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Miller

[11] **3,814,265**

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[54] **HYDRAULIC CRANE CONTROL SYSTEM HAVING MEANS FOR DEACTIVATING CONTROL VALVES WHEN OPERATING LIMIT IS EXCEEDED**

[75] Inventor: **Mickey J. Miller,** Cedar Rapids, Iowa

[73] Assignee: **Harnischfeger Corporation,** Milwaukee, Wis.

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[52] **U.S. Cl.** **212/35**

[51] **Int. Cl.** **B66c 23/54**

[58] **Field of Search** 212/30–35, 212/66, 69; 173/43

[56] **References Cited**

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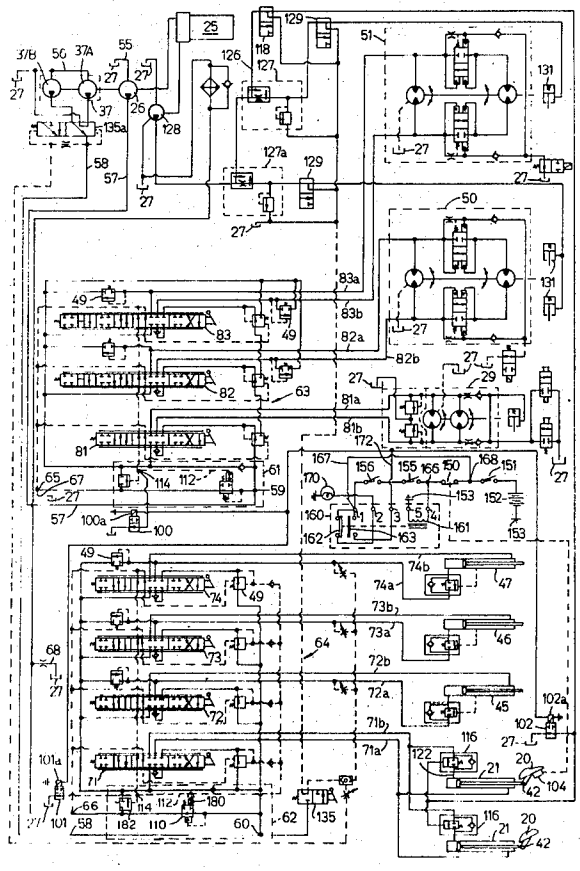
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Primary Examiner—Stanley H. Tollberg
Attorney, Agent, or Firm—James E. Nilles

[57] **ABSTRACT**

A mobile crane has a plurality of components which are selectively movable to various positions by means of individual hydraulic actuators (such as hydraulic motors or hydraulic rams) in response to selective operation of control valves. The control valves are grouped in one or more valve banks and, preferably, each bank is supplied with fluid from its own engine-driven hydraulic pump. Diversion of fluid from within a certain section of each valve bank has the effect of rendering the control valves in the bank inoperative. The crane also includes a pilot pressure operated holding valve for the hydraulic boom hoist cylinders and closure of this valve (effected by diversion of the pilot fluid thereto) prevents further boom movement. Means are provided to prevent further movement or operation of all crane components in the event one component, such as the boom, is operated or about to be operated beyond specified operating limits. Such means comprises a weight-load device for sensing that boom operating limits are about to be exceeded and an electric relay responsive to the sensing device to operate solenoid valves which divert fluid from the aforementioned section of the valve bank and divert pilot pressure from the boom hoist cylinder holding valve, thereby preventing further operation of any crane component by means of operation of a control valve and locking the boom in whatever position it is in. Selectively operable override means are provided to bypass the sensing device and operate the solenoids as to enable operation of the control valves and permit selective movement of the crane components.

7 Claims, 9 Drawing Figures



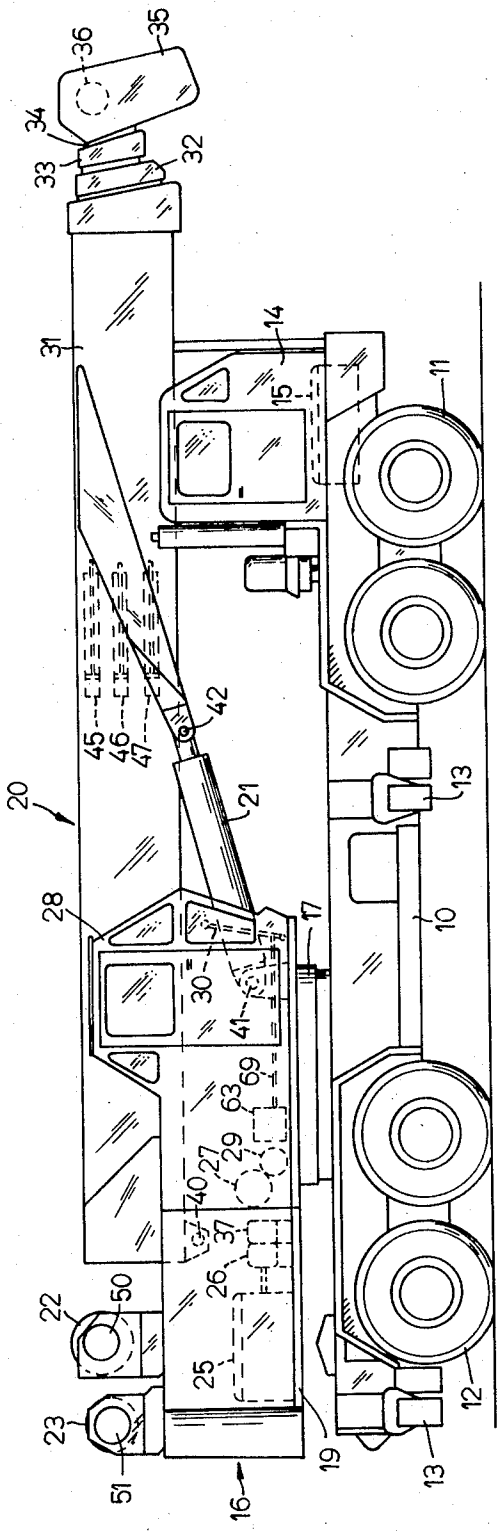
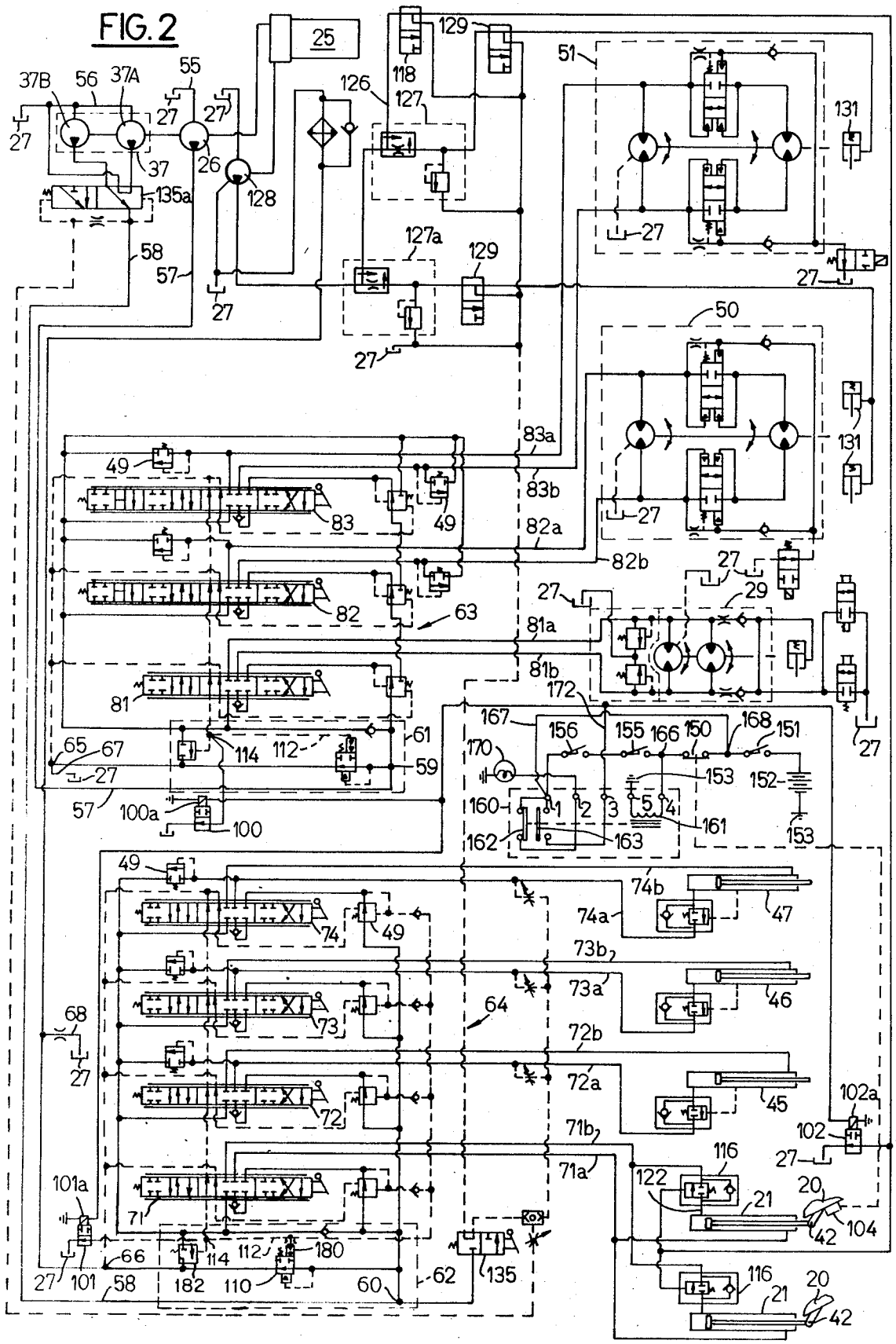

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FIG. 1

FIG. 2


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37B
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37A
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135a
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127a
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83a
83b
82a
82b
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81a
81b
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166
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168
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100a
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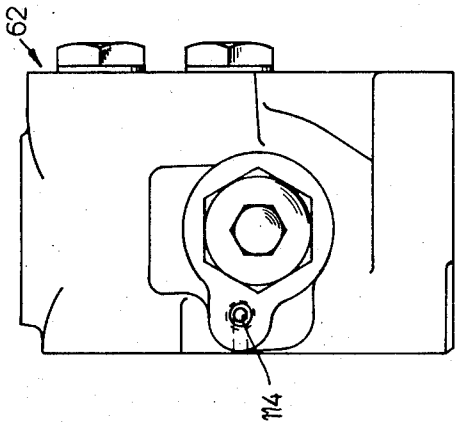


FIG. 4

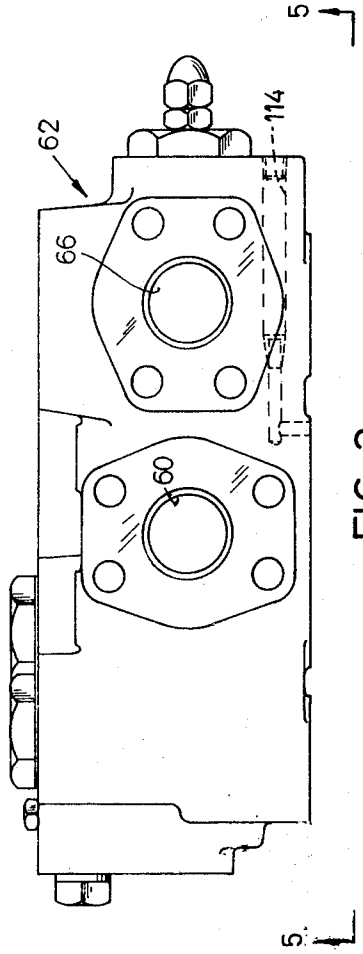


FIG. 3

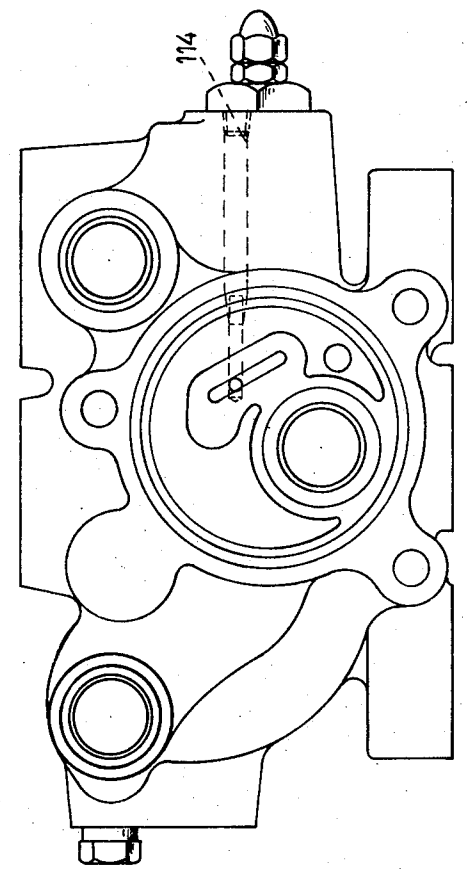


FIG. 5

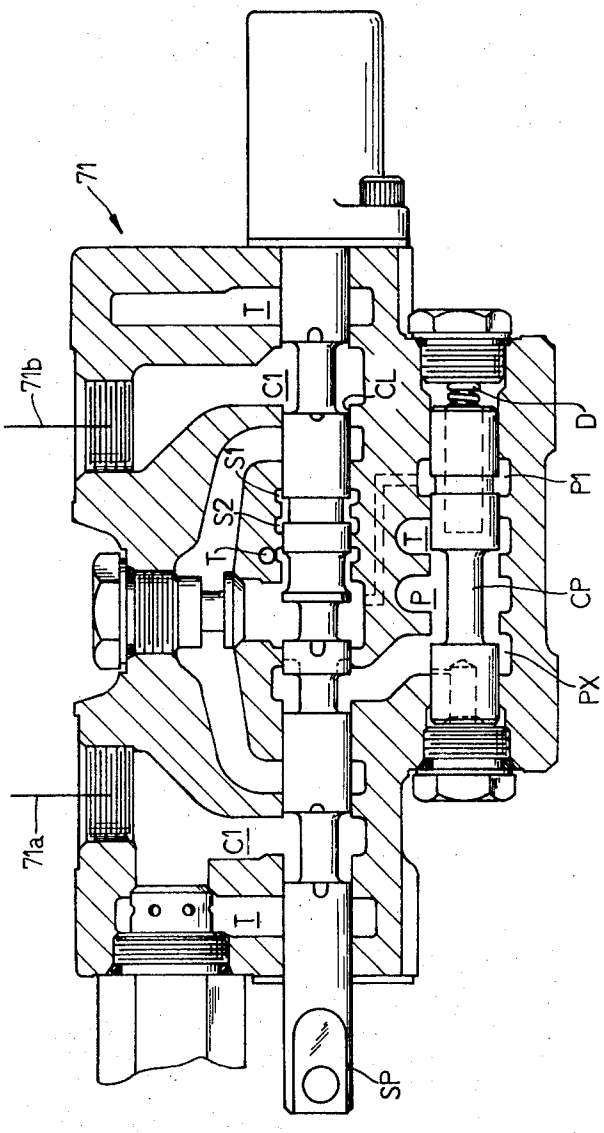


FIG. 6

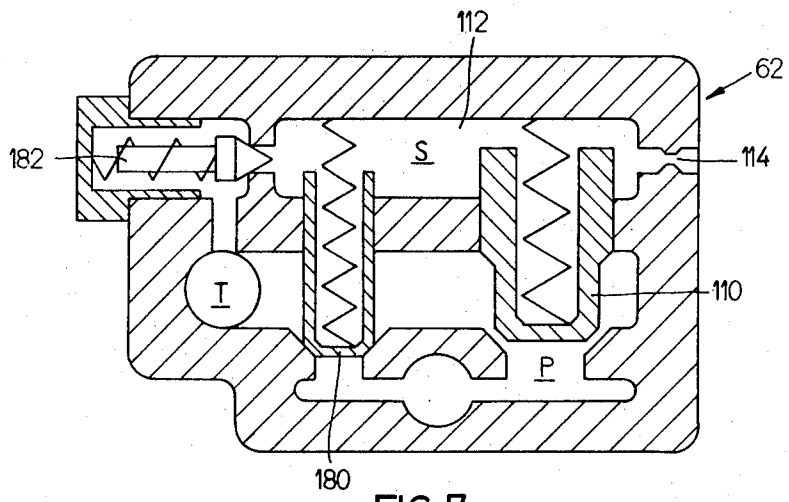


FIG. 7

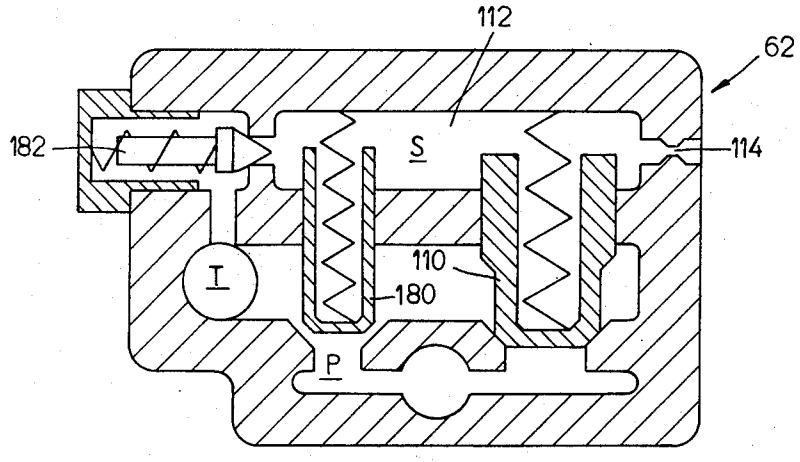


FIG. 8

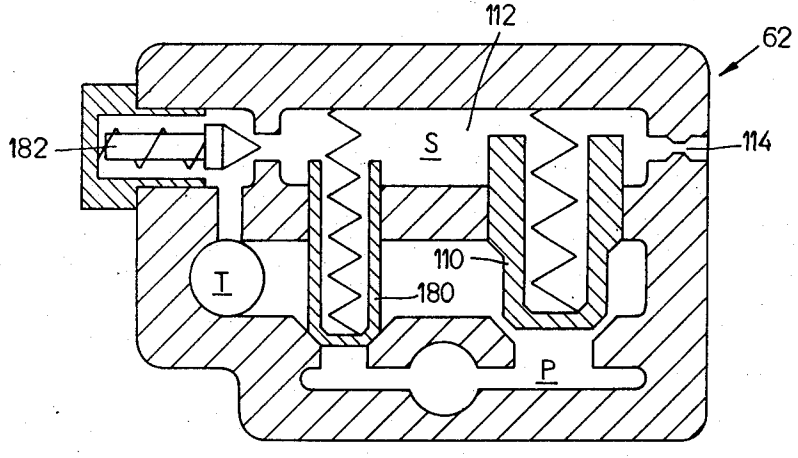


FIG. 9

HYDRAULIC CRANE CONTROL SYSTEM HAVING MEANS FOR DEACTIVATING CONTROL VALVES WHEN OPERATING LIMIT IS EXCEEDED

BACKGROUND OF THE INVENTION

1. Field of Use

This invention relates generally to control systems for mobile hydraulic cranes and, specifically, to electro-hydraulic means for deactivating hydraulic control valves in the event a crane component is moved or operated beyond certain operating limits.

2. Description of the Prior Art

In some machines such as mobile cranes, the movable components are operated by individual hydraulic actuators, such as hydraulic cylinders or motors, and selectively operable control valves direct hydraulic fluid from an engine-driven pump to the actuators. It is possible to move or operate some components, such as a crane boom, beyond desirable operating limits and thereby create a risk of damage to the crane and other dangers. Accordingly, as a safety measure, some cranes employed a solenoid-operated dumping valve for each individual valve and a sensing device responsive to the position or condition of the boom, for example, for operating the solenoid valves to dump fluid from the control valves and prevent further crane operation if operating limits were exceeded. This prevented further possibly dangerous operation of the crane until the sensing device was intentionally overridden. Since such cranes employed many control valves and required many solenoid valves, the necessary piping and wiring was complex and costly to install and repair. Furthermore, although such cranes usually employed a pilot valve operated holding valve to prevent accidental lowering of the boom, such prior art safety arrangements made no provision to prevent accidental operation of the boom resulting from dumping all fluid from the system.

SUMMARY OF THE PRESENT INVENTION

In accordance with the present invention, there is provided a mobile hydraulic crane comprising a lower section in the form of a self-propelled vehicle and a horizontally swingable upper section mounted hereon. A multi-section telescopic boom is pivotably mounted on the upper section and is vertically movable between raised and lowered positions. One or more load hoist line winches are mounted on the upper section. These various components are moved or operated by hydraulic actuators, such as a hydraulic motor for rotating the upper, hydraulic boom hoist cylinders for raising and lowering the boom, an extend-retract cylinder for each telescopically movable boom section, and a hydraulic motor for each winch. Each actuator is controlled by a selectively operable control valve which directs hydraulic fluid from an engine-driven pump to the actuator. The control valves are arranged or grouped in two control valve banks and each bank is supplied from a separate engine-driven pump. Both banks are dischargeable to a common reservoir.

Each bank comprises a fluid inlet-outlet section for supplying its control valves and the inlet-outlet section has a dump or unloading valve therein which is responsive to fluid pressure in a vent chamber in the inlet-outlet section. The dump valve responds to a drop in fluid pressure in the vent chamber, which occurs either when all the control valves in the bank are in neutral

or when a check port to the vent chamber is opened, to open and divert fluid from the pump to the reservoir. However, if one or more control valves in the bank is operated to perform a control function (and if the check port is closed), fluid pressure in the vent chamber maintains the dump valve closed.

The boom hoist cylinder is provided with a pilot valve operated holding valve which, when closed, presents raising or lowering of the boom. The pilot valve is supplied from and operated by the control valve for the boom hoist cylinders.

Electro-hydraulic means, including a boom condition sensing device, are provided for deactivating the control valve banks and the pilot valve for the boom hoist cylinder holding valve in the event the boom is operated or moved beyond desirable safe operating limits. The sensing device, operating through a relay, effects simultaneous deenergization (and opening) of a plurality of solenoid valves if boom operating limits are exceeded, to deactivate the control valve banks and the pilot valve operated boom hoist cylinder holding valve. More specifically, the solenoid valve for each bank opens the check port of the vent chamber thereby causing the unloading valve to open and dump fluid otherwise available to the control valves, thereby preventing any further operation of the control valves from effecting various crane functions. The solenoid valve acts to divert fluid from the vent chamber, even though one or more control valves are in operation and demanding fluid. The solenoid valve for the pilot valve operates to dump fluid from the pilot valve to thereby cause closure of the holding valve and prevent further boom movement.

In a preferred embodiment of the invention, for fail-safe considerations, each solenoid valve is located in a fluid line between a control valve bank (or the pilot valve) and the reservoir and is maintained closed by energization of the solenoid coil. Thus, deenergization of the solenoid valves, either in response to a fault signal from the sensing device or due to general or specific electrical failures in the system, causes deactivation of the associated valve bank or pilot valve.

The present invention provides several other advantages over prior art systems. For example, numerous solenoid valves, associated fluid lines and electrical wiring are eliminated thereby reducing system complexity, cost and maintenance. Also, additional safeguards are provided which are not found in prior art crane controls, such as closing of the pilot operated boom hoist holding valve in the event of crane limits being exceeded. Other objects and advantages of the invention will hereinafter appear.

DRAWINGS

FIG. 1 is a side elevational view of a mobile crane having an electro-hydraulic control system in accordance with the invention;

FIG. 2 is a schematic diagram of the control system for the crane shown in FIG. 1;

FIG. 3 is an enlarged top plan view of the inlet-outlet section of one of the two control valve banks shown in FIG. 2;

FIG. 4 is an elevational view of the left end of the inlet-outlet section shown in FIG. 3.

FIG. 5 is an elevational view of the inner side of the inlet-outlet section taken on line 5—5 of FIG. 3;

FIG. 6 is an enlarged view partly in cross-section of a typical control valve in the control valve banks shown in FIG. 2;

FIG. 7 is a schematic view of the valves in the inlet-outlet section, showing the by-pass poppet closed, the unloading poppet open, and the relief poppet closed;

FIG. 8 is a view similar to FIG. 7 but showing the by-pass poppet open, the unloading poppet closed; and the relief poppet closed; and

FIG. 9 is a view similar to FIG. 7 but showing the by-pass poppet closed, the unloading poppet open, and the relief poppet open.

DESCRIPTION OF A PREFERRED EMBODIMENT

FIG. 1 is a side elevational view of a mobile crane in accordance with the invention which comprises a chassis **10** on which are mounted front ground wheels **11**, rear ground wheels **12**, retractable outriggers **13**, a driver's cab **14**, an internal combustion engine **15** for driving the ground wheels, and a crane upper **16**.

Crane upper **16**, which is mounted for horizontal rotation in either direction on chassis **10** by revolving support means **17**, comprises a supporting framework **19** on which are mounted a telescopic boom **20** shown in stored position, two boom hoist cylinders **21** (only one of which is visible in FIG. 1) for raising and lowering the boom, main winch **22** and an auxiliary winch **23** for boom load hoist lines (not shown), an internal combustion engine **25** for driving two hydraulic pumps **26** and **37**, a hydraulic fluid reservoir or tank **27**, a crane operator's cab **28**, and control levers **30** for a hydraulic control system shown schematically in FIG. 2 and hereinafter described in detail. Crane upper **16** is rotatable by means of a hydraulic motor **29** carried on supporting framework **19**.

Telescopic boom **20** comprises a base section **31**, an inner mid section **32**, an outer mid section **33**, and a fly section **34** which is provided with a working head **35** on which, for example, a pulley or sheave **36** is rotatably mounted. Base section **31** of boom **20** is pivotally connected to upper framework **19** by pivot pin means **40**. Boom **20** is raised and lowered by the extendable and retractable boom hoist cylinders **21**, each of which is pivotally connected to and between upper framework **19** and base section **31** of boom **20** by pin means **41** and **42**, respectively.

The boom sections **32, 33** and **34** are extendable and retractable by means of hydraulic cylinders **45, 46** and **47**, respectively, which are physically located within the hollow boom **20**. The winches **22** and **23** are driven by hyraulic motors **50** and **51**, respectively.

As FIG. 2 shows, the components such as the crane upper **16**; the boom **20**; the boom sections **32, 33** and **34**; and the winches **22** and **23** are moved or operated by hydraulic actuators such as the hydraulic motor **29**; the boom hoist cylinder **21**; the cylinders **45, 46** and **47**; and the hydraulic motors **50** and **51**, respectively. These actuators, in turn, are controlled by the operator-actuated control valves or spool sections **81, 71, 72, 73, 74, 82** and **83**, respectively, which direct hydraulic fluid from the pumps **26** and **37** to the actuators.

FIG. 2 is a schematic diagram of the electro-hydraulic control system in accordance with the invention for the crane shown in FIG. 1. The system comprises the engine-driven hydraulic pumps **26** and **37** which have their fluid inlet ports connected by fluid supply lines **55** and **56**, respectively, to reservoir **27**. The fluid outlet or pressure ports of the pumps **26** and **37** are connected by fluid supply lines **57** and **58**, respectively, to the fluid inlet ports **59** and **60**, respectively, of the inlet-outlet sections **61** and **62**, respectively, of the control valve banks **63** and **64**, respectively. The fluid outlet ports **65** and **66** of the banks **63** and **64**, respectively, are connected by fluid return lines **67** and **68**, respectively, to reservoir **27**.

CONTROL VALVE BANKS

The control valve banks **63** and **64**, which are identical to each other except as to the number of control valves or spool sections in each and the crane control functions performed, are commercially available manually operated pressure compensated four-way directional control valves, such as Type 5070 control valves (Model X–308) produced by Hydraulic Industries, Incorporated, of Hartland, Wis. Direction of movement of the valve determines the direction of fluid flow therefrom and the extent of movement determines the amount of fluid flow. The banks **63** and **64** are physically located on crane upper **16** and the spool sections thereof are mechanically connected by a linkage **69** to the control levers **30** in cab **28**, as FIG. 1 shows.

Bank **64** comprises an inlet-outlet section **62** and valves **71, 72, 73** and **74** for controlling boom hoist cylinder **21**, inner mid section cylinder **45**, outer mid section cylinder **46**, and fly section cylinder **47**, respectively; being connected thereto by the fluid lines **71***a*–**71***b*, **72***a*–**72***b*, **73***a*–**73***b* and **74***a*–**74***b*, respectively. As FIG. 2 shows, a manually controlled two speed valve **135** is provided to effect operation of a selector valve **135***a* which enables the two sections **37A** and **37B** of torque splitter pump **37** to be paralleled to increase the speed of operation of the boom hoist cylinders **21** and/or the telescoping cylinders **45, 46, 47**.

Bank **63** comprises an inlet-outlet section **61**, and three spool sections **81, 82** and **83** for controlling crane upper swing motor **29**, main winch motor **50** and auxiliary winch motor **51**, respectively; being connected thereto by the fluid lines **81***a*–**81***b*, **82***a*–**82***b* and **83***a*–**83***b*, respectively. The valves in the banks **63** and **64** are provided with necessary internal passages and with internal pressure relief valves, such as **49**. The motors **29, 50** and **51** also comprise necessary internal valving, as shown in FIG. **2**.

Since the inlet-outlet sections and the spool sections of the control valve banks **63** and **64** are substantially identical, only inlet-outlet section **62** of bank **64**, shown in FIGS. **2, 3, 4, 5, 7, 8** and **9**, and spool section **71**, shown in FIGS. **2** and **6**, are hereinafter described in detail.

As FIGS. **7, 8** and **9** show, inlet-outlet section **62** comprises a vent chamber **112** wherein signal pressure exists, a check port **114** in communication therewith, a spring-loaded unloading valve poppet **110**, a spring-loaded by-pass valve poppet **180** and a spring-loaded main relief valve poppet **182**.

Unloading valve poppet **110** opens to dump fluid from pump **37** to reservoir **27** when there is zero demand from the control valves in bank **64** (i.e., when fluid pressure in vent chamber **112** is at a minimum value). By-pass valve poppet **180** operates to proportionally direct fluid flow to reservoir **27** and the control valves in bank **64**, depending on spool demands. Main

relief valve poppet **182** operates to relieve pressure if pump pressure is excessive.

Signal pressure in vent chamber **112** is generated by fluid pressure from pump **37** and appears in each control valve **71, 72, 73** and **74** in bank **64**, fluid flow being from passage S1 to S2 in each control valve in bank **64**, as FIG. **6** shows. Each passage S2 in one control valve in bank **64** is connected to passage S1 in the next adjacent downstream control valve and the passage S2 in the last control valve in the bank dumps to reservoir **27**. Any movement of any control valve spool SP shuts off flow from passage S1 to S2 and when this occurs, signal pressure increases in vent chamber **112**.

A more detailed description of the operation of the valve poppets in the inlet-outlet section **62** of bank **64** and the control valve spools is presented at the end of this specification. For present purposes it is sufficient to understand that if one or more spools SP of the control valves **71, 72, 73** and **74** in bank **64** is operated to perform a control function (and assuming that the check port **114** is closed), a pressure signal in the form of a pressure increase occurs in vent chamber **112** and unloading or dump valve poppet **110** either closes fully (as shown in FIG. **8**) or partially (as shown in FIG. **9**) to stop or diminish the dumping of fluid to reservoir **27**.

PILOT OPERATED HOLDING VALVE

The system shown in FIG. **2** further comprises a boom hoist cylinder holding valve **116**, shown externally of but preferably mounted on each hoist cylinder **21**, and adapted to prevent accidental movement of the boom, and a fluid operated pilot valve **118** for operating the holding valve **116**. The holding valve **116** is connected by fluid line **71***a* to one end of spool section **71** in bank **64** and by a fluid line **122** to the base end of boom hoist cylinder **21**. The rod end of cylinder **21** is connected by fluid line **71***b* to the other side of spool section **71**. The pilot valve **118** is connected by a pilot pressure fluid line **126** to a fluid outlet of a priority valve **127** which is supplied from a motor driven accessory pump **128**. The priority valves **127** and **127***a* also direct fluid to pilot valves such as **129** which direct fluid from accessory pump **128** to the main and auxiliary winch brake cylinders generally designated by numeral **131**. The holding valve **116**, when closed, acts to prevent fluid flow to or from the lower end of cylinder **21**. Thus, if boom **20** is in a raised position, closure of holding valve **116** locks the boom in raised position. Holding valve **116** is operated in response to operation of pilot valve **118**. More specifically, when pilot fluid is supplied to pilot valve **118**, holding valve **116** moves to open position. Therefore, if pilot fluid from pilot valve **118** is diverted, the latter closes holding valve **116**.

ELECTRO-HYDRAULIC CONTROL MEANS

In further accordance with the invention, the control system of FIG. **2** comprises electro-hydraulic means for deactivating the control valves or spool sections of the control valve banks **63** and **64** and for locking the boom hoist cylinder holding valve **116** is closed position in the event the boom is subject to an abnormal operation condition. The electro-hydraulic means comprise a boom condition sensing device, such as a conventional weigh-load device **104**, mounted on the crane in association with the boom **20** for sensing an abnormal boom condition and providing a signal in response thereto for effecting simultaneous operation of a plurality of solenoid valves **100, 101** and **102**.

Weigh-load device **104** is, for example, a known type of electrical device which is mounted at an appropriate location on the crane and is responsive, for example, to measure the relationships between the boom angle and the load on the boom and responds, as by opening a normally closed electric switch **150**, when an abnormal or undesirable boom angle relationship occurs during crane operation, i.e., when the boom component is exceeding safe or desirable operating limits. The sensing device **104** effects operation of the solenoid valves **100, 101** and **102** by means of an electric relay **160**.

Each solenoid valve **100, 101** and **102** is of a known type wherein the two-way valve thereof is open when the electric solenoid coil thereof is deenergized, as shown in FIG. **2**. A type 7W31 solenoid valve identified as a pilot operated, poppet style, two-way valve (normally open or normally closed) for oil, capable of handling up to 2 gallons per minute, 3,000 PSI and produced by Fluid Controls, Inc., is suitable for use in the present invention. Energization of the coil effects closure of the valve and prevents fluid flow therethrough.

As FIGS. **2, 3, 4, 5, 7, 8** and **9** show, each valve bank **63** and **64** is provided with a check port **114** which is normally used for checking the pilot pressure in the valve bank. If port **114** is opened so that fluid may flow therefrom (i.e., to relieve or diminish fluid pressure in vent chamber **112**), the resultant pressure drop in chamber **112** effects operation of the dump valve poppet **110** in the associated valve bank **63** or **64**.

Solenoid valves **100** and **101** operate to deactivate the control valve spool sections of the control valve banks **63** and **64**, respectively. Solenoid valve **102** operates to lock the boom hoist cylinder holding valve **116**. More specifically, solenoid valves **100** and **101** operate to actuate (open) the unloading valve poppets **110** located in the inlet-outlet sections **61** and **62** of the control valve banks **63** and **64**, respectively, and thereby divert or dump fluid otherwise available to the control valves therein, thereby preventing any subsequent control valve movements from effecting crane component movements. As hereinbefore mentioned, the unloading valve poppet **110** is responsive to a minimum pressure signal in vent chamber **112** to open and divert fluid from the control valve spool sections to reservoir **27**. Operation of solenoid valves **100** and **101** diverts fluid flow from the pilot pressure signal chamber, even though one or more control valve spool sections are demanding fluid and otherwise providing a maximum pressure signal in vent chamber **112**, to open the unloading valve poppet **110** and starve the spool sections. The solenoid valve **102** operates to divert or dump fluid otherwise available from pilot valve **118** of boom hoist cylinder to holding valve **116** to thereby close the latter and prevent release or unlocking of the holding valve **116** and accidental movement of boom **20**.

However, if one or more of the control valve spool sections SP in either bank is operated to perform a control function, the pressure signal in vent chamber **112** increases and unloading valve poppet **110** closes to stop or at least diminish the dumping of fluid to reservoir **27**. However, if one or more of the spool sections is being operated and, as a consequence of boom move-

ment, the check ports 114 of the control valve banks 63 and 64 are opened, the pressure loss in the vent chambers 112 makes it appear as if there is no signal (even though a spool section is open and a signal would otherwise exist) and the unloading valve poppet 110 then operates (opens) to divert fluid from the pumps 26 and 27, away from the banks 63 and 64, and to reservoir 27.

For fail-safe considerations, the valve of each solenoid valve 100, 101 and 102 is located in a fluid line between its associated valve and reservoir 27 and is maintained closed by energization of the solenoid coil. Thus, deenergization of the solenoid coil in response to a fault signal from the sensing device 104 (which opens switch 150) or an electrical failure, causes deenergization of that control valve bank or boom hoist holding valve associated with the solenoid coil.

RELAY ARRANGEMENT

Referring again to FIG. 2, weigh-load device 104 is actuated when crane boom 20 exceeds a certain operating range or limit to effect opening of a normally closed electric switch 150. Switch 150 is connected on one side through an on-off master switch 151 (preferably associated with an ignition switch for engine 25) to one side of a power source such as a battery 152 which has its other side connected to a chassis ground 153. The other side of switch 150 is connected through a pair of normally open series connected limit switches 155 and 156 to a relay terminal 1 of a relay assembly 160. Relay assembly 160 comprises a relay coil 161 which operates a set of normally closed relay contacts 162 and a set of normally open relay contacts 163. Relay coil 161 is connected to a relay terminal 5 which is connected to chassis ground 153 and is also connected to a relay terminal 4 which, in turn, is connected by a conductor 164 to a point 166 between switches 150 and 155. A conductor 167 is connected between relay terminal 1, hereinbefore referred to, and a point 168 between switches 150 and 151. Relay assembly 160 is further provided with relay terminals 2 and 3 which are connected as follows. Relay terminal 2 is connected on one side to the normally closed relay contacts 162 and the latter are connected to relay terminal 1. The other side of relay terminal 2 is connected through a signal light 170 to chassis ground 153. Relay terminal 3 is connected on one side to one side of the normally open relay contacts 163 and the other side of the latter are connected to relay terminal 1. Relay terminal 3 is also connected by a conductor 172 to one side of each of the coils 100*a*, 101*a*, and 102*a* of the solenoid valves 100, 101 and 102, respectively.

Assuming that master switch 151 is closed (on) and that switch 150 is also normally closed as a result of the boom being in proper position, relay coil 161 is energized and thereby effects closure of the relay contacts 163 and opening of the relay contacts 162. When relay contacts 163 are closed current is able to flow from battery 152, through master switch 151, through conductor 167, through closed contacts 163 and through each of the solenoid coils 100*a*, 101*a* and 102*a* to energize them and cause closure of their two-way solenoid valves 100, 101 and 102, respectively. In this condition the warning light 170 which is not illuminated and the limit switches 155 and 156 are open. When the solenoid valves 100, 101 and 102 close, each of the control valves in the control valve banks 63 and 64 are in operative condition and the pilot valve 118 supplies fluid to open holding valve 116, i.e., so that cylinders 21 are ready to receive and discharge operating fluid from operation of control valve 71 in either direction.

When weigh-load device 104 responds to boom 20 exceeding an operating limit, it effects opening of fault signal switch 150. Opening of switch 150 causes deenergization of relay coil 161 which, in turn, causes opening of relay contacts 163 and closure of relay contacts 162. When relay contacts 163 open, the solenoid coils 100*a*, 101*a* and 102*a* are deenergized and the solenoid valves 100, 101 and 102 are moved to open condition. When relay contacts 162 close, current flows from battery 152, through switch 151, through conductor 167, through contacts 162 and through lamp 170 which illuminates to provide a warning signal. When the solenoid valves 100 and 101 open, the control valve banks 63 and 64 are rendered inoperative because fluid is being dumped therefrom in the manner hereinbefore explained. Similarly, when solenoid valve 102 opens pilot fluid from pilot valve 118 to valves 116 is dumped and holding valves 116 assume a closed position. When the control valve banks 63 and 64 are rendered inoperative, operation of any control valve in either bank will not effect a control function and the components of the crane are immobilized. With holding valves 116 closed, boom hoist cylinders 21 cannot be extended or retracted.

In order to override the open fault switch 150, it is necessary to manually close both the normally open limit switches 155 and 156. Closure of the limit switches 155 and 156 establishes a circuit from battery 152, through master switch 151, through conductor 167, through relay terminal 1, through the limit switches 156 and 155, through conductor 64 and through relay coil 161 to the chassis ground 153. Establishment of this circuit energizes relay coil 161 which, in turn, effects re-energization of the solenoid coils 100*a*, 101*a* and 102*a* in the manner and with the result hereinbefore described. Closure of the solenoid valves 100, 101 and 102 again places the control valve banks 63 and 64 and pilot valve 118 again supplies fluid for holding valves 116 to open the latter. In this manner the crane components are ready to be moved back to within desirable operating limits.

DETAILED OPERATION OF CONTROL VALVE BANKS

As hereinbefore explained, valve bank 64 comprises a combined inlet-outlet section 62 and a plurality of control valves 71, 72, 73 and 74 arranged in side by side relationship with the inlet-outlet section. The inlet and outlet ports 60 and 66 (pressure and tank ports, respectively), are combined in the inlet section. As FIGS. 7, 8 and 9 show, inlet section 62 comprises an unloading valve poppet 110 which dumps fluid from the pump 26 or 27 directly to the reservoir 27 when there is zero demand from the spool sections. The inlet-outlet section 62 further comprises a by-pass valve poppet 180 for proportionately directing fluid flow to the reservoir 27 and to the spool sections, depending upon spool demands. The inlet-outlet section 62 further comprises a main relief valve poppet 182. The inlet-outlet section 62 also comprises a vent chamber 112 wherein a signal pressure exists. The signal pressure is generated by pump pressure and flows through or appears in each control valve spool section. Fluid containing the signal

pressure flows from passage S1 and S2 in each individual control valve spool SP. Each passage S2 in one spool is connected to passage S1 in an adjacent spool and the passage S2 in the last spool dumps to the reservoir **27.** Any movement of any spool shuts off the flow from passage S1 to passage S2 and when this occurs signal pressure is transmitted through an orifice to the vent chamber **112** in the inlet-outlet section **62.**

As FIGS. **7, 8** and **9** show, the unloading poppet **110** in inlet-outlet section **62** has a proportionately large area differential between its area exposed to the signal pressure in chamber **112** and its area exposed to the pump pressure in chamber P. Consequently, upon the appearance of signal pressure in the vent chamber **112,** the unloading poppet **110** closes, as FIG. **8** shows. When the unloading popper **110** is closed, fluid flow from the pump is diverted through the inlet-outlet section **62** to the control valve spool sections **71** and **74,** passing through passages **51** and **52** in any spool section which is in neutral position to any one or more of the other spool sections which are not in neutral and which, therefore, demand a fluid flow in order to function.

As a condition arises whereby pump flow is greater than the combined demand from all spools, the by-pass poppet **180** has a proportionately less area differential between its area which is exposed to pump pressure in chamber P and signal pressure in vent chamber **112.** Consequently, the by-pass poppet **180** becomes balanced between the pressure in chamber P and that in chamber S, as FIG. **8** shows, and allows the excess pump flow to escape to tank **27.** If, while the by-pass poppet **180** is functioning, the signal pressure in chamber **112** exceeds the setting of the main relief poppet **182,** the main relief poppet **182** opens and vents signal pressure from the vent chamber **112,** thereby allowing the unloading poppet **110** to open and dump the pump pressure to the reservoir **27,** as shown in FIG. **9.** This latter condition is also a balanced condition and allows just enough fluid flow from the pump to escape to reservoir **27** to maintain downstream pressure at the arbitrary main relief valve setting.

Referring now to FIG. **6** which shows a typical spool section **71,** fluid from the pump enters at passage P. Pump pressure is always present, being sensible through the orifice PX at the left end of the floating compensator spool CP. If the main spool SP is in neutral position, the pump pressure in passage P is sensed at the compensator area on the left end of spool CP but there is no balancing pressure on the right spring end, so the net effect is for the fluid flow from the pump to push the compensator spool CP out of the way so that fluid may flow through passage T which is connected to passage P of the next spool.

As the main spool SP begins to move leftward, several events occur simultaneously. First, as previously described, the flow of signal fluid is stopped at the passages S1 and S2. Pump flow is then diverted from the inlet-outlet section **62** into the spool section **71** at passage P. Next, the metering notches of the center land of main spool SP move off dead center and admit fluid now entering at passage P into the region **P1.** Fluid then flows through the load holding check and into region C2 past that adjacent control land CL which is now opened by leftward spool movement. Fluid in the region C1 is then metered out to reservoir **27** as a result of concurrent movement of its own control land.

As is apparent from FIG. **6,** at any working position of the spool SP, the center land metering notch is an orifice. Main fluid flow passing through this orifice incurs a pressure drop, and, therefore, the pressure at passage P1 is less than the pressure at passage P in proportion to the value of the pressure differential therebetween. The fluid pressure at passage P1 is transmitted to the spring end of compensator CP and adds to the spring force of spring D to balance the compensator CP against the force of pressure in chamber P at the left end and to thereby throttle the fluid flow in the direction from passage P to passage T. In other words, the force of spring D is a constant. Therefore, the differential between the pressures at passage P1 and passage P is a constant and, therefore, the pressure differential is constant for the assumed spool position for all values of pressure in chamber P. It is, therefore, to be understood that for any fixed orifice the fluid flow will also be a constant if the pressure differential is constant. Therefore, the rate of any function being controlled through passage C2 (connected to line 71*b*) will remain fixed regardless of changes in applied load or required pressure.

As the spool SP moves, the size of the center land orifice keeps changing, but the floating spool CP is insensitive to this fact. The floating spool CP senses changes in pressure in chamber P and P1 and shifts as required so as to stay in balance between the two. As hereinbefore explained this served to maintain the pressure differential at a fixed predetermined value, regardless of changes required in flow direction. It is to be noted that the compensator spool CP also responds to downstream demands at greater or lesser pressure conditions than its own and shifts as required to enable fluid flow to succeeding spools as needed.

RESUME

A mobile hydraulic crane comprises a vehicle on which movable components are mounted, including a horizontal swingable upper crane unit, a vertically pivotable multisection telescopic boom and rotatable winches for a load hoist line on the boom. Each component is moved or operated by an actuator such as a hydraulic cylinder or hydraulic motor and each actuator is controlled by an operator-actuated control valve which directs hydraulic fluid from an engine-driven pump to the actuator. The control valves are arranged in two control valve banks **63** and **64** which are supplied from engine-driven pumps **27** and **37,** respectively. The boom hoist cylinder **21** for raising and lowering the boom **20** is provided with a pilot valve **118** which operates a holding valve **116** which, when closed, prevents movement of the boom. Electro-hydraulic means are provided to dump hydraulic fluid from each control valve bank **63** and **64** and from the pilot valve **118** in the event a crane component, such as the boom, is moved or operated beyond desirable safe limits by the crane operator. Such dumping of fluid prevents further effective operation of any control valve by the crane operator and also prevents the pilot valve operated holding valve **116** from opening and enabling accidental lowering or raising of the boom. The electro-hydraulic means comprises an electrically operated sensing device, such as a conventional weigh-load device **104,** which actuates, by means of a relay **160,** a plurality of solenoid valves **100, 101** and **102** which operate simultaneously to dump fluid from the control

valve banks **63** and **64** and the pilot valve **118.** Manually operable override means, including switches **155** and **156,** are provided to override or by-pass the sensing device **104** to enable intentional movement or operation of the crane components back to within safe operating limits.

I claim:

1. In a hydraulic machine having a plurality of movable components, at least one of said components having an operating limit beyond which further operation is undesirable; a plurality of hydraulic actuators, at least one hydraulic actuator for operating each component; a control valve bank comprising a plurality of selectively operable control valves, at least one control valve being provided for operating each hydraulic actuator, pump means for supplying pressurized hydraulic fluid to said control valve bank for direction by each control valve to its respective actuator to effect operation of a respective component; dump valve means connected to said control valve bank and responsive to a pressure condition therein to divert fluid from said control valves and thereby prevent actuation thereof from effecting operation of said actuators and corresponding operation of said components; first valve means operable to affect pressure conditions in said control valve bank and thereby effect operation of said dump valve; a source of pilot pressure; holding valve means responsive to said pilot pressure for controlling locking operation of the hydraulic actuator for said one component; second valve means operable to affect the flow of pilot fluid to said holding valve means; and sensing means responsive to operation of said one component to said operating limit to operate said first valve means and effect operation of said dump valve thereby rendering actuation of said control valves ineffective and to operate said second valve means to cause said holding valve means to effect locking operation of said hydraulic actuator for said one component.

2. A machine according to claim **1** wherein said first and second valve means each include a solenoid valve and wherein said sensing means includes electroresponsive means for effecting operation of the solenoid valves.

3. In a hydraulic machine having a plurality of movable components, at least one of said components having an operating limit beyond which further operation is undesirable; a plurality of hydraulic actuators, at least one hydraulic actuator for operating each component; a plurality of selectively operable control valves, at least one control valve being provided for operating each hydraulic actuator, said control valves being arranged in two separate control valve banks, two pumps for supplying pressurized hydraulic fluid to said control valve banks for direction by each control valve to its respective actuator to effect operation of a respective component, one pump being provided for each control valve bank, dump valves connected to said control valve banks, each dump valve being responsive to a pressure condition in its respective control valve bank to divert fluid from the control valves in that bank and thereby prevent actuation thereof from effecting operation of the associated actuators and corresponding operation of components operated by said associated actuators; first and second valve means operable to affect pressure conditions in said control valve banks and thereby effect operation of the dump valves therefor; a source of pilot pressure; holding valve means responsive to said pilot pressure for controlling locking operation of the hydraulic actuator for said one component; third valve means operable to affect the flow of pilot fluid to said holding valve means; and sensing means responsive to operation of said one component to said operating limit to operate said first and second valve means and effect operation of said dump valves thereby rendering actuation of said control valves ineffective and to operate said third valve means to cause said holding valve means to effect locking operation of said hydraulic actuator for said one component.

4. A machine according to claim **3** wherein said first, second and third valve means each include a solenoid valve and wherein said sensing means includes electroresponsive means for effecting operation of the solenoid valves.

5. In a hydraulic crane having a plurality of movable components including a boom, said boom having an operating limit beyond which further operation is undesirable; a plurality of hydraulic actuators, at least one hydraulic actuator for operating each component and including a boom hoist cylinder for said boom; a control valve bank comprising a plurality of selectively operable control valves, at least one control valve being provided for operating each hydraulic actuator, pump means for supplying pressurized hydraulic fluid to said control valve bank for direction by each control valve to its respective actuator to effect operation of a respective component; dump valve means connected to said control valve bank and responsive to a pressure condition therein to divert fluid from said control valves and thereby prevent actuation thereof from effecting operation of said actuators and corresponding operation of said components; first valve means operable to affect pressure conditions in said control valve bank and thereby effect operation of said dump valve; a source of pilot pressure; a boom hoist cylinder holding valve responsive to said pilot pressure for controlling locking operation of said boom hoist cylinder; second valve means operable to affect the flow of pilot fluid to said boom hoist cylinder holding valve; and sensing means responsive to operation of said boom to said operating limit to operate said first valve means and effect operation of said dump valve thereby rendering actuation of said control valves ineffective and to operate said second valve means to cause said boom hoist cylinder holding valve to effect locking operation of said boom hoist cylinder.

6. A crane according to claim **5** wherein said first and second valve means each include a solenoid valve and wherein said sensing means includes electroresponsive means for effecting operation of the solenoid valves.

7. In a hydraulic crane having a plurality of movable components including a boom, said boom having an operating limit beyond which further operation is undesirable; a plurality of hydraulic actuators, at least one hydraulic actuator for operating each component and including a boom hoist cylinder for said boom; a plurality of selectively operable control valves, at least one control valve being provided for operating each hydraulic actuator, said control valves being arranged in two separate control valve banks, two pumps for supplying pressurized hydraulic fluid to said control valve banks for direction by each control valve to its respective actuator to effect operation of a respective component, one pump being provided for each control valve bank; dump valves connected to said control valve

banks, each dump valve being responsive to a pressure condition in tis respective control valve bank to divert fluid from the control valves in that bank and thereby prevent actuation thereof from effecting operation of the associated actuators and corresponding operation of components operated by said associated actuators, first and second valve means operable to affect pressure conditions in said control valve banks and thereby effect operation of the dump valves therefor, each of said first and second valve means including a solenoid valve; a source of pilot pressure; a boom hoist cylinder holding valve responsive to said pilot pressure for controlling locking operation of the boom hoist cylinders for said boom; third valve means including a solenoid valve operable to affect the flow of pilot fluid to said boom hoist cylinder holding valve; and sensing means responsive to operation of said boom to said operating limit to operate the solenoid valve of said first and second valve means and effect operation of said dump valves thereby rendering actuation of said control valves ineffective and to operate the solenoid valve of said third valve means to cause said boom hoist cylinder holding valve to effect locking operation of said boom hoist cylinder.

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