Sept. 29, 1959 J. E. MINTY 2,906,413

HYDRAULIC CRANE

Filed Dec. 6, 1955 5 Sheets-Sheet 1

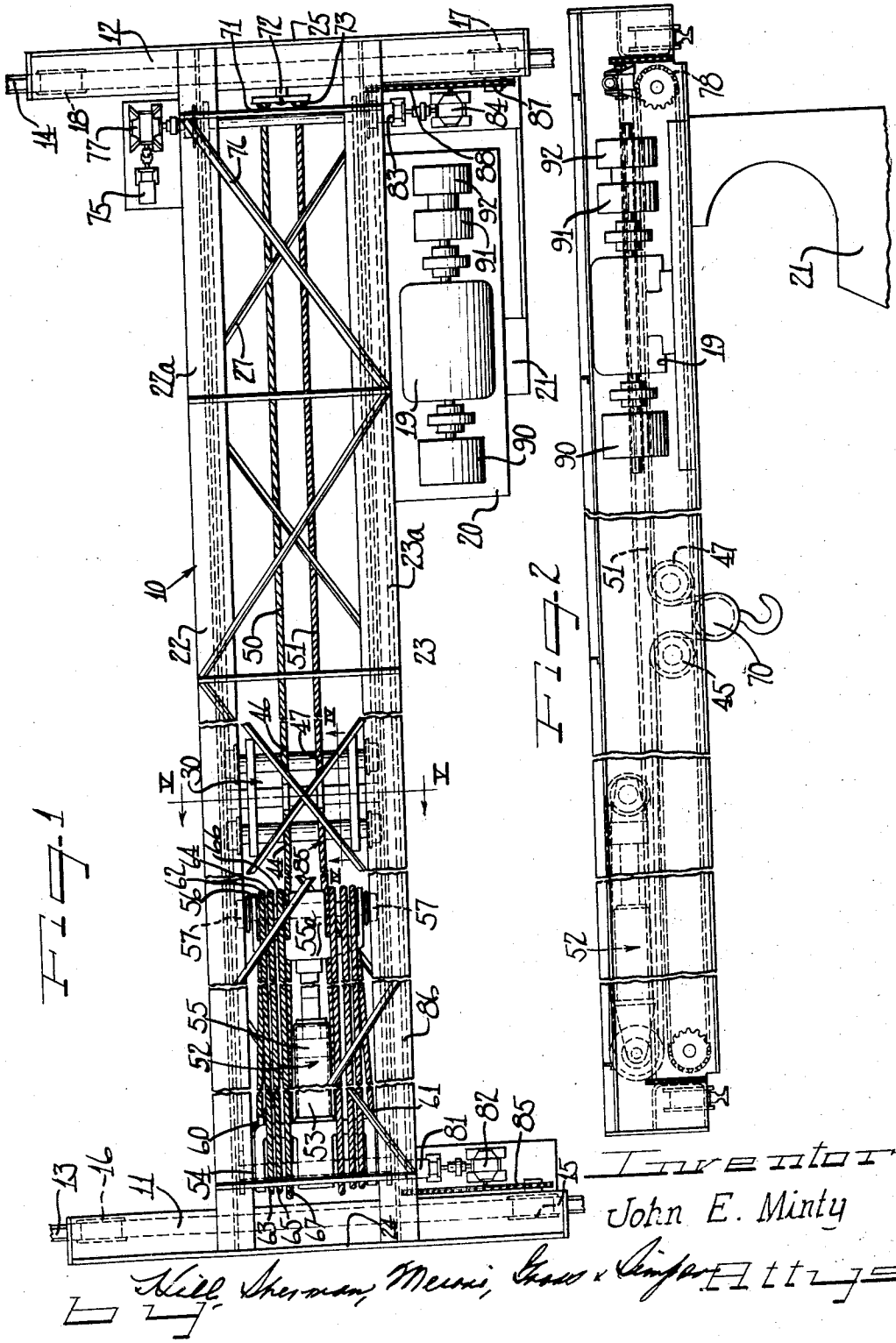


Fig. 1

Fig. 2

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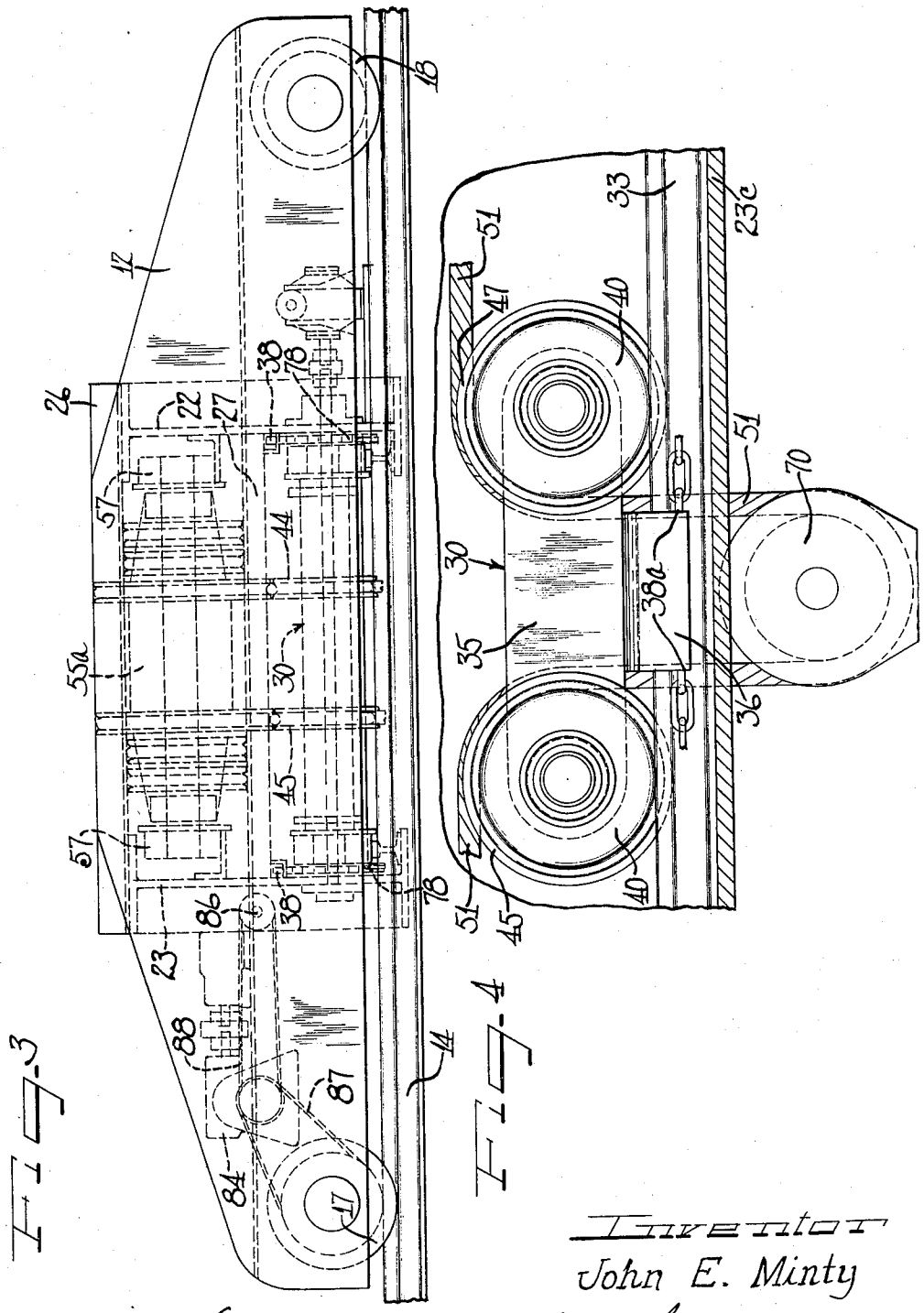


Fig. 3

Fig. 4

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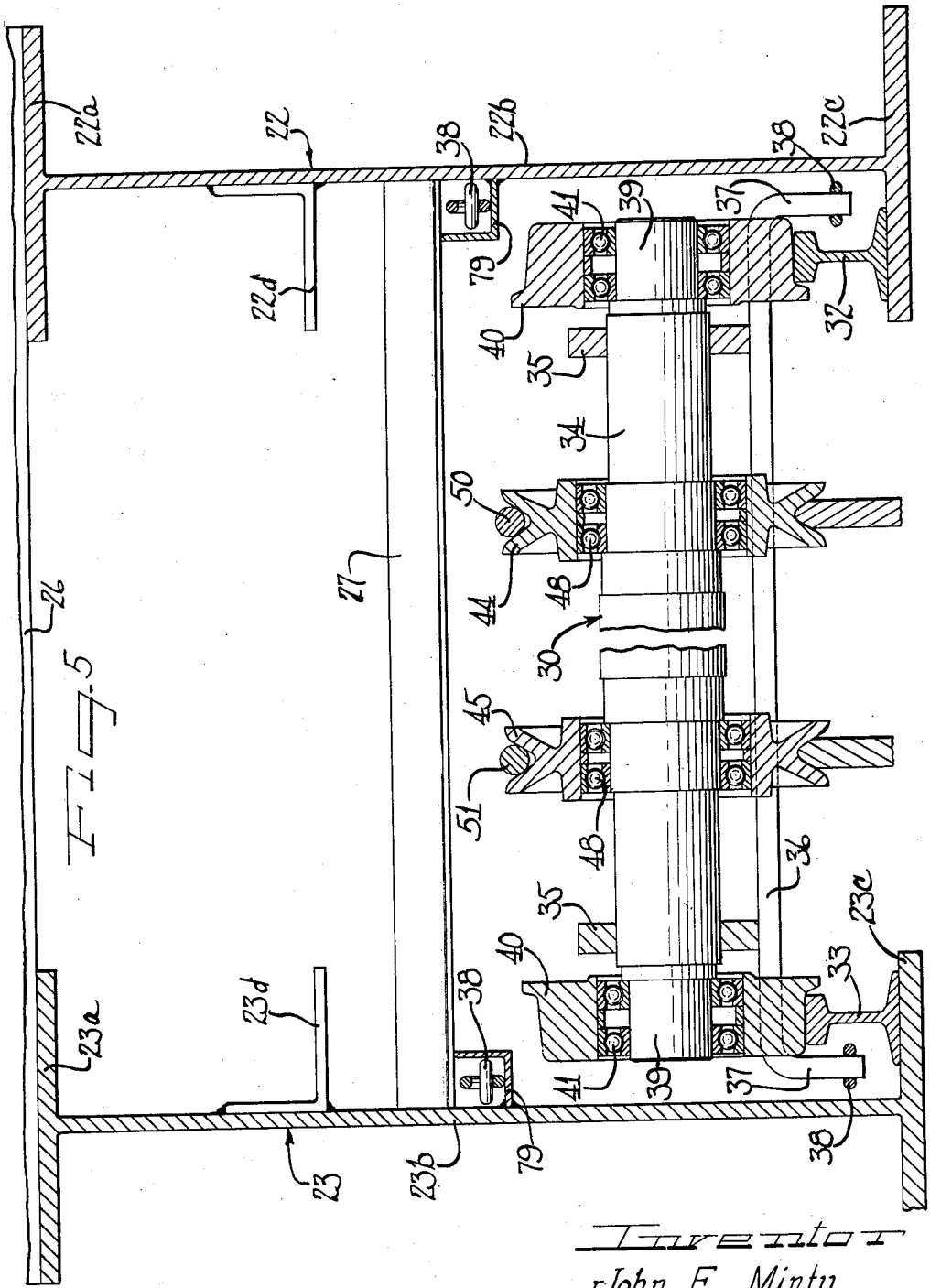


Fig. 5

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HYDRAULIC CRANE

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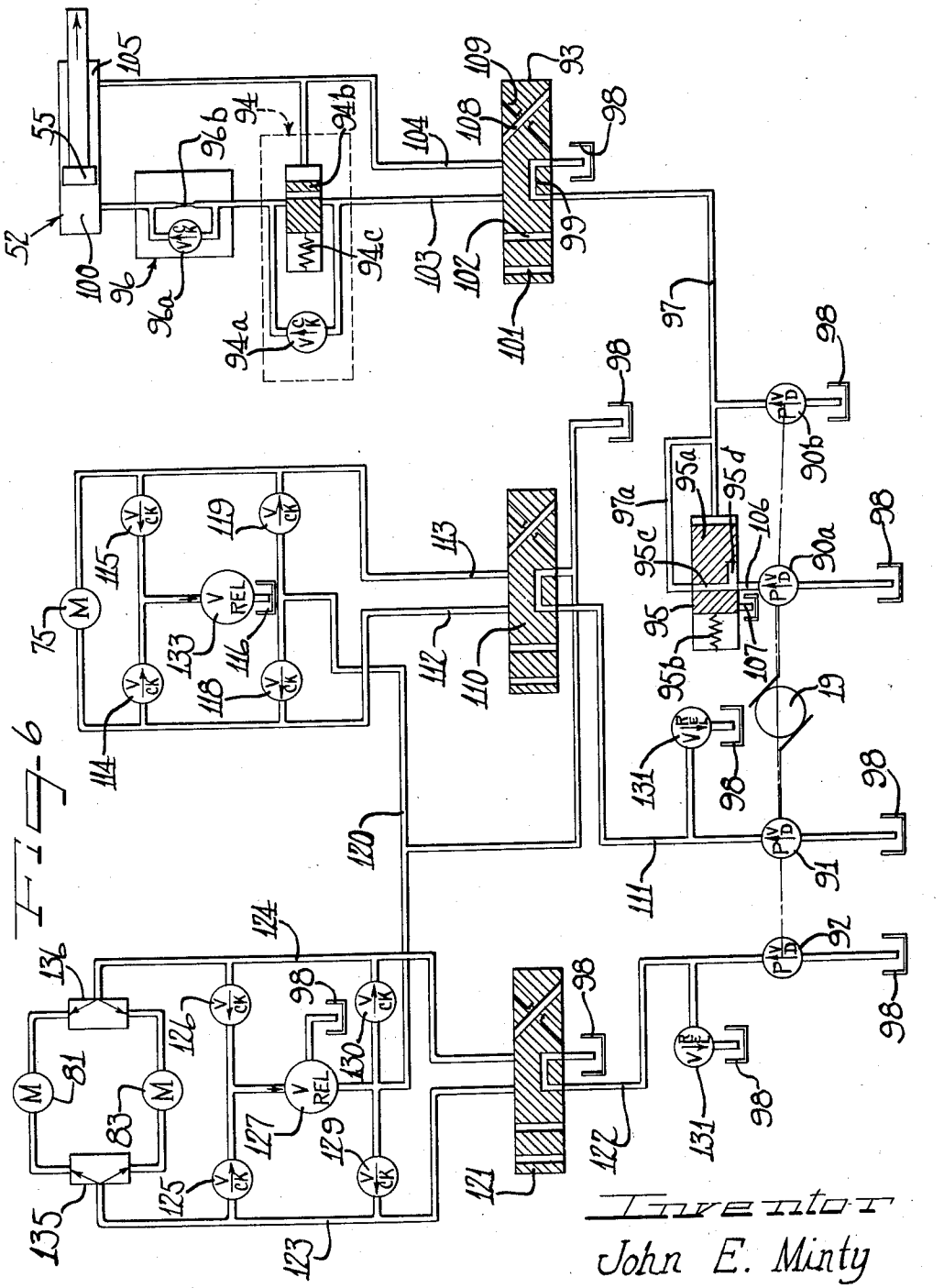


FIG. 6

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HYDRAULIC CRANE

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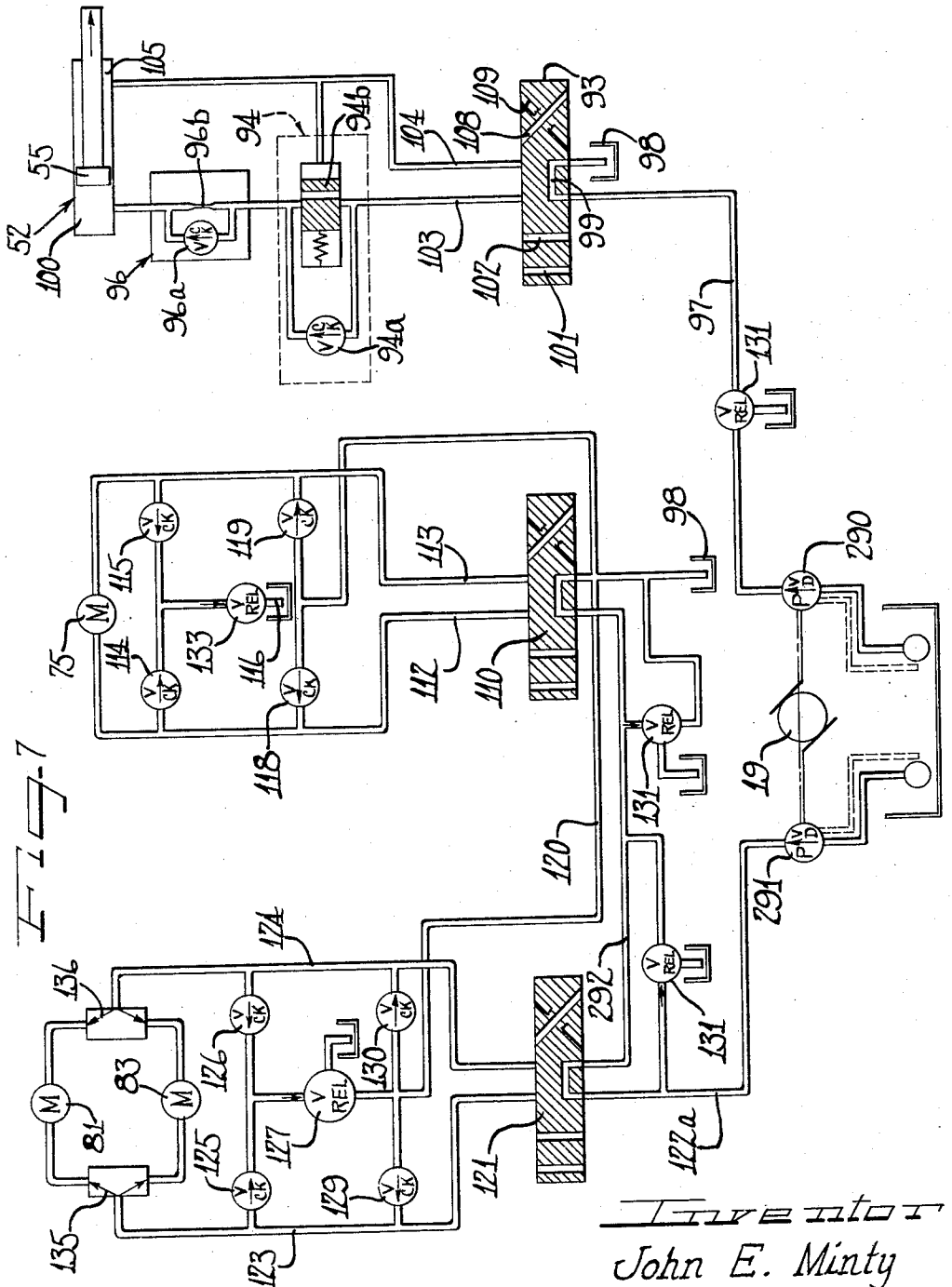


Fig. 7

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2,906,413

HYDRAULIC CRANE

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Application December 6, 1955, Serial No. 551,398

3 Claims. (Cl. 212—20)

The present invention relates to crane construction and is, more particularly, concerned with the provision of a novel and substantially improved heavy duty crane having three motions each of which is hydraulically actuated and controlled.

As those skilled in the art of crane construction are aware, many structural problems exist in the manufacture of heavy duty cranes of large span. Entirely aside from problems resulting from limited head room, prior art long span cranes require elaborate structural bracing, torsional resistance to the crane operating electric motor thrusts, and complex methods of obtaining speed control. Substantially all cranes presently in operation comprise electric motor driven structures employing a large, heavy trolley for transversing the span of the crane and carrying the cable or rope winding drums as well as the large electric motors used for operating the load lifting hook. Such electrically powered trolleys are, where heavy duty cranes are concerned, extremely heavy and extremely bulky and are ordinarily supported for movement along the top of a pair of I or box beams. This arrangement has traditionally taken substantial amounts of head room and elaborate internal bracing of the separate support beams since movement of the trolley over the tops of the beams prevents satisfactory inter bracing between the beams. Accordingly, and in spite of their size, many of the heretofore used heavy duty cranes have been subject to excessive lateral beam deflection and other lack of rigidity.

In addition to the problems of beam construction, trolley construction and operation, electric cranes have also suffered other serious defects. For example, substantially all heavy duty electrical cranes have an entirely separate small motor driven hoist for handling small items since the speed control in the conventional heavy duty electrical motors for the main lift hook is insufficiently flexible to permit operation of the large hook at rapid speeds under light load. Further, in the electrical systems with which I am familiar, serious dangers of trolley destruction arise from the possibility of failure of the lift hook limit switches so that the lift hook has frequently been lifted up against the rope or cable winding drum crushing the latter as well as the lift hook block sheaves before the motor can be stopped.

While the utilization of other means of powering cranes has, of course, been considered in the past, and while, specifically, hydraulic cranes have been considered, to my knowledge none of the heretofore known hydraulic crane structures have satisfactorily overcome all of the objections above voiced relative to electrical crane structures. In accordance with the principles of the present invention, a hydraulic crane is provided which utilizes an absolute minimum of head room, provides extremely rigid cross bracing between trolley support means, provides a system wherein over-travel of the load lifting hook and block assembly is impossible and which provides superior speed control in the hoisting operation

while utilizing inexpensive and very simple working components.

In accordance with the present invention, a crane is provided comprising a pair of generally conventional bridge supports adapted to carry a crane bridge along a pair of widely spaced overhead crane rails. The bridge comprises, preferably, a pair of spaced beams extending between the bridge supports and, in the embodiment illustrated, comprising I beams. A crane trolley comprising a body supported by four trolley wheels runs on rails extending the full length of the bridge I beams and secured to the top side of the lower flange thereof. Hoisting power is applied to the rope or cable carried by the trolley by means of a reciprocal hydraulic motor of relatively long stroke supported immediately above the path of the trolley and, preferably, wholly contained below the top level of the I beams.

Motive power for operation of the hoisting apparatus is, in accordance with the present invention, hydraulic fluid under pressure supplied by an electric motor driven pump. The same motor likewise may also drive auxiliary pumps for separately supplying motive power to the hydraulic motors driving the bridge trucks along the crane rails and to a fluid motor for actuating the trolley. It is also satisfactory to use but one pump of sufficient capacity to drive all the three fluid motors and the hoisting cylinder. Controls are provided for the several motors in the form of reversing hydraulic valves and accordingly a simple, though relatively powerful, electric motor may be utilized for powering the crane. This motor need not, of course, be designed for variable speed operation and hence may comprise a relatively inexpensive A.C. or D.C. high torque motor of the constant speed variety. Since the valves necessary for the control of the several motors are relatively simple in construction and require no flexible hydraulic lines for their connection to the various motors, an extremely simple control network may be utilized and accordingly only a very nominal space requirement for the power source is necessary. In accordance with the form illustrated herein, the electric motor and pumps or single pump may be positioned in such a manner as to prevent any interference whatever with overhead objects and the control equipment may all readily be carried in a small control station suspended to one side of and below the crane structure.

In view of the arrangement of the trolley components and the hoisting components in substantially horizontal planes and substantially within the confines of a pair of spaced I beams, cross bracing may effectively be accomplished between the top edges of the I beams and at an additional point part way up the vertical web of the I beam at a point immediately below the guide tracks for the hydraulic hoist cylinder. As a result of this cross bracing and rigidification it has been found that no outriggers or other elaborate bracing is necessary to provide a frame substantially free from twist or buckling under heavy loads, even though the crane is rapidly accelerating or decelerating with the load.

It is, accordingly, an object of the present invention to provide a novel, compact, highly efficient heavy duty three-motion crane.

Another object of the present invention is to provide a substantially stronger crane bridge of I beam or plate girder construction without the necessitty of a lattice auxiliary girder to support the bridge drive machinery and without any necessity to provide box girders for cranes of longer span, thus substantially reducing the cost of conventional crane bridge structures.

Still a further object of the present invention is to provide a novel fully hydraulic crane.

Yet another object of the present invention is to provide a hydraulic crane having simplified fully automatic preventive means for preventing overhauling of the load carried by the crane during the load-lowering operation.

A feature of the invention is the utilization of an inexpensive constant speed electric motor for powering all three crane motions.

Another feature of the invention is the utilization of a hydraulic motor for load lowering and lifting functions, in combination with hydraulic means for varying the load lifting and lowering speed.

Another feature of the invention is the utilization of a cross-braced bridge construction.

Still a further feature of the invention is the provision of an extremely small light weight crane trolley which is required to carry no hoisting apparatus, such as for example hoisting motors, winding drums, and the like ordinarily associated with crane trolleys, thereby providing the crane with substantially improved speed control and minimizing the head room necessary for installation of the crane.

Still other and further objects and features will at once become apparent to those skilled in the art from a consideration of the attached drawings wherein a preferred embodiment of the present invention is shown by way of illustration only, and wherein:

Figure 1 is a plan view of an hydraulic crane constructed in accordance with the principles of the present invention;

Figure 2 is a side elevational view of the crane shown in Figure 1;

Figure 3 is an end elevational view of the crane as shown in Figures 1 and 2;

Figure 4 is an enlarged side elevational view of the crane trolley taken along the line IV—IV of Figure 1;

Figure 5 is an enlarged cross sectional view of the crane trolley taken along the line V—V of Figure 1;

Figure 6 is a schematic illustration of a hydraulic circuit suitable for control and operation of the hydraulic crane of the present invention; and

Figure 7 is a modified form of hydraulic circuit for use with the crane of the present invention.

As shown on the drawings:

As may be seen from a consideration of Figures 1 through 3, the crane of the present invention comprises a bridge generally indicated at **10** rigidly carried by a pair of bridge supports **11** and **12** which are in turn supported on the respective longitudinally extending crane rails **13** and **14** by means of wheels **15, 16, 17** and **18**. Power for operating the crane is supplied by an electric motor **19** carried on an outrigger platform **20** and supplied with electrical energy by any suitable means, such as for example through the provision of a conventional third rail (not shown) running parallel to the longitudinal rail **14**. The controls for the crane may be conveniently provided in an operator's compartment **21** secured beneath the motor support **20**.

As may be seen the bridge **10** comprises a pair of longitudinally spaced transversely extending I beams **22** and **23** rigidly secured, as for example by welding, to the heavy plate end walls **24** and **25** of the bridge supports **11** and **12**, respectively. It will, of course, be appreciated by those skilled in the art that a mere rectangular structure as thus far described has relatively little stability as far as bridge twist is concerned or as far as movement of one of the bridge supports **11** or **12** along the rails **13** and **14** a greater distance than the other. Twist and angular deformation must be eliminated in any practical hoist and are overcome in the present instance through a very simple bracing structure which in no way interferes with crane operation.

The novel bracing arrangement of the present invention comprises a plurality of angle braces **26** rigidly secured to the top flanges **22***a* and **23***a* of the respective bridge beams **22** and **23**. Additional angle braces **27** are

secured to the main web or body portion **22***b* and **23***b* of the beams **22** and **23** respectively, with the angle of installation being reversed from that of the beams **26**, as shown in Figure 1. As a result of the angle bracing between the beams **22** and **23**, as well as the rectangular connection between the beams **22** and **23** and the end support walls **24** and **25**, an extremely rigid bridge structure is provided which resists twist as well as angular deflection to a remarkable degree. At the same time, as will be more fully set forth below, the bracing members **26** and **27** of the present invention do not in any way interfere with the efficient operation of the crane as would such braces in conventional cranes utilizing overhead-mounted trolleys and other similar conventional equipment.

The cross braced bridge structure above described carries a trolley generally indicated at **30** by means of a pair of trolley rails **32** and **33** supported by the base flanges **22***c* and **23***c* respectively of the bridge beams **22** and **23**. The trolley **30** comprises a pair of non-rotating axle members **34** secured together by side frame members **35** which in turn are rigidly connected to a cross tie **36** carrying downturned ears **37** for connection to trolley drive chains **38**. The fixed axles **34** carry, at their ends **39**, wheels **40** mounted for anti-friction rotation on the bearings **41**. As may be seen from Figures 5 and 6 the wheels **40** cooperate with the trolley rails **32**. The fixed axles **34** carry pulleys **44, 45, 46** and **47** mounted for anti-friction rotation on bearings **48**. The pulleys **44, 46** and **45, 47** carry the respective hoist ropes or cables **50** and **51** as set forth in more detail below.

Power for hoisting is supplied by means of a long stroke reciprocating fluid motor **52** comprising a cylinder **53** secured to the beams **22** and **23** by means of pulley shaft **54**, and a piston rod **55** carrying a pulley yoke or cross head member **55***a*. The yoke **55***a* supports a pulley shaft **56** which in turn pivotally supports a pair of guide wheels **57** and a plurality of rope pulleys. The guide wheels **57** roll between the angle iron flanges **22***d* and **23***d* on the respective beams **22** and **23** and the upper flanges **22***a* and **23***a* thereof, thereby requiring the fluid motor **52** to operate in substantially horizontal position. The hoisting cables **50** and **51** are secured at **60** and **61** to the fixed cylinder **53** and are sequentially trained around the pulleys on the pulley shafts **56** and **54** as shown in Figures 1 and 3. Thus, as may be seen, the rope **50** leaves the connection **60** toward the right as viewed in Figure 1, passes under the first pulley **62**, leaves the pulley **62** at the top thereof and passes over pulley **63** on shaft **54**, passes under the second pulley **64** on shaft **56** and thereover to the second pulley **65** on shaft **54**, then passes to the innermost pulley **66** on shaft **56** and from thence to the innermost large diameter pulley **67** on shaft **54**. From the large diameter pulley **67** the rope passes under the bracing **27**, as shown in Figure 3, to pulley **44** on the trolley. The rope then drops downwardly and around the hoist pulley block **70**, upwardly over pulley **46** and from thence to a point of securement **71** on the pivotal equalizer bar **72**. As may be seen from a consideration of Figure 1, the rope **51** follows a path substantially symmetrical to that above described relative to rope **50** and is finally secured at **73** to the pivotal equalizer bar **73**. It will be understood that the connections **71** and **72** are preferably adjustable to permit taking up any excessive unevenness in the lengths of the cables **50** and **51** and that the pivotal movement of the equalizer bar **72** will permit slight differences in the length of the cables **50** and **51** without adversely affecting the operation of the hoisting apparatus.

In operation, it will be apparent that the position of the trolley **30** has no effect whatever on the raising and lowering of the lifting block **70** and that actuation of the piston **55** toward the right as viewed in Figure 1 will raise the block to its uppermost position as shown in Figure 2. Movement of the piston **55** toward the left

as viewed in Figure 1, away from its extreme right hand position as there shown, will permit the block **70** to lower.

While it will, of course, be apparent that the individual lengths of the ropes will vary with different cranes, it has been found that in a crane having a 60 foot span, such as illustrated in the drawings, a 30 foot lift will be provided by a piston **55** having a stroke of 10.0 feet. This will be seen from the fact that the use of three pulleys or sheaves provides a 6 to 1 ratio of lift to piston movement while the hoisting block pulleys **70** provide a 1 to 2 ratio of lift to piston movement, the net, overall ratio therefore being 3 to 1. The diameter of the hydraulic cylinder **53** and the piston **55** will, of course, depend upon the amount of load intended to be applied to the hoisting block **70** and the fluid pressure utilized.

In considering the size of the piston **55** it will be noted that in the arrangement shown in the drawings the hydraulic motor **52** acts, in lifting, under a compressive load, with pressurized fluid acting against the left hand face of the piston **55** as viewed in Figure 1. This arrangement is to be preferred in heavy cranes since it permits a larger lifting piston area for any given piston diameter while at the same time permitting a relatively large diameter piston rod. Since the load itself will aid in the lowering of the block **70**, and hence in the contraction of the motor **52**, the reduced area of the piston, on the right side thereof, will not be detrimental to operation of the hoist. In the situation in which light loads are involved, it will be apparent that a pull, or tension, type reciprocal fluid motor would be adequate and it is, accordingly, within the scope of the present invention to employ such a mechanism rather than the push, or compression, type illustrated. Of course, the piston rod can be reduced in diameter if it is loaded in tension rather than in compression in view of the elimination of columnar effects.

Movement of the trolley **30** back and forth along the rails **32** and **33** is accomplished by means of a fluid motor **75** of the rotary type. The motor **75** drives a shaft **76** through reduction gearing **77**. The shaft **76** carries a pair of sprocket wheels **78** which are fixedly secured thereto and which drive the chains **38**. As may be seen the chain **38** is rigidly secured to the cross plate **36**, as for example at **38***a* in Figure 4 and accordingly reciprocates the trolley **30** in opposite directions as the motor **75** is reversed. Angles **79** are secured to the webs **22***b* and **23***b* of the respective beams **22** and **23** to carry the upper portion of the chains **38** to prevent any possible entanglements or kinking thereof.

The bridge may be moved along the rails **13** and **14** by applying power to the bridge support wheels. This has been accomplished in the presnet invention by fluid motors **81** and **83** which rotate the bridge support wheels **15** and **17**, respectively, through reduction gearing **82** and **84**, respectively. The drive connection between the reduction gearing and the individual wheels may, of course, comprise any conventional mechanism but as illustrated, as shown in Figure 3, comprises a roller chain drive **85**, **87**. In the form illustrated the power applied to the wheels **15** and **17** is synchronized by means of a cross shaft **86** which may be a roller chain driven from the reduction gearing **82**, **84** by a roller chain shown at **88** in Figure 3. This synchronism may be desirable but is not essential in the present invention where the fluid motors **81** and **83** each receive substantially identical energization. Such an arrangement will be discussed below in connection with the description of the preferred embodiments of the hydraulic circuits used in controlling the crane motions.

It will, of course, be apparent that various hydraulic circuits may be utilized for accomplishing efficient operation of the crane above described. The crane may effectively be operated, if desired, by providing a simple hydraulic pump for supplying fluid under pressure to the hydraulic motor **52** and a separate, independent, pump may be provided for supplying pressurized fluid to the bridge controlling motors **81** and **83** and the trolley position controlling motor **75**. Likewise a single large capacity pump may be provided to supply pressurized fluid to all of the motors in parallel through individual control valves. While the hydraulic circuitry and control may, accordingly, be very rudimentary and provide satisfactory crane operation, two improved control circuits are illustrated in Figures 6 and 7 of the drawings.

In the form of hydraulic circuitry illustrated in Figure 6 the electric motor **19** operates to drive four individual hydraulic pumps **90***a*, **90***b*, **91** and **92**. The pumps **90***a* and **90***b* are, respectively, a high volume low pressure pump and a low volume high pressure pump, preferably positioned in one housing **90**, shown in Figure 1, and operative to actuate the hoisting motor **52**. The pumps **91** and **92** supply hydraulic fluid under pressure to the trolley operating fluid motors **75** and the bridge driving motors **81**, **83**. In the circuit illustrated in Figure 6, automatic high speed-low speed hoisting is accomplished, hydraulically equalized control is provided for the separate bridge driving motors **81** and **83**, and an anti-load overhauling control valve is provided in the hoisting circuit.

Details of the control circuit in Figure 6 may be considered separately insofar as the three separate motions are concerned. The hoisting motor **52** is under the control of a manually reciprocable control valve **93**, an anti-load overhauling valve **94**, and automatic pump unloading valve **95**. In addition, a one-way restrictor **96** is utilized. As shown, the control valve **93** is in a neutral position in which no lifting is desired. Under such circumstances fluid pumped from the pumps **90***a* and **90***b* travels through the pressure conduit **97** and is by-passed to a low pressure hydraulic pump **98** by means of the valve port **99**.

If a relatively light load is applied to the lifting block **70**, fluid may be fed from the pressure conduit **97** to the chamber **100** of the motor **52** to move the piston **55** to the right, in the load lifting direction by moving the valve **93** to the right as viewed in Figure 6. This movement will connect the pressure conduit **97** with the load lifting conduit **103** through port **101** and the sump **98** with the load lowering conduit **104** through port **102**. Accordingly, fluid from the pumps **90***a* and **90***b* will flow through the check valve **94***a* of the anti-load overhauling valve **94** and through the check valve **96***a* of the restrictor **96** to the chamber **100**. At the same time, the chamber **105** of the motor **52** is vented to the sump **98** through conduit **104** and port **102** thereby permitting the piston **55** to lift the load.

As above noted, under a light load condition fluid will flow from both pumps **90***a* and **90***b* into the pressure conduit **97** since the valve core **95***a* of the unloading valve **95** will be positioned in its right hand extreme position by compression spring **95***b* such that port **95***c* will permit the passage of fluid from pump outlet conduit **106** to pressure conduit branch **97***a*. Since, during light load conditions, the output of the pump **90***b*, which is of a small output type will be negligible compared to the output of the pump **90***a* and will not affect the general operation of the system. However, during the lifting of a heavy load which requires a greater pressure than the design output pressure of pump **90***a*, the pump **90***b* takes over the operation to lift the load. This is accomplished by means of the application of the pressure in line **97** to the right hand end of the unloading valve port **95***a*, causing it to move against the pressure of the spring **95***b* to close off the connection between conduits **106** and **97***a* and vent conduit **106** to sump outlet **107** via the port output **95***d*. At such time, the pump **90***a* is entirely disconnected from the system and the low volume high pressure fluid from pump **90***b* operates to lift the heavy load at a substantially slower rate than the rate of load lifting provided by the high output pump **90***a* under light loads.

In view of the dual pump, automatic arrangement above described, the crane of the present invention operates to lift lighter loads at a very rapid rate and heavier loads at a slower rate. This variation in load lifting speed and capability provides a universally adaptable hoist usable in shops where high speed operations are desirable when carrying small objects about but where extremely heavy duty operations are also necessary. In prior art crane structures it has been the practice to provide an entirely separate small light load hoist for light duty work since it has been considered substantially impractical to provide a rapid speed for the main lifting block **70**. By providing hydraulic actuation as above described great versatility is achieved and the cost of such versatility is substantially less than the cost of versatility with previously known systems.

In lowering the load fluid control valve **93** is moved to the left as viewed in Figure 6 until port **108** connects conduit **103** with the sump **98** and port **109** connects the lowering conduit **104** with pressure conduit **97**. With the valve in this position fluid under pressure is applied to conduit **104** forcing the piston **55** to the left as viewed in Figure 6. Movement of the piston **55** toward the left is, however, carefully controlled in order to permit lowering of the load at a desired speed. In the first place, a restrictor **96** is provided having a check valve **96***a* which permits the flow of pressurized fluid only into the chamber **100** rather than out of it. On flow out of the chamber **100**, on the load lowering cycle, fluid must flow through the restrictor **96***b*, thereby limiting the rate of load descent.

If for any reason the load should overhaul the system or, in other words, tend to move faster than the fluid flow through conduits **97** and **104** will permit, such overhaul is absolutely prevented by the present system. This is accomplished by means of anti-overhauling valve core **94***b* which normally prevents passage of fluid through conduit **103** in the downward direction. Flow is permitted only when the pressure in the conduit **104** builds up sufficiently to force the core **94***b* to the left against spring **94***c*. Pressure if, of course, built up in conduit **104** when pressure is applied tending to lower the lifting block **70**, but only when such pressure is applied. If the load attempts to overhaul the system and descend at a rate greater than the fluid pressure in conduit **104** forces it, the pressure in the conduit **104** will decrease and the valve **94***b* will prevent further egress of fluid from chamber **100** until such time as a pressure again builds up in conduit **104**. As a result of this arrangement an absolute positive pressure is essential in the chamber **105**, tending to force the load downwardly, before any movement whatever of the load is permitted.

The trolley motor of the crane, namely motor **75** is under control of a manually actuated valve **110** which is identical to the valve **93** in operation. Accordingly, fluid pressure from pump **91** travels through conduit **111** to a forward direction motor actuating conduit **112** and thence to motor **75**. Rotation of the motor in the opposite direction is achieved by connection of conduit **111** with conduit **113** by movement of the control valve in the opposite direction from that providing positive energization of the conduit **112**. Overloads developing in the system at the motor **75** are prevented by means of check valves **114** and **115** which vent, respectively, pressure conduits **112** and **113** to a sump **116**. Valves **118** and **119** which connect the pressure conduits **112** and **13** respectively to sump conduit **120**, operate to prevent damage to the system by closure of the valve **110** abruptly. Upon such abrupt action inertia of the trolley motor **75**, which is directly connected to the trolley by the chain **38** would tend to cause continued rotation of the motor after the supply of pressure fluid had been cut off, resulting in the creation of a vacuum

in the line **112** or **113**, depending upon the direction of trolley movement. The check valves **118** and **119** eliminate any possibility of the creation of a vacuum in the pressure line by permitting the inlet of fluid from the sump line **120** as soon as the pressure in the conduits **112** or **113** drops below atmospheric pressure.

The motors **81** and **83** used for moving the crane bridge are operated in unison through a system substantially identical to that used in the motor **75**. Thus, control valve **121** operates to connect pressure conduit **122** to a forward movement line **123** or a reverse movement line **124**. Check valves **125** and **126** provide for flow from the conduits **123** and **124**, respectively, to the relief valve **127** leading to the sump conduit **120**. As in the case of the motor **75**, the check valves **125** and **126** prevent the possibility of an overpressure occurring in the lines **123** or **124** upon movement of valve core **121** to trap fluid therein, or for any other reason. Likewise, check valves **129** and **130** permit flow from the low pressure sump conduit **120** into the lines **123** or **124**, respectively, during situations of overtravel of the bridge or other possible circumstances in which a vacuum is induced in the line **123** or **124** as a result of actuation of the valve **121**. Of course, in all instances, pressure relief valves **131** are provided on the pumps **91** and **92** to prevent a build up of excessive pressure in the lines **111** or **122** as a result of valve movement to block the pressure conduits, or an overload in the lines **123** or **124** with simultaneous failure of the relief valve **127** or **133**.

As was described above, the crane of the present invention may provide a mechanical interconnection between the motors **81** and **83**, in the form of a transversely extending connecting shaft **86**. In view of the expense of this mechanical interconnection, however, it is preferred that hydraulic equalizing valves of any conventional structure be provided at **135** and **136**. These equalizers or flow dividers automatically provide equal flow to the motors **81** and **83** in either the forward or reverse direction of rotation and provide sufficiently accurate synchronization between the motors **81** and **83** in most cranes to permit elimination of the synchronizing shaft **86**.

Further, it has been found in actual practice that where the conduits leading to the motors **81** and **83** are of substantially the same hydraulic resistance special equalizer valves are not needed and a conventional **T** or **Y** conduit connection may be employed at **135** and **136** with satisfactory results. It will thus be understood that the synchronizing shaft **86** and the flow dividers may be used individually or together, or in suitable cases eliminated entirely.

In the embodiment of the hydraulic circuit illustrated in Figure 7 a system is provided in which only two fluid pumps are utilized. The reciprocating hydraulic motor **52** is supplied with pressurized fluid from pump **290** via valve **93**, conduits **103**, **104** and control valves **94** and **96** in the manner fully discussed above. However, pump **290** differs materially from pumps **90***a* and **90***b* in that it provides automatic volume control responsive to pressure in the conduit **97**. The pump **290** is constructed to provide an initial high volume output at low pressure, which volume automatically decreases as the pressure at the pump output pressure responsive variable volume pump may be of any conventional construction, for example, the well known radial piston pump having a transversely adjustable rotor having decreasing eccentricity with increased output pressure, thereby decreasing the pump stroke with such increasing pressure. It will be understood, however, that any of a large number of automatically controlled pumps having a reduced output with increased output pressure may be satisfactorily used. When such pumps are used, light loads lifted by the block **70** will be lifted rapidly while

heavier loads will be lifted at a decreasingly rapid rate as the weight of the load increases. Accordingly, the crane of the present invention is utilized very satisfactorily with small load operations in which conventional large cranes are unsatisfactory due to their extremely slow rate of load lifting.

In addition to the difference in the pump operating the lifting motor **52**, the system shown in Figure 7 provides only a single pump **291** which supplies motors **81**, **83**, and **75**. As will be seen, the output of pump **291** is initially directed through conduit **122***a* to valve **121** for direction in equal amounts to the motors **81** and **83** through flow equalizers **135**, **136**. If the valve **121** is in its neutral position as shown in Figure 7, the bridge motors **81** and **83** are motionless and fluid under pressure flows from the pump **291** into conduit **292** which leads directly to valve **110**. Fluid under pressure arriving at the valve **110** via conduit **292** may be directed to the fluid motor **75**, as described above relative to the embodiment shown in Figure 6 when the valve is in either of its extreme left or right hand positions. When the valve **110** is in neutral, however, hydraulic flow is to the sump **98**. As in the case of the embodiment shown in Figure 6, the sump line **120** leads to valves **129** and **130** as well as valves **118** and **119** to prevent evacuation of the system which might otherwise result upon rapid movement of valves **121** or **110** into a neutral, blocking, condition.

In the embodiment shown in Figure 7, the use of one pump **291** provides a satisfactory system for most installations. It will be appreciated, however, that in view of the series relationship between the valve **121** and the valve **110**, the pressure available to motor **75** will be substantially reduced if the motors **81** and **83** are being operated. This will be apparent when it is noted that conduit **292** is the exhaust conduit of the motors **81** and **83** during either forward or reverse operation of the bridge. Therefore, where extreme maneuverability and fast action are considered particularly important, the dual pump system shown in Figure 6 is, of course, preferably utilized.

It will thus be seen that I have provided a novel and substantially improved crane having a maximum versatility while requiring an absolute minimum of space. Since all three motions of the crane, namely motions of the bridge, trolley, and load, are controlled by hydraulic fluid under pressure no torques from the electric drive motor **19** are transmitted to the frame of the crane in a twisting manner, as in electric motor controlled cranes of the prior art. Since no winding drums are incorporated in the instant crane, as in prior art electrical cranes, the width of the bridge, between the I beams **22** and **23** may be substantially reduced from that required in prior art structures in which the length of the cable winding drums was the determinate factor in such dimension. As a result of the arrangement of parts, cross bracing has been introduced into the bridge to prevent twist of the bridge and extreme stability of the entire crane structure is accordingly provided. Since the trolley of the present crane is not required to carry any lifting motors or other intricate mechanism it may be extremely light and easily moved and may be constructed without any space consuming machinery thereon. Accordingly, the trolley of the present invention may be placed between the I beams rather than above them and the head room on the crane substantially reduced. Additionally, since the maximum lift of the present crane is controlled by the length of the stroke of the fluid motor **52**, the length of the rope and the stroke may readily be adjusted to prevent any possibility of drawing the lifting block **70** up into the trolley in a bottoming condition. This is extremely important since it automatically prevents overtravel of the lifting block **70** which is a common failure in prior art cranes and which is a cause of very great damage and time loss. Further advantages of extreme importance in the construction herein described are the complete elimination of gearing as well as mechanical load lowering brakes designed to prevent overhauling of the load. In the present construction load overhauling is automatically prevented by hydraulic means. Still further, a unidirectional electric motor of the least expensive type may be used in the present invention rather than the extremely expensive reversible, rapid start and stop, high torque electric motors ordinarily used. Overload damage to the motor of the present crane is impossible since upon the application of such overload the pressure relief valves **131** merely open thereby preventing any damage to the crane and also preventing damage to personnel by automatically preventing operation of the crane with unsafe loads.

It will be obvious to those skilled in the art that variations and modifications may be made in accordance with the principles of the present invention without departing from the scope of the novel concepts thereof. Accordingly, it is my intention that the scope of the present invention be limited solely by that of the hereinafter appended claims.

I claim as my invention:

1. A three motion crane comprising a bridge mounted for rolling motion along a pair of spaced rails, a first hydraulic motor for moving said bridge, said bridge comprising a pair of spaced beams having top and bottom flanges facing each other, a trolley mounted on said bottom flanges for rolling movement along said bridge between said beams, a second hydraulic motor for moving said trolley, a hydraulic hoisting motor positioned between said beams comprising a cylinder fixed to said beams, guide rails on said beams above said bottom and substantially parallel thereto but below said top flanges, a piston reciprocable along said guide rails and having guide members thereon positioned on said guide rails between said guide rails and said top flanges for guided reciprocation below said top flanges, sheaves on said cylinder and said piston, a hoisting rope operatively secured to said cylinder and trained about said sheaves with its other end cooperating with said trolley to provide a vertically extending load carrying rope.

2. A three motion crane comprising a bridge mounted for rolling motion along a pair of spaced rails, a first hydraulic motor for moving said bridge, said bridge comprising a pair of spaced beams having top and bottom flanges facing each other, a trolley mounted on said bottom flanges for rolling movement along said bridge between said beams, a second hydraulic motor for moving said trolley, a hydraulic hoisting motor positioned between said beams comprising a cylinder fixed to said beams, guide rails on said beams between said top and bottom flanges and substantially parallel thereto, a piston reciprocable along said guide rails and having guide wheels thereon positioned on said guide rails between said guide rails and said top flanges for positively guided reciprocation between said rails and below said top flanges, first generally horizontal angle cross braces securing said beams together at their top surfaces, second cross braces securing said beams together below said guide rails and above said bottom flanges, sheaves on said cylinder and said piston, a hoisting rope operably secured to said cylinder and trained about said sheaves with its other end cooperating with said trolley to provide a vertically extending load carrying rope, and a source of hydraulic fluid under pressure for actuating all of said motors.

3. In a crane, a bridge comprising a pair of spaced beams having top and bottom flanges facing each other, a trolley straddling and supported by said bottom flanges for reciprocal movement along said bridge between said beams, an intermediate flange on each of said beams extending substantially parallel to said bottom flange at a point above the path of said trolley, a hydraulic reciprocating motor having a cylinder secured between said beams between the intermediate flanges and the top

flanges above the path of said trolley and a piston substantially horizontally reciprocal along and guided between said intermediate flanges and top flanges, sheaves on said cylinder and said piston, a rope trained about said sheaves and over said trolley whereby actuation of said motor will lift a load on said rope upwardly toward said trolley and substantially horizontal angle cross braces extending across the top flanges of said beams above said piston and securing said top flanges together whereby said beams and guide rails are maintained in rigid relation.

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