TELESCOPIC MASTS OR TOWERS

Inventor: Donald Edward Wellman, Komoka, Ontario, Canada

Assignee: General Crane Industries Limited, London, England

Filed: Nov. 2, 1972

Appl. No.: 303,041

Foreign Application Priority Data
Nov. 4, 1971 Great Britain 51288/71
Mar. 16, 1972 Great Britain 12480/72

U.S. Cl. 212/57
Int. Cl. B66c 23/06
Field of Search 212/30, 144, 55, 57

References Cited
UNITED STATES PATENTS
3,462,023 8/1969 Grove 212/144 X
3,465,899 9/1969 Reuter et al. 212/144 X

Primary Examiner—M. Henson Wood, Jr.
Assistant Examiner—Gene A. Church
Attorney, Agent, or Firm—Brady, O’Boyle & Gates

ABSTRACT

A telescopic mast or tower, particularly the tower of a mobile tower crane, in which the sections are telescopically extendible by a hydraulic cylinder and have wedging means on adjacent sections which come into engagement when the adjacent tower sections are fully extended relative to each other. The wedging means both limit extension of the tower sections and hold these rigidly together when extended. The hydraulic cylinder is constantly maintained under pressure while the crane is operating to maintain the pressure between the wedges and to reduce or eliminate compressive stress in the tower.

27 Claims, 6 Drawing Figures
TELESCOPIC MASTS OR TOWERS

The present invention relates in general to telescoping structures and particularly to telescoping towers for example for tower cranes. Such structures may however be used for many different purposes, for example as masts for supporting mobile fire-fighting or rescue devices.

Known telescoping towers for cranes are of several types. One type is that used in the static type of tower crane, in which the tower is firmly fixed to the ground or to a building, the tower being rigid enough to support a turntable at its top carrying a jib which can rotate about the tower axis. Tower cranes of this type are often made with two telescoping tower sections, one section sliding within the other. As far as Applicant is aware, fixed tower cranes of this type have never been made with more than two tower sections, this being at least partly due to the lack of rigidity in the joints between the tower sections.

Another type of tower is that used in mobile tower cranes. In this case, the tower is generally a light structure designed to take loads almost entirely in compression rather than in bending, and forces which would otherwise cause bending of the tower are taken by cables which pass up the rear side of the tower (in relation to the load position). Such cables may also serve to support a jib mounted for luffing movement (i.e., movement in the vertical plane) at the top of the tower. Due to the use of cables, towers used in cranes of this type do not have to withstand heavy bending forces, and there have been proposals to make towers for cranes of this type with more than two telescoping sections.

A further and novel type of mobile tower crane is known from my Canadian Pat. No. 842,040, issued May 19, 1970, and from my copending U.S. Pat. application No. 144,199, filed May 17, 1971. This mobile tower crane uses a rigid self-supporting type of tower generally similar to that used in the static tower cranes referred to above, the tower being rigid enough to withstand bending moments in different directions without being stayed by cables, and having a turntable for a boom at its upper end. The boom of this crane is luffed by hydraulic cylinder means, so that in this crane the use of cables (except that for the crane hook) is entirely avoided.

The object of the present invention is to provide an improved telescoping structure giving good rigidity between adjacent telescoping sections when extended, and which is also of relatively light weight. In accordance with one aspect of the present invention, there is provided a structure having at least two telescoping sections slidably arranged one within the other, a fluid cylinder and piston means connected between the outermost and innermost sections for causing the sections to extend when the cylinder is supplied with pressurized fluid, and in which each section carries wedging means entering into engagement with the wedging means of an adjacent section when said sections are telescoped apart, said wedging means being effective to hold the two sections rigidly together when the sections are at their maximum extension, the wedging means limiting relative extension of these two sections by the fluid cylinder and piston means.

The wedging means include co-operating parallel wedge surfaces arranged at a small angle to the structure axis, this angle being substantially less than 45°, and preferably of the order of 10°.

In the simplest case, a single wedge surface would be arranged on each structure section, arranged to engage with a similar parallel surface on the adjacent structure section. In this case, such wedge surfaces would in effect co-operate with other opposed surfaces limiting relative lateral movement between the structure sections to complete the wedging effect. In the preferred embodiment, however, the opposed surfaces are also wedge surfaces, so that on each section there is provided at least a pair of wedge surfaces, the surfaces of said pair being inclined at opposite small angles to the axis of the structure.

Where the structure is required to withstand bending forces in different directions, at least two wedging means are provided for each adjacent pair of structure sections each being arranged to give rigidity to the tower in a plane at right angles to the other. In the preferred embodiment the sections are square in cross-section, and wedging means are arranged on each of the four sides of each section.

In order to give good rigidity between adjacent structure sections, without having single wedge surfaces of excessive length, the wedge surfaces preferably include two separate portions located respectively near the ends of the overlap of the sections when extended. The vertical spacing between the extreme ends of the wedge surface portions (i.e. the effective length of the wedge surfaces) is preferably at least equivalent to the width of a structure section, and may be of the order of one fifth, or at least one sixth, of the length of a tower section.

The wedge surfaces may be formed by the edges of plates welded respectively to the inside of one end of an outer structure section and to the outside of the end of the next inner section which is adjacent to said one end when extended.

In order for the wedging means to operate effectively, the force provided by the fluid cylinder and piston combination must be sufficient for the wedge surfaces to be pressed continuously into firm contact. In the case of a structure which is not subjected in use to any external loading, but which may be used in a vertical or near vertical position, fluid pressurizing means are provided for continuously maintaining fluid in the cylinder at a pressure substantially higher than the minimum pressure required for raising the movable section or sections and parts fixed thereto to the extended position, in order to maintain pressure between the wedge surfaces. In the case of a tower for a crane or like device having load handling means at the top of the tower, the fluid pressurizing means must be capable of continuously maintaining pressure in the cylinder such that the force applied thereby is at all times greater than the total weight of the movable sections and parts attached thereto when the crane or like device is carrying its maximum permitted load. By “movable sections” is meant those telescoping sections of the structure which must be held extended against the force of gravity.

It is believed to be quite novel in the crane art to provide a tower for a crane which is extendible by a fluid cylinder having pressurizing means capable of maintaining pressure in the cylinder such that the force given by the cylinder can be continuously maintained at a value higher than the total weight of the parts to
be lifted, including the load to be lifted by the crane. Although it is known to provide telescopic towers for cranes which are extendible by hydraulic cylinder means, in the known designs the telescoping sections are fixed in extended position by means of pins, latches or the like, after which the fluid pressure is released. This means that in operation the tower is subject to high compressive stress caused by the weight of the tower, the jib and/or other parts carried by the tower, and by the weight being lifted. In addition, the tower may carry substantial bending moment, which itself causes increased compressive stress in the members on the side of the tower adjacent to the load. The need to ensure that tower members do not buckle under this compressive stress is a critical factor in tower design. The use in accordance with the invention of fluid cylinder means which continuously applies forces greater than the weight of the movable tower sections and parts carried thereby, including the load being lifted by the crane, relieves the tower structural members of a large part of the compressive stress present in conventional designs. In practice, with the invention, the whole length of the tower may be maintained in continuous overall tension even while operating, although it will be appreciated that where the tower is subject to substantial bending moment there will still be some compressive stress in the tower members on one side of the tower. The fact that the structural members of the tower are subject to reduced compressive stress means that the tower sections can be made lighter, by about 10 percent to 20 percent, than would be the case in a conventional tower in which all compressive stress is taken by the structural members of the tower sections. This advantage is independent of the improved rigidity given by the wedging surfaces, and would still be apparent even if the wedging surfaces were to be replaced by some other interengaging means limiting the extension of the tower sections.

The wedging means described are convenient in providing means which both limit the relative extension of two tower sections, and which also limit (and in fact virtually prevent) angular movement (or sway) between adjacent fully extended sections. It is possible to envisage other inter-engaging means performing a similar function, for example having sliding and abutting surfaces, the abutting surfaces limiting extension of the two adjacent sections, and the sliding surfaces being close enough to prevent angular movements between the sections. The sliding surfaces would only need to interact over only a very short distance relative to the lengths of the tower sections, and so could be machined to close tolerances, these being considerably less than the relatively large clearances between sliding surfaces guiding the majority of movement of the tower sections.

In accordance with another aspect of the invention, therefore, a telescoping tower structure comprises, in combination:

a. a lowermost tower section and one or more movable, upper tower sections telescopically mounted on said lowermost tower section and having cooperating sliding surfaces;

b. hydraulic cylinder and piston means interposed between the lower end of the lowermost tower section and the upper end of the uppermost tower section;

c. inter-engaging means arranged at the upper end of the lowermost tower section, at both ends of any intermediate tower section, and at the lower end of the uppermost tower section, the inter-engaging means of each tower section cooperating with complementary inter-engaging means of an adjacent section when said telescoping tower sections are telescoped apart and the tower structure is in erected condition, said inter-engaging means both limiting extension of the tower sections and also limiting relative angular movement between adjacent fully-extended sections to an amount considerably less than the angular movement permitted by said sliding surfaces; and

d. fluid pressurizing means for continuously maintaining said hydraulic cylinder and piston means under pressure and thereby to hold the tower structure in its erected condition and the respective inter-engaging means in engagement with each other.

Where the structure carries load handling means, such as in the case of a crane, the pressurizing means preferably maintains a pressure in the cylinder such that the thrust applied thereby is greater than the total weight of the movable sections and parts (such as the jib) fixed thereto, plus the maximum permitted load of the crane. This maximum permitted load is a predetermined quantity in any crane design, and would be available to a person wishing to purchase a crane or to actually purchase a crane to any particular job. Also, in preferred embodiments, the pressurizing means is such that the cylinder applies a thrust at least 25 percent higher than that force required for raising the movable section or sections and parts fixed thereto, and preferably is at least 50 percent and more particularly of the order of 60 percent, greater than this force.

The invention also includes a method for erecting and operating a tower, for example the tower of a tower crane, in the manner described above so that the structural members of the tower are stressed in optimum manner. Thus, in accordance with a further aspect of this invention, a method for erecting and operating a tower comprising a fixed section and one or more relatively movable sections telescopically mounted on said fixed section and extendible relative thereto by hydraulic cylinder and piston means comprises the steps of supplying fluid to the hydraulic cylinder at a first pressure to telescopically extend said tower sections to a desired extent as predetermined by inter-engaging means on said tower sections, and subsequently maintaining a fluid pressure in the cylinder higher than said first pressure, said higher pressure being such that the thrust applied by said cylinder is greater than the total weight of the tower sections and parts carried thereby plus the weight of any loads which in operation are carried by the tower. The thrust applied by the cylinder is preferably greater than this total weight by about 10 percent of this weight.

Furthermore, the invention includes a method of erecting and operating a tower crane which includes a tower comprising a fixed section and one or more relatively movable sections telescopically mounted on said fixed section and extendible relative thereto by hydraulic cylinder and piston means and carrying at its upper end load handling means comprising the steps of supplying fluid to the hydraulic cylinder at a first pressure sufficient to raise the movable tower sections and the load handling means carried thereby to thus extend the tower to a desired extent as predetermined by inter-engaging means on said tower sections, and operating the crane by attaching loads to the load handling means.
while maintaining a fluid pressure in said cylinder higher than said first pressure, said higher pressure being such that the thrust applied by the cylinder is at all times greater than the total weight of the movable tower sections and the load handling means plus the weight of the loads being carried by the load handling means.

The invention will now be described by way of example with reference to the accompanying drawings, in which:

FIG. 1 shows a side elevation of a tower crane incorporating the tower of this invention, when in erected condition.

FIG. 2 shows the same crane when folded into the travelling condition.

FIG. 3 shows diagrammatically the hydraulic cylinder means which causes telescoping movement of the tower sections.

FIG. 4 shows a partly sectioned detail view of the top of one tower section and the lower part of an adjacent upper tower section.

FIG. 5 shows a view of parts similar to those shown in FIG. 4, but with the tower partially collapsed, and

FIG. 6 shows a cross-sectional plan view on a corner of the tower on line 6--6 of FIG. 5.

Referring to the drawings, FIGS. 1 and 2 illustrate a crane basically similar to that described in my Canadian Patent No. 842,040 and copending U.S. Pat. application No. 144,199, but with various modifications to be described herein.

The crane is mounted on a semi-trailer vehicle 10 having a flat bed and raised sides 11 arranged to receive between them the collapsed tower 12 when this has been lowered into the horizontal position as shown in FIG. 2. The sides 11 give rigidity to the trailer without undue weight, and also give good support for a raised base mounting for the tower which includes pivot bearings 14 on the rear upper corners of the sides 11, and hydraulically operated locking means on the tower which are on the front side of the tower (i.e., that side facing the front of the vehicle) when raised and which cooperate with bearing means also on the tops of the sides 11. Further details concerning the trailer vehicle and the tower mounting are given in my copending Pat. Application No. 303,042 filed Nov. 2, 1972.

The trailer 10 also includes two front outriggers 16 in fixed positions somewhat forwards of the trailer centre, and two rear outriggers which include horizontal telescopic load supporting members 16a which are pivotal on vertical axes attached to the trailer, and which can be swung out and extended away from the trailer as shown in FIG. 1. All the outriggers include hydraulically operated ground engaging pads 16b.

The tower 12 includes four telescoping sections of lattice construction, the lowermost or base section 12a being pivotally connected at its base to the bearings 14 for movement between the horizontal position of FIG. 2 and the vertical position of FIG. 1. The tower is movable (when telescopically collapsed) between these positions by hydraulic rams 18, mounted one at each side of the tower and connected between the base tower section 12a and the chassis of the trailer vehicle. The top of the tower 12 carries a turntable 20 rotatable by hydraulic slewing means, a cab 21 mounted on the turntable, a tiltable platform 22 mounted on top of the cab and pivotal about a horizontal pivot 22a under control of a hydraulic cylinder 23, and a boom 24 pivotally mounted on the tiltable unit 22. The boom is arranged to be luffed by the hydraulic cylinders 25 (one at each side of the boom), and is also telescopically extendible under hydraulic control. The platform 22 carries a hydraulic pump driven by an engine 26, and hydraulic fluid tanks 26' for supplying hydraulic fluid to the upper part of the crane. FIG. 1 shows the boom near to its highest position, the boom being movable between this position and an approximately horizontal position by hydraulic cylinders 25. Details of various suitable arrangements for the top part of the crane including the turntable and parts mounted thereon are given in my Pat. application No. 144,199. The top parts of the crane, including the turntable 20 and all parts mounted thereon will hereinafter be referred to as the crane upper structure.

The tower sections 12a, 12b, 12c and 12d are each of similar construction but are of decreasing width so as to telescope one within the other, section 12a being the outermost section and 12d the innermost. Each tower section is constructed of box beam corner members 27, connected by a lattice work of horizontal and diagonal struts 28 which are also tubular. The suffices a, b, c, and d are used to denote the members 27 and 28 of the different tower sections. The bracing members 28 are of extra strength in the end portions of the tower sections. The nature of the box beam corner members is shown clearly in FIG. 6, which figure also shows angle members 29 welded to the inside faces of members 27. The angle members 29 have inside surfaces slideable on and providing guidance for the corner member of the next inner tower section. It may be noted that, because of inevitable inaccuracies in manufacture, a fairly substantial clearance space (about one-fourth inch) is provided between these cooperating sliding surfaces, so that these of themselves will still allow the tower sections to sway relative to each other.

The tower sections are telescopically extendible by means of a single, multi-section telescopic hydraulic cylinder 30 shown in FIG. 3. The cylinder includes four telescopic tubular sections 30a, 30b, 30c, and 30d, having decreasing diameters towards the top of the tower, each tubular section corresponding to one of the tower sections. Clearly, intermediate sections 30b and 30c act both as cylinders and as pistons. The lower end of the base tubular section 30a is welded to a base plate 31 securely fixed across the lower end of the base tower section 12a, and the upper end of the uppermost cylindrical section 30d is secured by nut 32 to a plate 32a fixed to the top of the top tower section 12d. The cylinder sections are of such a length that when the cylinder is extended each section extends upwardly from the base of one tower section to the base of the next upper tower section. Each tubular section except section 30d includes a top end closure 33, the closures 33 for sections 30b and 30c having short cylindrical portions 34 which are of the same external diameter as the closure of section 30a and bevelled portions leading radially inwardly from the cylindrical portions. The end closures 33 are engaged by stop rings 35 on the outside of the next inner tubular section, these rings 35 also forming seals. In addition, further seals 36 are provided spaced below rings 35. It will be apparent that cylinder 30 is connected between the base tower section 12a and the top tower section 12d in such manner that, when the tower is vertical and when the hydraulic cyl-
In the extended condition of the tower (FIG. 1) the two lower tower sections overlap by an amount slightly more than the width of the tower at its base, and slightly more than one fifth the length of the base tower section. The other tower sections overlap by slightly smaller amounts, these however still being more than the widths of the appropriate (larger) sections and more than one fifth the length of such sections.

In accordance with the invention inter-engaging means are provided which both limit extension of adjacent tower sections and limit relative angular movement between adjacent sections when these two sections are at their maximum extension relative to each other. The angular movement permitted (i.e., these inter-engaging means may be practically nil, but is in any case considerably less than that which would be permitted by the interaction of the sliding surfaces provided by angle members 29 and corner members 27. In this embodiment, these inter-engaging means are wedging means. These wedging means are shown in FIGS. 4, 5, and 6, and includewedging surfaces provided for by the machined inner edges of upper and lower pairs of rectangular plates 40 and 40' respectively welded to the inner edge of the top portion of the lower tower section (i.e., all tower sections except the top section and exemplified by section 12b in FIG. 4), and by the cooperating machined outer edges of upper and lower pairs of rectangular plates 41 and 41' respectively welded to the outside of the bottom of each tower section except the base section 12a (and exemplified by section 12c in FIG. 4). The suffixes a, b, c, and d are used to denote the plates 40, 40', 41, and 41' of the respective tower sections 12a, 12b, 12c and 12d.

As particularly seen in FIG. 4, an upper pair of opposed wedge surfaces is provided by the inner edges of two plates 40b welded to the inner surface of the uppermost horizontal struts 28b and the adjacent diagonal struts near the upper corners of lower tower section 12b, and a lower pair of opposed wedge surfaces is provided for by the inner edges of two plates 40'b welded to the inside surface of horizontal struts 28b' next uppermost to struts 28b on section 12b, and to the adjacent diagonal struts. Also, the lower end of section 12c has an upper pair of wedge plates 41c welded to the outside thereof adjacent the horizontal strut 28c nearest the base strut, and has a lower pair of wedge plates 41'c welded to the outside of the base strut, the outer edges of these plates 41c and 41'c providing opposed wedge surfaces which cooperate with those of plates 40b and 40'b.

It will be noted that the pairs of plates 40, 40', 41 and 41' have a horizontal spacing which is equivalent to a major portion of the tower width. More importantly, the plates of each tower section have a vertical spacing which is quite substantial in relation to the total length of the tower section, so that the effective vertical length of the wedges, i.e., the distance from the top of wedges 40 to the bottom of wedges 40', is at least one-sixth and preferably from one-fifth to one quarter the length of the lower tower section of a pair and also roughly equivalent to the width of the lower tower section of the pair. The wedge surfaces are arranged at a small angle of the order of 10° to the tower axis. Also, the lowermost pairs of plates 40 and 40' are spaced wider apart than the uppermost pairs of plates 40 so as to allow the uppermost pairs of plates 41 of an upper tower section to pass between the lowermost pairs of plates 40' without interference when the tower is being extended.

The wedging plate arrangement is symmetrical when viewed from the side of the tower, and this symmetrical arrangement described for one side of the joint between the tower sections is repeated for all four sides of the joint, so that four wedging means act around the tower at right angles to each other.

It will be apparent that the co-acting wedge surfaces act to limit extension of the tower sections by the hydraulic cylinder 30. Accordingly when the crane is operating, the wedge surfaces are constantly under pressure from the hydraulic cylinder 30 which is kept pressurized during crane operation. By virtue of the constant pressure between these surfaces, there can be no play between these surfaces, and since there is substantial vertical distance between the upper and lower pairs of wedge surfaces which are kept in contact the two tower sections are maintained quite rigid relative to each other during crane operation.

FIG. 4 also shows means carried by the base of an upper tower section (such as section 12c) for supporting the cylinder 30 against sideways movement. The base of tower section 12c is provided with a plate which carries a central guide member 43 surrounding the cylinder 30 and sized to slide over the cylindrical portion 34b of end closure 33b of the cylinder section 30b. The bases of tower sections 12b, 12c and 12d all have similar guide members, all of the same diameter, engaging the other end closures 33, so that when the tower is fully extended the cylinder 30 is supported against sideways movement at three spaced positions.

FIGS. 4, 5, and 6 also show a safety catch mechanism designed to prevent collapse of the tower should the pressure in cylinder 30 fail or be cut off. This mechanism includes two brackets 45 one at each end of one of the lowermost horizontal struts 28c of an upper tower section such as section 12c, two similar brackets being provided at the ends of the similar struts on the opposite side of the tower section to that shown. Brackets 45 have bearings supporting two parallel shafts 46 extending across the tower width, the shafts 46 carrying at their outer ends latches 47. As shown in FIG. 6, these latches 47 are vertically aligned with the outer faces of the tower section 12c and are arranged so that onwards pivoting movement their outer ends are aligned with the tops of lugs 48 welded to the inside of the corner members 27b of the next lower tower section 12b. The latches 47 are movable by links 49 attached to those latches on the side of the tower section shown in FIG. 4, the inner ends of links 49 being pivoted at 50 to a wheel 51 mounted for rotation on a short shaft 52 held by brackets 53 depending down from opposite sides of the base strut 28c. The links 49 are so arranged as to have slight resiliency in their movements, so that the pivotal connections 50 moves over-centre during rotation of wheel 51 in the anticlockwise locating direction (as viewed in FIG. 4) rotation of the wheel 51 in
this direction causing outwards movement of the latches 47 into the latch position as shown and the resiliency of the links 49 tending to maintain the latches in the position as shown, stop means being provided to prevent further movement of wheel 51 in the anticlockwise direction. The movement caused to the latches 47 shown in FIG. 4 is transmitted via the shafts 46 to the similar latches on the other side of the tower. The shaft 52 also carries a chain wheel over which passes a loose chain 56 which hangs down inside the tower and which has a length somewhat greater than a single tower section. It may be noted that a clearance space is provided between the lower end of latches 47 and the upper ends of lugs 48, so that the latches can easily be moved into the latching position when the wedge means are engaged. These latching means are unidirectional in operation, and merely serve to prevent unwanted collapse of the tower should there be a pressure failure within the cylinder 30. In normal operation, with cylinder 30 fully pressurized at all times, all the forces between tower sections are transmitted by the wedges and no forces are taken by the latching means.

FIGS. 5 and 6 also illustrate further cooperating locating means which maintain one tower section rigid relative to the next lower tower section when fully retracted therein. The upper end of each longitudinal corner member 27 of the base tower section 12a is provided with a plate 60 surmounted by a vertically extending pin 61a having a tapered and rounded top. Each tower section except the base section 12a has mounted on top of corner members 27a plate 63 which is firmly attached to the corner member and to the adjacent ends of the uppermost horizontal struts 28, and which projects diagonally from the corner member 27. Projecting upwardly from each plate 63 (except that of upper tower section 12d) is a pin 61, aligned with the corner member 27. Each plate 63 has a vertical bore which is spaced outwardly from the pin 61 associated with that plate and which is aligned with the pin 61 of the next lower tower section, so as to locate therein when the two tower sections are fully retracted as particularly shown for sections 12a and 12b in FIGS. 5 and 6. FIG. 6 illustrates plate 63b of section 12b, carrying upwardly projecting pin 61b and having a bore for receiving pin 61a. The pins 61 are made of sufficiently close fit in the bore of plate 63 that the tower sections are quite rigid relative to each other when fully retracted; the amount of angular movement (sway) being in any case limited by these locating means to an amount considerably less than that permitted by the sliding surfaces of parts 27 and 29.

In addition, the horizontal members 28a, 28b, and 28c at the tops of the three lowermost tower sections are each provided with screwed holes for bolts, which correspond with bores in the plates 63 of the next upper tower sections. When two tower sections are fully retracted relative to each other, bolts 65 may be placed in position to secure the adjacent tower sections together. The sections are secured together in this manner in two circumstances, i.e.:

1. When travelling. In this case the sections are secured together so that sudden braking of the vehicle cannot cause the sections to extend telecopsically towards the driver’s cab, and
2. When operating the crane with the tower fully retracted, or only partially extended. The crane can carry its heaviest loads with the tower fully retracted and

with the sections bolted together. If it is required to operate the crane with the tower only partly extended, this can be done by having two or more sections retracted one within the other and bolted together, the remaining section, or sections being fully extended so that the wedge means are operative. As mentioned above, the cylinder 30 applies constant thrust during operation of the crane to maintain the wedge surfaces in firm contact, so that the members 27 of the tower sections are maintained in constant tension. Thus, it is necessary to fix together tower sections which remain retracted, so that the tensile forces can be transmitted through the whole of the tower.

Since the rigidity of the extended tower depends on firm contact being maintained between the wedging surfaces, fluid pressurizing means are provided not only for pumping hydraulic fluid to the cylinder 30 during erection, but additionally for maintaining the fluid in the cylinder at a pressure substantially higher than the minimum pressure for raising the movable tower sections and the crane upper structure mounted thereon. The fluid in the cylinder is maintained at such a pressure that the tower structure as a whole is subject to overall tension even when the crane is carrying its maximum permitted load; i.e., the thrust of the cylinder is always greater than the combined weight of the movable tower sections, the crane upper structure, and the maximum permitted load. Clearly, when the tower is fully extended the movable sections will be sections 12b, 12c and 12d, whereas when partially retracted as in FIG. 5 only sections 12c and 12d can be considered as movable sections.

The fluid pressurizing means includes a hydraulic pump driven by engine 70 mounted on the front end of vehicle 10, and delivering hydraulic fluid from tanks 71 on the outside of trailer sides 11 (omitted in FIG. 2 for clarity) to the cylinder 30 at 2,400 psi. Automatic repressurizing means are provided in the form of monitoring means, for example pressure sensitive switching means arranged to re-start the pump engine 70 automatically when the pressure in cylinder 30 falls below a predetermined limit, the engine 70 being automatically shut off when the pressure in the cylinder has been raised to a higher limit. Repressurizing is required at intervals of about 30 minutes. Re-pressurizing is necessary to counteract both leakage and the effect of temperature changes causing differential expansion and contraction of the parts. Warning means are provided to prevent operation of the crane if the pressure in cylinder 30 is below a predetermined level. In such event however, leakage from the cylinder would normally be slow enough to give very ample time for the cane to be unloaded. The engine 70 and associated pump also provide the fluid pressure for the hydraulic outriggers 16a, the rams 18, and hydraulic base locking means for the tower which are described in Canadian Patent Application.

The pressure maintained in cylinder 30 by the pressurizing means is such that the total thrust in the cylinder is maintained at about 100,000 lbs. The combined weight of the three upper tower sections and the upper crane structure (i.e., all the parts carried by the upper tower section including the turntable, the boom and boom support means) is about 61,000 lbs. The thrust in the cylinder thus exceeds the weight of these parts by 39,000 lbs., or over 60 percent of the weight of these parts. The maximum permitted load on the crane, with
the tower sections fully extended, but with the boom retracted and raised so that the load is at minimum radius, is 30,000 lbs. The cylinder thrust thus exceeds the total weight of the movable tower sections, the crane upper structure, and the maximum permitted load by at about 9,000 lbs., or by about 10 percent the total weight of these parts including the load. The compressive forces in the tower members 27 on the side of the tower near to the load are therefore minimized, being always less than the tensile stress at the other side of the tower even when the tower is subjected to its maximum load.

The cylinder thrust given optimum advantages will of course depend on many factors.

Firstly, the thrust must be sufficient to support the movable tower sections, the crane upper structure (as defined above), and the maximum permitted load on the crane, the thrust preferably exceeding the total of these amounts by a substantial amount (say at least 5 percent and preferably 10 percent of this total); this ensures proper functioning of the wedging means at all times.

Secondly, the thrust to be given by the cylinder will depend on the bending moment to which the tower is subjected; the bending moment on the tower being likely to produce much higher stresses than direct loading. For example, the crane described is capable of carrying a load of 30,000 lbs displaced at 18 feet from the tower axis, giving a bending moment on the tower of 540,000 lbs; the bending moment itself (ignoring other forces) producing stresses on the tower many times as great as those produced by direct compressive forces on the tower. For these cases an advantageous cylinder thrust may be calculated by reference to the relation between the maximum permitted stresses in the tower members in tension and compression. For example, the material used in the tower described herein has a maximum permissible stress in tension of 30,000 p.s.i., and a maximum permissible stress in compression of 27,000 p.s.i. The difference in these maximum permitted stresses, i.e. 3,000 p.s.i., can be compensated for by providing cylinder thrust which gives an initial pre-stressing in the tower of the order of 3,000 p.s.i. The actual amount of tensile stress in the tower members with a cylinder thrust of 100,000 lb will decrease from top to bottom of the tower, being about 3,400 p.s.i. at the top of the tower and about 2,300 p.s.i. near the base; and will clearly be equal to the difference between the maximum permitted stresses in tension and compression (3,000 p.s.i.) in an intermediate position along the tower length. It may also be noted that the maximum tensile pre-stress in the tower (near the top) is about 1 1 percent of the maximum permissible tensile stress, and the tensile pre-stress near the base of the tower is about 7.5 percent of the maximum permitted tensile stress. The maximum tensile pre-stress in the tower (near the top) is preferably between 7 percent and 15 percent of the maximum permissible tensile stress in the tower.

In operation, the crane may be driven to a suitable site in the condition shown in FIG. 2, and when the site has been chosen the outriggers 16 are extended and put into operation, and assuming that the tower is to be operated at its maximum height all the bolts 65 locking the sections together are removed, and the collapsed tower is then raised to the vertical position by operation of the rams 18. The tower is locked in the vertical position by the hydraulic locking means described in my copending Patent application Ser. No. 303,042. In addition, the top platform 22 of the tower is brought to the operating position shown in FIG. 1 by retraction of the hydraulic cylinder means 23, this operation proceeding simultaneously with raising of the tower by rams 18 so that the platform 22 remains approximately level at all times.

The tower 12 is then extended to the desired height by pumping pressurized fluid into cylinder 30. In the first stage, sections 30b, 30c and 30d of the cylinder rise simultaneously out of section 30a, raising the uppermost tower section 12d, until the wedging means of section 12d and 12c slide into engagement with each other preventing further relative movement of the sections and effectively locking these sections together. Tower section 12c is then drawn up simultaneously with cylinder sections 30b and 30c, and lastly tower section 12b rises simultaneously with cylinder section 30a. When each tower section has been fully extended relative to the next lower section, the chain wheel 55 is rotated in the anti-clockwise direction (referring to FIG. 4) by pulling on one side of the chain 56, this chain being operated as soon as the particular tower section has been fully extended relative to the next lower tower section which is still in the collapsed position, so that the height of the wheel 55 at this point is no greater than the height of one tower section.

During extension, the pressure within cylinder 30 will be determined by the weight being lifted, which increases as successive sections of the tower are lifted out of the base section 12a. A maximum thrust of 61,000 lbs will be needed when all three top tower sections are being lifted in the final stages.

When the tower is fully extended, the crane is operated by an operator who climbs the tower and operates the crane from cab 21. Alternatively, the crane may be operated by remote control. As stated, the cylinder 30 remains fully pressurized during crane operation, and the pressurizing means are operated intermittently whenever the pressure falls below a predetermined limit. In the crane described, the pressurizing means are used to maintain the cylinder pressure at all times higher than that required for extending the tower; i.e. the pressure will normally be maintained such that the thrust exerted by the cylinder is 100,000 lb, as against 61,000 lb required to raise all the movable tower sections and the crane upper structure. It is of course within the scope of the invention to use somewhat lower pressures, providing these produce a thrust sufficient to support the tower sections which are extended, the crane upper structure and the loads being handled in any particular operation, with some margin of excess thrust to maintain pressure between the wedges. Where the tower is used in the partly extended condition, the cylinder thrust may be reduced by an amount corresponding to the tower section or sections not being held extended. The invention comprehends the method of erecting and operating the tower in the manner just described, as well as the method of moving loads, for example in constructing buildings, using a tower crane operated in the manner described.

For lowering of the tower, the safety latches between the tower section 12b and section 12a are disengaged by operation of the chain wheel 55, and fluid is released from the cylinder 30 until the tower section 12b is fully retracted within section 12a. This operation is repeated
for the remaining tower sections, until the tower is fully collapsed. Operations for folding the crane for traveling are the reverse of the operations described for erecting the crane.

It may be noted that the use of separate, vertically spaced pairs of wedging surfaces is a useful way of giving good rigidity while using short wedge surfaces. This does not however preclude the possibility of using single pairs of wedge surfaces of suitable vertical length.

It is believed that telescoping towers for cranes in accordance with this invention may have as many as seven telescoping sections. Clearly the number of sections which can be used is mainly limited by the lateral space inside the outermost tower section, and unlike known arrangements for telescopic boom cranes the use of a large number of sections does not give rise to particular difficulties with the means for extending the sections, as is the case where separate side-by-side hydraulic cylinders are used. The wedging means in accordance with the invention give very greatly improved rigidity as compared to conventional constructions. The tower can also be erected very rapidly by a single operator; the tower illustrated can be erected from the horizontal, retracted condition to the upright, extended condition, in which the top of the tower (to the boom pivot) is 139 ft. above ground level, in about twelve minutes.

The tower construction in accordance with this invention may have uses quite apart from in the crane industry. One such use is in firefighting or rescue equipment, where the tower is thought to have great possibilities in providing a quickly erected structure of greater height than that available with conventional fireman’s ladders.

For this purpose, a fire ladder may be connected to the top of the tower, the ladder being longitudinally extendable and mounted for luffing movement in manner similar to a crane boom.

As stated, the fully extended tower cylinder 30 is located at three spaced positions by guide means 43 which locate portions 34 of the end closures 33 of the cylinder section. While the cylinder is being extended, there is no support for intermediate end closures; a certain amount of side-sway in the cylinder results, although the operation has been found to be quite satisfactory. It would, however, be possible to add further rigidity to the extending cylinder by mounting the whole cylinder in inverted manner, i.e., connecting the largest cylinder portion 30a to the upper end of tower section 12d, and the smallest cylinder portion 30d to the base of tower section 12a. The cylinder would then extend with its end closures 33 constantly engaged by appropriate guide means 43.

I claim:

1. A telescoping structure comprising, in combination:
   a. a plurality of telescoping sections slidably arranged one within the other;
   b. fluid cylinder and piston means interposed between said sections to cause telescopic extension of said sections when the cylinder is supplied with fluid; and
   c. each section carrying wedging means entering into engagement with the wedging means for an adjacent section when such consecutive sections are telescoped apart into extended position, said wedg-

2. A telescoping structure according to claim 1, said wedging means includes a pair of oppositely inclined wedge surfaces fixed to each of a pair of adjacent sections and arranged to mate together when said pair of sections are at their maximum extension, said wedge surfaces being inclined at a small angle to the structure axis.

3. A telescoping structure according to claim 1, wherein said wedging means of each section have an effective length at least equivalent to the width of one of the associated sections.

4. A telescoping structure according to claim 1, wherein said wedging means of each section have an effective length at least equivalent to one sixth of the length of one of the associated sections.

5. A telescoping structure according to claim 1, wherein said wedging means on each section include wedge portions spaced apart axially along a portion of the respective section.

6. A telescoping structure according to claim 1, wherein at least two wedging means are provided for each adjacent pair of sections each being arranged to act in a plane at right angles to that of the other.

7. A telescoping tower structure having at least two telescoping sections, hydraulic cylinder means connected between the lowermost and uppermost tower sections for causing the tower sections to extend when the cylinder means is supplied with hydraulic fluid, and in which the top of a lower tower section and the base of the next upper tower section are provided with cooperating wedging means effective to hold these two tower sections rigidly together when the sections are at their maximum extension, the wedging means including a pair of opposed wedge surfaces arranged to wedge together thereby limiting further extension of these two tower sections by the hydraulic cylinder means, the wedging surfaces being at a small angle to the axis of the tower.

8. A telescoping tower structure, comprising, in combination:
   a. a lowermost tower section and one or more movable, upper tower sections telescopically mounted on said lowermost tower section and having cooperating sliding surfaces;
   b. hydraulic cylinder and piston means interposed between the lower end of the lowermost tower section and the upper end of the uppermost tower section;
   c. inter-engaging means arranged at the upper end of the lowermost tower section, at both ends of any intermediate tower section, and at the lower end of the uppermost tower section, the inter-engaging means of each tower section including a pair of opposed wedge surfaces and said wedge surfaces being at a small angle to the axis of the tower;
d. fluid pressurizing means for continuously maintaining said hydraulic cylinder and piston means under pressure and thereby to hold the tower structure in its erected condition and the respective inter-engaging means in engagement with each other.

9. A telescoping tower structure according to claim 8, wherein said inter-engaging means are wedging means.

10. A telescoping tower structure according to claim 8, wherein the said fluid pressurizing means are capable of continuously maintaining pressure in said cylinder such that the force applied by said cylinder is greater than the total weight of the movable tower sections and parts carried thereby including the maximum permitted load on the structure.

11. A telescoping tower structure according to claim 8, wherein the said fluid pressurizing means are capable of continuously maintaining pressure in said cylinder such that the force applied by said cylinder is at least 25 percent greater than the minimum force required for extending the structure by raising the upper tower section or sections and parts fixed thereto.

12. A telescoping tower structure according to claim 8, wherein the said fluid pressurizing means are capable of continuously maintaining pressure in said cylinder such that the force applied by said cylinder is at least 50 percent greater than the minimum force required for extending the structure by raising the upper tower section or sections and parts fixed thereto.

13. A telescoping tower structure according to claim 8, wherein the said fluid pressurizing means include pressure monitoring means, and fluid pressure supply means operated automatically by said monitoring means to increase fluid pressure within said cylinder if said pressure falls below a predetermined limit.

14. A telescoping tower structure according to claim 8, wherein said tower structure carries at its upper end load handling means which, in operation, apply a bending moment to said tower, and wherein said fluid pressurizing means is capable of continuously maintaining pressure in said cylinder such that the force applied by said cylinder, in the absence of any load on said load handling means, produces a tensile stress in said tower structure which stress is a maximum of about 7 percent to 15 percent of the maximum permissible tensile stresses in the tower.

15. A telescoping tower structure according to claim 8, wherein said tower structure carries at its upper end load handling means which, in operation, apply a bending moment to said tower, and wherein said fluid pressurizing means is capable of continuously maintaining pressure in said cylinder such that the force applied by said cylinder, in the absence of any load on said load handling means, produces a tensile stress in said tower structure which stress, at an intermediate position along the tower length between the bottom and the top ends, is equal to the difference between maximum permitted stresses on the tower structure in tension and in compression.

16. A telescoping tower structure according to claim 8, wherein said structure is the tower of a tower crane, and wherein said parts fixed to said movable section or sections include a jib or boom extending from the top of said tower.

17. A tower structure according to claim 8, further comprising unidirectional latching means having inter-engaging parts on adjacent tower sections engageable to hold said sections in extended relationship on reduction of fluid pressure in said cylinder.

18. A tower structure according to claim 8, further comprising cooperating locating means on adjacent tower sections operative to hold said sections rigidly together when said sections are fully retracted relative to each other, said locating means limiting angular movement between said sections to an amount considerably less than that permitted by said sliding surfaces.

19. A tower crane comprising mobile platform means, a telescopic tower tiltably mounted on said platform means for movement between a substantially horizontal travelling position and a vertical operating position, means interconnecting said platform means and said tower for moving the tower between said positions, a turntable at the top of said tower, and a crane upper structure including jib or boom means mounted on said turntable, wherein said tower comprises:

a. a lowermost tower section pivotally connected to the platform means and one or more movable, upper tower sections telescopically mounted on said lowermost tower section and having cooperating sliding surfaces;

b. hydraulic cylinder and piston means interposed between the lower end of the lowermost tower section and the upper end of the uppermost tower section;

c. inter-engaging means arranged at the upper end of the lowermost tower section, at both ends of any intermediate tower section, and at the lower end of the uppermost tower section, the inter-engaging means of each tower section cooperating with complementary inter-engaging means of an adjacent section when said telescoping tower sections are telescoped apart and the tower structure is in erected condition, said inter-engaging means both limiting extension of the tower sections by said hydraulic cylinder and piston means and also limiting relative angular movement between adjacent fully extended sections to an amount considerably less than the angular movement permitted by said sliding surfaces; and

d. fluid pressurizing means for continuously maintaining said hydraulic cylinder and piston means under pressure to thereby hold the tower in erected condition with the respective inter-engaging means in engagement with each other, said fluid pressurizing means being capable of continuously maintaining pressure in said cylinder such that the thrust applied thereby is greater than the total weight of the movable tower sections and the weight of the turntable and crane upper structure by a margin of at least 25 percent.

20. A tower crane according to claim 19, wherein said fluid pressurizing means is capable of continuously maintaining pressure in said cylinder such that the thrust applied thereby is greater than the total weight of the movable tower sections and the weight of the turntable and crane upper structure by a margin of at least 50 percent.

21. A tower crane according to claim 19, wherein said inter-engaging means are wedging means.

22. A method of erecting and operating a tower comprising a fixed section and one or more relatively movable sections telescopically mounted on said fixed section and extendible relative thereto by hydraulic cylin-
A method of erecting and operating a tower crane which includes a tower comprising a fixed section and one or more relatively movable sections telescopecally mounted on said fixed section and extendible relative thereto by hydraulic cylinder and piston means, comprising the steps of supplying fluid to the hydraulic cylinder at a first pressure sufficient to raise the movable tower sections and the load handling means carried thereby to thus extend the tower to a desired extent as predetermined by inter-engaging means on said tower sections, and operating the crane by attaching loads to the load handling means while maintaining a fluid pressure in said cylinder higher than said first pressure, said higher pressure being such that the thrust applied by the cylinder is at all times greater than the total weight of the movable tower sections and the load handling means plus the weight of the loads being carried by the load handling means.

A method of erecting and operating a tower or the tower of a tower crane, in accordance with claim 22, wherein the thrust applied by the cylinder is greater than the total weight of the tower sections and parts carried thereby plus the weight of loads carried by the tower by about 10 percent of this total weight.

A method of erecting and operating a tower comprising a fixed section and one or more relatively movable sections telescopecally mounted on said fixed section and extendible relative thereto by hydraulic cylinder and piston means, comprising the steps of telescopecally extending at least the uppermost movable tower section relative to the fixed section by supplying fluid at a first pressure to extend the hydraulic cylinder means, lockingly engaging the uppermost and fixed sections of the tower by upward extension of the hydraulic cylinder means, and tensioning the lockingly engaged extended and fixed tower sections by supplying fluid to the hydraulic cylinder means at a pressure greater than the first pressure.

The method according to claim 26 including the step of lifting the next lower movable tower section with the uppermost movable tower section by continued extension of the hydraulic cylinder means.

* * * * *
UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,817,397 Dated June 18, 1974

Inventor(s) Donald Edward Wellman

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In the heading, change the address of the Assignee from "London, England" to London, Canada.

In the Claims:

Claim 22, Col. 17, line 4, correct the spelling of "predetermined".

Signed and sealed this 8th day of October 1974.

(SEAL)

Attest:

McCoy M. Gibson Jr. C. Marshall Dann
Attesting Officer Commissioner of Patents