mast having first and second vertically disposed guide means, a lifting platform adapted to be movably displaced along said first guide means between said first position and said second position, counterweight means adapted to be movably displaced along said second guide means between said first position and said second position, means supported on said mast for operatively connecting said lifting platform to said counterweight means, and drive means carried by said counterweight means for causing movable displacement of said counterweight means and of said lifting platform along said second and first guide means respectively,

wherein said counterweight means comprises first and second counterweight members adapted to be movably displaced along said first guide means between said first and second positions on said mast, said first counterweight member carrying said drive means and being connected to said operatively connecting means, and said second counterweight member carrying a series of dead weights and being connected to said first counterweight member.

17. The apparatus of claim 16 wherein said second counterweight member is adapted to be disconnected from said first counterweight member to permit the latter to be movably displaced between said first and second positions independent of said second counterweight member.

18. Apparatus for lifting personnel and/or material from a first position to a second position elevated with respect to said first position comprising:

a supporting mast, said mast having first and second vertically disposed guide means, a lifting platform adapted to be movably displaced along said first guide means between said first position and said second position, counterweight means adapted to be movably displaced along said second guide means between said first position and said second position, disconnectable means adapted to be supported on said mast for connecting said lifting platform to said counterweight means, drive means carried by said counterweight means for causing movable displacement of said counterweight means along said second guide means, first control means on said counterweight means, said drive means being operatively responsive to actuation of said first control means to cause said movable displacement of said counterweight means along said second guide means, and second control means on said lifting platform, said drive means being operatively responsive to actuation of said second control means to cause related movable displacement of said counterweight means and of said lifting platform along said second and first guide means, respectively, when said disconnectable means supported on said mast is connecting said lifting platform to said counterweight.

19. The apparatus of claim 18 in which said disconnectable means adapted to be supported on said mast for connecting said lifting platform to said counterweight means includes a cable guide assembly adapted to be mounted on the upper portion of said mast and disconnectable cable means extending between said lifting platform through said cable guide assembly to said counterweight means.
20. The apparatus of claim 18 in which said mast supports a vertically disposed gear-toothed rack member in substantially juxtaposed relation to said second guide means, and said drive means includes at least one pinion gear assembly cooperatively engaging said gear-toothed rack member and motor drive means for causing said at least one pinion gear assembly to ride upon said gear-toothed rack member thereby causing said movable displacement of said counterweight means.

21. The apparatus of claim 20 wherein said second guide means comprises a pair of spaced apart substantially vertically disposed guide rails supported by said mast, and said counterweight means comprises a substantially rectangularly-shaped frame member adapted for up and down movement relative to said guide rails in juxtaposed relation to said gear-toothed rack member, said drive means being supported on said frame member.

22. The apparatus of claim 21 wherein each of said guide rails includes a transverse extremity extending forwardly and laterally with respect to said mast and said frame member includes a plurality of guide roller units cooperatively engaging each of said guide rail extremities respectively.

23. The apparatus of claim 22 wherein each of said guide rails has a substantially Z-shaped transverse cross-section defining two spaced apart parallel portions, one of said portions being integral with said mast and the other of said portions comprising said transverse extremity extending forwardly and laterally with respect to said mast.

24. The apparatus of claim 22 wherein each of said guide rails has a substantially U-shaped transverse cross-section defining two spaced apart parallel portions, one of said portions being integral with said mast and the other of said portions comprising said transverse extremity extending forwardly and laterally with respect to said mast.

25. The apparatus of claim 21 wherein said mast comprises a plurality of individual mast sections connected together one above the other, each of said individual mast sections comprising a plurality of vertically disposed corner post members and a plurality of substantially horizontally disposed rib members connected between said corner post members, each of said individual mast sections including fastening means enabling it to be connected to neighboring individual mast sections.

26. The apparatus of claim 25 in which said pair of guide rails comprises individual guide rail sections connected to a like plurality of said corner post members respectively.

27. The apparatus of claim 25 in which said pair of guide rails comprises individual guide rail sections integral with a like plurality of said corner post members respectively.

28. The apparatus of claim 26 in which each one of said pair of individual guide rail sections has a transverse cross-section defining two parallel spaced apart laterally extending portions, one of said portions being connected to a corner post member, the other of said portions defining a transverse extremity extending forwardly and laterally with respect to said corner post member.

29. The apparatus of claim 28 in which said transverse cross-section is substantially Z-shaped.

30. The apparatus of claim 28 in which said transverse cross-section is substantially U-shaped.

31. The apparatus of claim 27 wherein said like plurality of said corner post members each has a transverse cross-section defining two parallel spaced apart laterally extending portions, one of said portions defining said corner post member, the other of said portions defining said individual guide rail section wherein said individual guide rail section comprises a transverse extremity of said corner post member extending forwardly and laterally with respect to said one portion defining said corner post member.

32. The apparatus of claim 31 wherein said transverse cross-section is substantially Z-shaped.

33. The apparatus of claim 31 wherein said transverse cross-section is substantially U-shaped.

34. The apparatus of claim 25 wherein said pair of guide rails comprises individual guide rail sections adapted to be connected to a like plurality of said corner post members respectively, said fastening means being adapted to connect said individual guide rail sections to corresponding corner post members respectively, and to simultaneously connect the corner post members on said individual mast section to corresponding corner post members on neighboring individual mast sections.

35. The apparatus of claim 34 wherein each of said corner post members on said individual mast sections includes a hollow bore portion in its upper and lower extremities respectively, said fastening means comprising a longitudinally extending member adapted to be receivably engaged in telescoping relation within each of the hollow bore portions common to a pair of corresponding corner post members located on neighboring individual mast sections respectively, and means connecting each of said pair or corresponding corner post mast members to said longitudinally extending member.

36. The apparatus of claim 35 in which said connecting means comprises a pair of bolt fastening elements extending through said pair of corresponding corner post members respectively, and said longitudinally extending member.

37. The apparatus of claim 35 in which said connecting means comprises a pair of bolt fastening elements extending through a pair of individual guide rail sections respectively, said pair of corresponding corner post members respectively, and said longitudinally extending member.