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Knutson

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[45] **July 24, 1973**

[54] **FLEXIBLE CABLE HYDRAULIC CONTROL MEANS**

[75] Inventor: **Dale A. Knutson,** Oconomowoc, Wis.

[73] Assignee: **Applied Power Inc.,** Milwaukee, Wis.

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[21] Appl. No.: **209,247**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 156,620, June 25, 1971.

[52] **U.S. Cl.** ..... **91/384,** 91/413, 91/461, 60/97 P, 60/471

[51] **Int. Cl.** **F15b 9/16**

[58] **Field of Search** ..... 91/384, 413, 461, 91/365, 383; 60/52 HE, 97 P, 471, 392, 388; 137/636.2

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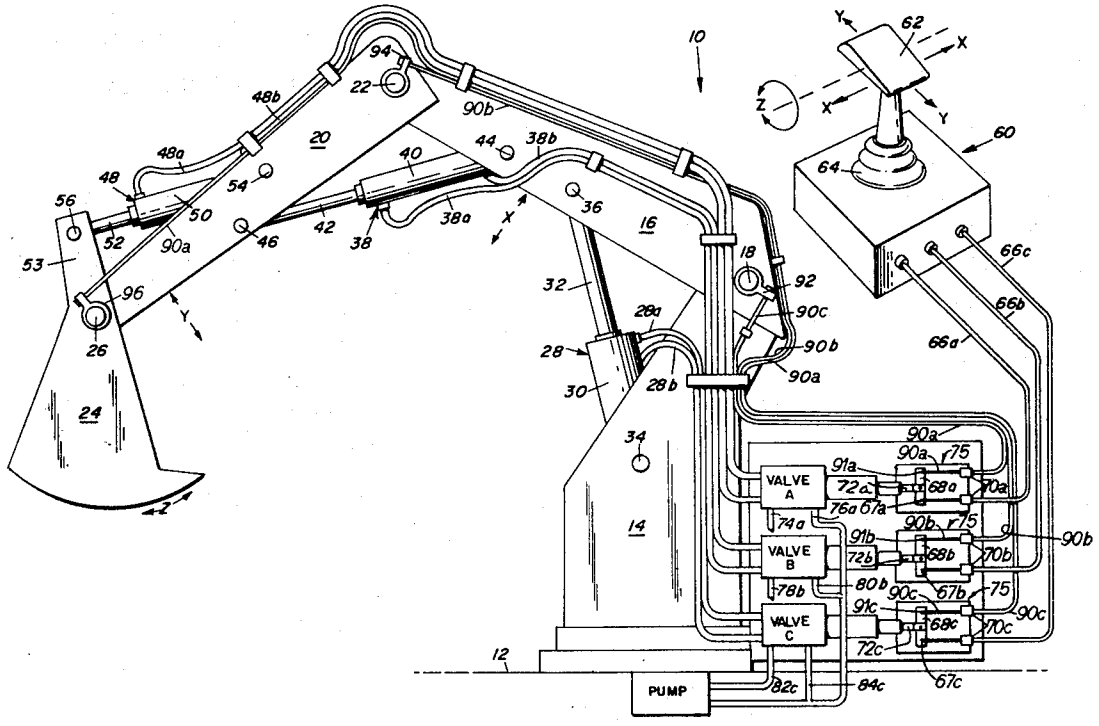
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Primary Examiner—Edgar W. Geoghegan
Attorney—James E. Nilles

[57] **ABSTRACT**

A hydraulic control system for controlling remotely positioned hydraulic cylinders, the system including a number of hydraulically actuated control valves which selectively communicate the hydraulic cylinders to a pressure source, a proportional force amplifier for each of the control valves for selectively opening and closing the control valves, and a feed back assembly to control the amount of movement of the hydraulic cylinders in accordance with the amount of movement of the input lever.

11 Claims, 7 Drawing Figures



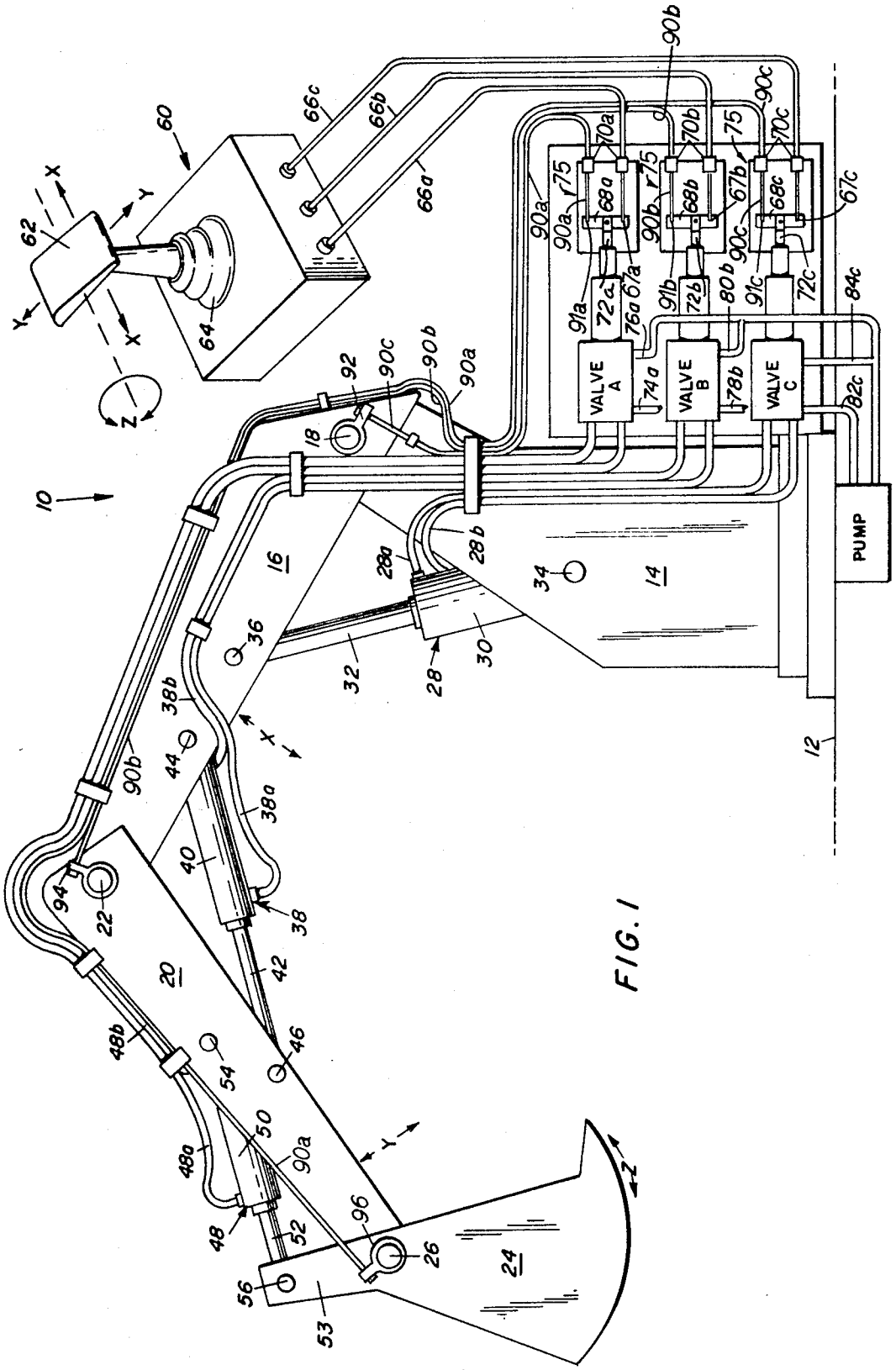


FIG. 1

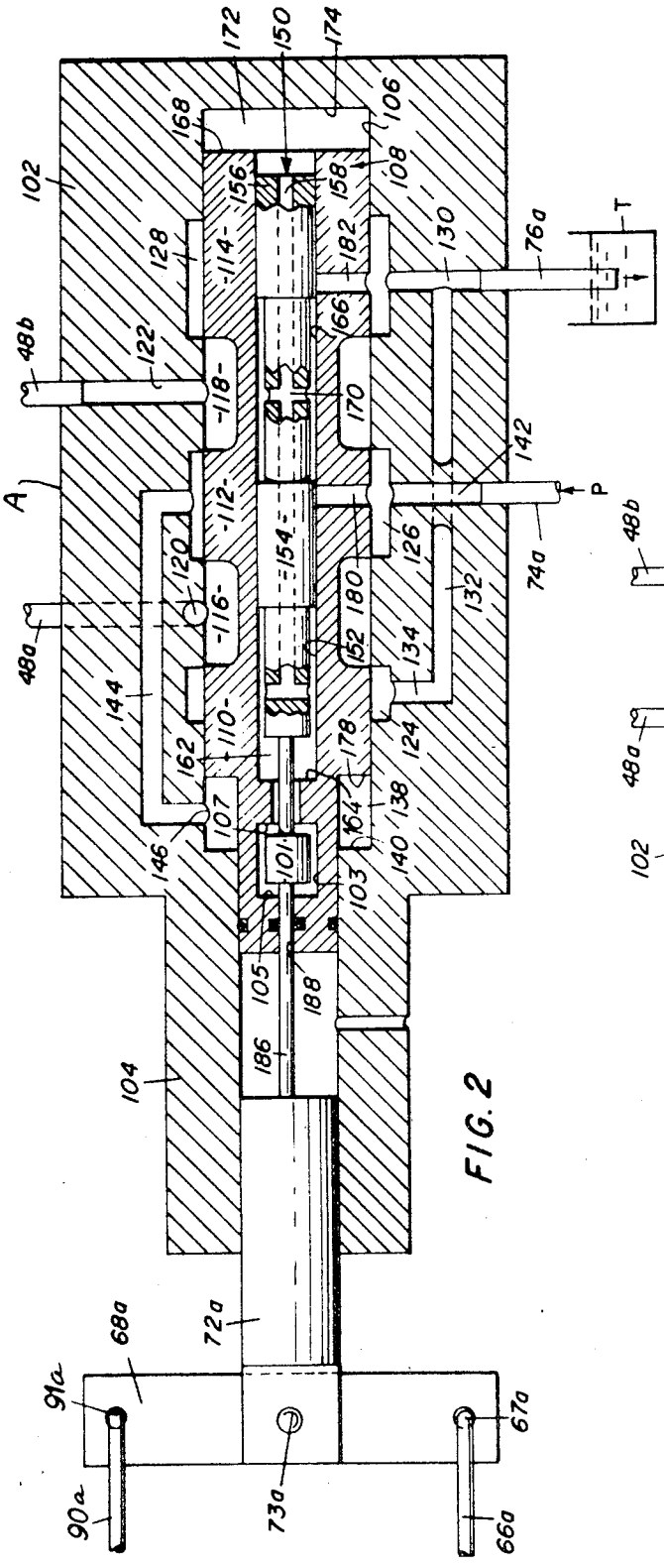

172
150
174
168
106
102
156
158
108
128
114
182
130
76a
T
48b
122
118
166
170
A
142
112
P
74a
120
154
126
48a
116
180
152
132
134
144
110
178
124
162
107
164
138
146
101
140
103
105
188
186
104
72a
68a
91a
67a
90a
73a
66a

FIG. 2

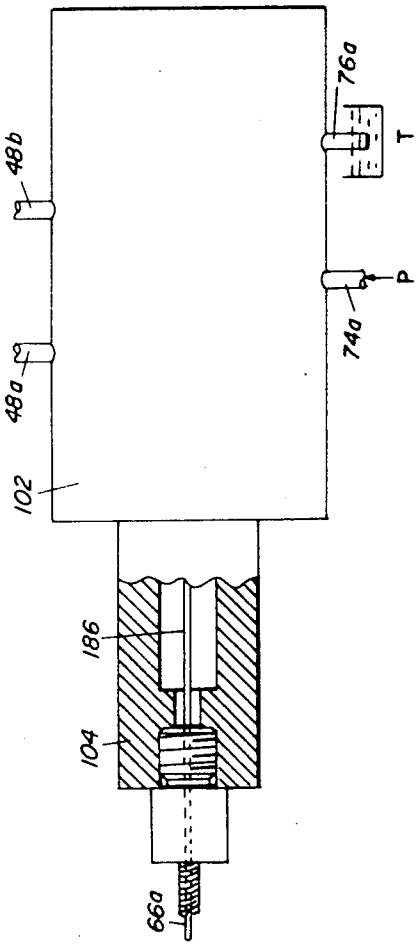

76a
T
48b
P
74a
48a
102
186
104
66a

FIG. 3

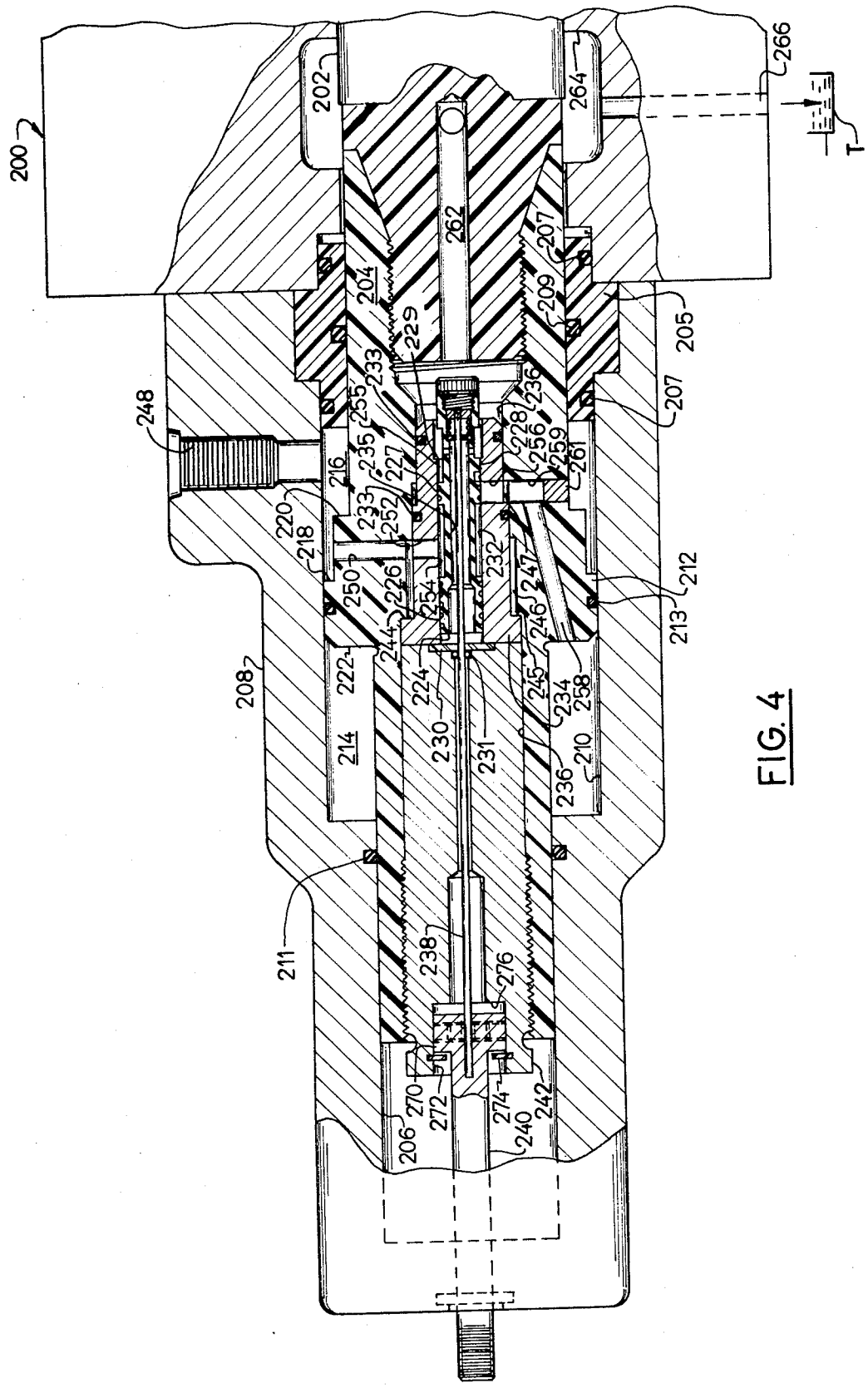

200
202
264
266
T
262
204
207
209
205
229
233
236
248
255
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227
228
256
259
261
216
220
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252
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247
250
226
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213
244
222
224
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234
258
208
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211
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276
270
272
274
240
242
206

FIG. 4

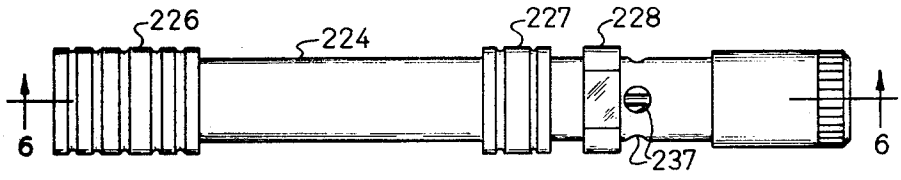


FIG. 5

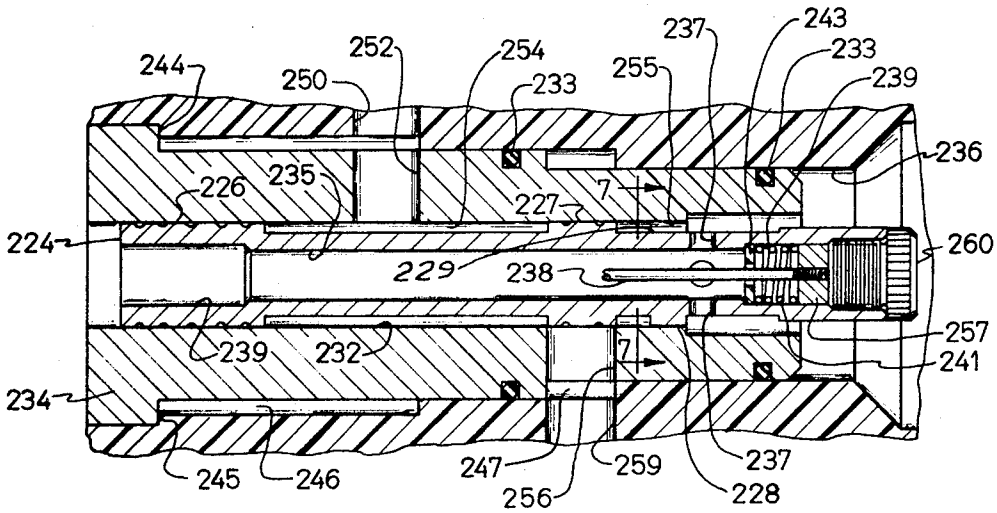


FIG. 6

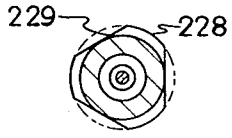


FIG. 7

FLEXIBLE CABLE HYDRAULIC CONTROL MEANS

RELATED APPLICATION

This application is a continuation in part of my earlier filed copending application Ser. No. 156,620 filed on June 25, 1971.

BACKGROUND OF THE INVENTION

In hydraulically actuated articulated booms commonly employed in heavy equipment such as earth working equipment, the boom sections are moved by double acting hydraulic cylinders. These cylinders are connected to and span the joints between the articulated boom sections and cause relative movement as generally understood in the art. The hydraulic cylinders are actuated directly by a series of mechanical linkages leading from control levers or handles in the control cab to the valves. The mechanical input force required to operate these valves is generally quite substantial due to the high fluid flow rates required to operate the hydraulic cylinders.

High flow directional control valves of the type contemplated herein are also subject to steady state flow forces which are proportional to net axial change of momentum of the fluid passing through the valve. These forces are well known and can be accurately calculated. 100 lb. forces are common in 90 GPM valves. These forces make the valve difficult to control particularly when "metering" the flow of fluid to the cylinder. When the valve is being closed there is resistance to movement due to friction. Then the flow forces build up and aid in the closing of the valve to the point where the operator must resist these forces through the linkage system in order to control the handle. If there is any backlash through the linkage system, due to this change in force, the valve can become uncontrollable at these flow forces.

SUMMARY OF THE INVENTION

The control system of the present invention combines a feed back assembly with a proportional force amplifier to control the movement of the hydraulic cylinders for the boom sections. The feed back assembly senses the movements of the various boom sections and through flexible cables transmits these movements back to the porportional force amplifier in an equal but opposite direction to the input forces from the control handle. Predetermined amounts of movement are thereby provided for the boom sections in response to predetermined movements of the control handle.

Further the proportional force amplifier operates in accordance with the principles disclosed in my copending application entitled "PROPORTIONAL FORCE AMPLIFIER," Ser. No. 196,495, filed Nov. 8, 1971. The proportional force amplifier is a power assist mechanism which is connected to the control valve and responds to manual mechanical input displacement to cause a displacement in the control valve in the same direction in a one-to-one proportion to the input but at a greatly increased force. In this invention the amount of force required to operate the control valve is approximately 100 times that required to operate the pilot valve. Additionally, the amount of movement of the main valve is proportioned to the amount of movement of the pilot valve in a one-to-one ratio.

These and other objects of the invention will become more apparent to those skilled in the art by reference to the following detailed description when viewed in light of the accompanying drawings wherein:

FIG. **1** is a diagrammatic view of the control system of this invention as applied to an articulated boom;

FIG. **2** is a cross-sectional view of the control valve of this invention with feedback means;

FIG. **3** is a cross-sectional view of the control valve of this invention without feedback means; and

FIG. **4** is a cross-sectional view of a modified form of the control valve of this invention;

FIG. **5** is an enlarged view of the pilot spool valve for the control valve shown in FIG. **4**;

FIG. **6** is a section view taken on line **6—6** of FIG. **5** showing the flow path through the pilot spool valve;

FIG. **7** is a cross-section taken on line **7—7** of FIG. **6** showing one of th lands.

DESCRIPTION OF THE INVENTION

Referring now to the drawings wherein like numerals indicate like parts, the control system **10** of this invention is shown applied to an articulated boom **12.** The boom is attached at its inner end to a rotatable support diagrammatically illustrated at **14,** which support is adapted to be positioned on a mobile unit such as track or wheeled vehicle. As is conventional in apparatus of this type, the boom consists of a first boom section **16** pivotally connected to the rotatable support **14** by pivot pin **18** for movement in a vertical plane. The second boom section **20** is pivotally attached to the first boom section **16** by pivot pin **22** for movement in a vertical plane. The bucket **24** is pivotally attached to the outer end of the second boom section **20** by pivot pin **26.**

The pivotal movement between the first boom section **16** and the support **14** is controlled by means of a first hydraulic piston and cylinder assembly or jack **28** which includes a cylinder **30** and piston rod **32.** The base of the cylinder **30** is pivotally connected to the support **14** by pivot pin **34** and the outer end of the piston rod **32** is pivotally connected to an intermediate point along the first boom section by pivot pin **36.** The hydraulic jack **28** is double-acting as are the jacks to be described hereinafter and includes inlet-outlet hydraulic conduits **28***a* and **28**b.

The pivotal movement between the first and second boom section **16** and **20** respectively is controlled by means of a second hydraulic piston and cylinder assembly as jack **38** which includes a cylinder **40** and a piston rod **42.** The base of the cylinder **40** is pivotally connected to the first boom section by means of pivot pin **44** and the outer end of the piston rod **42** is pivotally connected to the second boom section **20** by means of pivot pin **46.** The jack **38** is provided with inlet-outlet hydraulic conduits **38***a* and **38***b*.

The pivotal movement between the bucket **24** and the second boom section **20** is controlled by means of a third hydraulic piston and cylinder or jack **48** which includes a cylinder **50** and piston rod **52.** The base of the cylinder **50** is pivotally connected to the second section **20** intermediate its length by pivot pin **54.** The outer end of the piston rod **52** is pivotally connected to a bucket extension **53** by pivot pin **56.** The jack **48** includes inlet-outlet hydraulic conduits **48***a* and **48***b*.

The direction of pivotal movement between the support **14** and the first boom section **16** is indicated by the

arrow X; between the first boom section **16** and second boom section **20** by the arrow Y; and between the bucket **24** and the second boom section **20** by the arrow Z. The apparatus described above is conventional and well known in the art. This invention is directed toward but not limited to a control system for actuating the aforementioned hydraulic cylinders and thereby causing relative pivotal movement between the articulated sections.

CONTROL SYSTEM

In accordance with the invention, the hydraulic jacks **28, 38** and **48** are controlled by means of the control system **10** which generally includes a manual input control box **60,** feed back assemblies **75** and control valves A, B and C. The manual input control box **60** includes a universally movable handle or lever **62** which enters the box **60** through a resilient or flexible grommet **64.** Movements of the handle **62** are transmitted to the feed back assemblies **75** by means of flexible lightweight, push-pull cables **66**a, **66**b and **66**c, which move back and forth in response to the appropriate movement of the handle **62** through suitable mechanical means in the box **60,** which mechanical means are well known in the art and do not form a part of this invention. As will hereinafter be described,by pushing or pulling one or a combination of the cables, the hydraulic jacks **28, 38** and **48** will be actuated under the control of the valves A, B and C.

More particularly, the feed back assemblies **75** each include a yoke **68***a*, **68***b* and **68***c* respectively, pivotally connected to actuator rods **72***a*, **72***b* and **72***c* which actuate valves A, B and C respectively. The cables **66***a*, **66***b* and **66***c* are connected through fixed guides **70***a*, **70***b* and **70***c* to one end of the corresponding yoke by pins **67***a*, **67***b* and **67***c*, respectively. Valve A communicates with hydraulic jack **48** through inlet-outlet conduit **48***a* and **48***b* on one end, on the other it communicates with a source of pressure, such as a pump through conduit **74***a* and with the reservoir through conduit **76***a*. Valve B communicates with the jack **38** via inlet-outlet conduits **38***a* and **38***b* and with pressure and tank through conduits **78***b* and **80***b*. Valve C likewise communicates with hydraulic jack **28** via inlet-outlet conduits **28***a* and **28***b*, and pressure and tank via conduits **82***c* and **84***c*.

Means are provided for sensing the movement of the boom sections **16** and **20** and the bucket **24** and transmitting such movements to the feed back assemblies **75.** Such means is in the form of feed back cables **90***a*, **90***b* and **90***c* connected at one end to yokes **68***a*, **68***b* and **68***c* respectively, by means of pins **91***a*, **91***b* and **91***c*. Feed back cable **90***c* is connected at its other end to pivot pin **18** via clamping collar **92.** The clamping collar **92** is fixed to the pin **18** and rotates therewith. The pin **18,** in turn, rotates with the first boom section **16** such that angular movement of the first boom section **16** will be translated back to the corresponding yoke **68***c* by means of the flexible feed back cable **90***c*. Feed back cables **90***a* and **90***b* are connected to pivot pins **26** and **22** respectively by means of collars **96** and **94.** As with collar **92,** collars **94** and **96** rotate with the second boom section **20** and bucket **24** respectively.

To this point it can be seen generally that by actuation of the handle **62** one or more of the control valves A, B or C will be opened to actuate the corresponding hydraulic jack **48, 38** or **28.** Arrows X, Y and Z are shown adjacent to the control handle **62** to generally indicate the direction of the handle must be moved to cause the respective boom sections **16, 18** and the bucket **24** to move in the indicated directions X, Y and Z. The amount of movement of the boom sections **16** and **18** and the bucket **24** is controlled by means of the push-pull cables **66***a*, **66***b* and **66***c* to correspond to the amount of movement of the handle **62,** i.e., each movmeent of the handle **62** will produce a predetermined amout of movement in the respective boom section or bucket.

In this regard and referring to FIG. **2** the yoke **68***a* for the bucket **24** is shown. Assuming that the control handle **62** is moved in the Z direction and the cable **66***a* is pulled to the left, the yoke **68***a* will pivot clockwise about pivot point **91***a* pulling actuator rod **72***a* outward from the control valve A. Opening of valve A will pressurize jack **48** producing a pivoted motion in bucket **24** about pivot pin **26.** The motion of the bucket **24** is sensed by collar **96** on pivot pin **26** and transferred back to the yoke **68***a* by cable **90***a*. The cable **90***a* should move to right in FIG. **2** pivoting the yoke **68***a* clockwise about pivot point **67***a*, to push the actuator rod **72***a* into the control valve A to close the valve and stop the movement of bucket **24.**

CONTROL VALVE

Since valves A, B and C are identical, only one, valve A, will be described in detail. As indicated above the yoke **68***a* is pivotally attached to the actuator rod **72***a* by means of pivot pin **73***a*. The control valve includes a valve housing **102** having a tubular extension **104** extending from one end thereof for slidably receiving the actuator rod **72***a*. The housing **102** includes a central bore **106** which slidably receives a spool **108** having a first land **110,** a second land **112** and a third land **114** axially spaced thereon and defining annular chambers **116** and **118** therebetween with the interior walls of the bore **106.** Inlet-outlet conduits **48***a* and **48***b* communicate with the chambers **116** and **118** respectively via ports **120** and **122.** The axial bore **106** is counterbored at axially spaced points to define chambers **124, 126** and **128** with lands **110, 112** and **114.** Reservoir conduit **76**a communicates with chamber **128** via port **130,** and with chamber **124** via passageway **132** and port **134.**

A chamber **138** is defined between the end of the first land **110** of the spool **108** and the end wall **140** of the bore **106.** Pressure conduit **74***a* communicates with annular chamber **126** via port **142** and with chamber **138** via chamber **126** passageway **144** and port **146.**

In the position shown in FIG. **2,** the spool **108** is in the null or balanced position. It can be seen that when the spool is moved to the left, inlet-outlet conduit **48***b* is communicated to pressure and inlet-outlet conduit **48***a* is communicated to tank and vice versa when the spool moves to the right. As mentioned, however, oftentimes, the movement of the spool is quite difficult due to the flow forces and centering spring forces of the system. Hence a pilot valve or servo valve **150** is slidably received in an axially extending bore **152** in the spool valve **108,** whereby, by actuation of the pilot valve **150** as will hereinafter be described, the spool valve **108** is shifted hydraulically and proportionally less amount of manual input force is required.

More particularly, the main valves A, B and C are actuated by means of proportional force amplifiers as dis-

closed in my copending application Ser. No. 196,495. In this regard, each amplifier includes a pilot valve **150** having lands **154** and **156** and is provided with an axial passageway **158** which communicates chambers **162**, **166** and **172** with each other. Chamber **162** is defined by the end **164** of the bore **152** and the land **154**. Chamber **166** is defined by the two lands **154** and **156** and chamber **172** is defined by the end wall **174** of the bore **106** and the annular end surface **168** of the spool **108**. The area of the end surface **168** is approximately one half the area of the surface **178** defining the one end wall of constantly pressured chamber **138**.

Ports **180** and **182** communicate the pressure conduit **74***a* and the tank conduit **26***a* respectively to the bore **152** and are normally blocked by lands **154** and **156** when the pilot valve is in the null or balanced position. The facing edges of the lands **154** and **156** are spaced apart from each other a distance corresponding to the distance between the edges of the apertures of ports **180** and **182**. The edges of the lands can be used effectively to meter the fluid flow through the ports. The pilot valve **150** is connected at one end to rod **186** which in turn is connected to actuator rod **72***a*. The rod **186** passes through an opening **188** in the end wall of the spool **108**.

The operation of the pilot control valve **150** is as follows. Referring to FIG. **2**, assume that by suitable actuation of the control handle **62**, the cable **66***a* is moved to the left. The yoke will move clockwise to the left about the point of connection **91***a* between the feed back cable **90***a* and the yoke **68***a* which point provides a fixed pivot. Upon such movement of the cable to the left, the pilot valve **150** will likewise be pulled to the left a distance determined by the amount of movement of the control handle **62**. The land **154** will uncover the pressure port **180** and fluid under pressure will enter chamber **172** via port **170** and axial passageway **158**. As mentioned earlier, chamber **138** is in constant communication with the pressure source via passageway **144**, and, due to the fact that the area of surface **168** is approximately twice that of the area of surface **178**, the spool **108** will shift to the left because of this differential in surface areas. The spool **108** by shifting to the left will communicate the pressure passageway **74***a* to uncovered annular areas **126** and **118** and permit fluid under pressure to enter the inlet-outlet conduit **48***b*, while at the same time inlet-outlet conduit **48***a* is communicated with tank passageway **76***a* via chambers **116** and **124** and passageway **132**. Operating upon the principles described in my earlier mentioned copending application Ser. No. 196,495, the spool **108** will continue to move to the left relative to the pilot valve until the pressure port **180** is again completely covered by the land **154** on the pilot valve **150**.

The spool **108** will move relative to the pilot valve **150** and will move the same distance; that is, it will move proportionately in a one-to-one ratio. The hydraulic jack **48** will contract, causing feed back cable **90***a* to move to the right in FIG. **2** exactly the same distance that the input cable was caused to move to the left initially. The point of connection **67***a* of the input cable will serve as a fixed pivot point, and the yoke will move clockwise thereabout causing the pilot valve **150** to move in the reverse direction, to the right. Prior to this latter movement, it is to be understood that the pressure source will be in open communication with the conduit leading to the hydraulic jack.

When the pilot valve **150** is shifted back to the right relative to the spool **108** by the feed back means, the land **156** will uncover port **182** thereby communicating control chamber **172** with tank pressure and causing a loss of pressure in chamber **172**. As mentioned, since the chamber **138** is under constant static pressure, the spool will be caused to move to the right relative to the spool valve **108** until both the pressure port and tank port **180** and **182** are again covered by lands **154** and **156** at which time the spool valve **150** will be back in the null and balanced position. The principle behind this operation will be more fully understood by referring to my earlier mentioned copending application. It is to be emphasized that the force ratio between the mechanical input and the hydraulic force acting on the spool valve is approximately 1 to 100 such that a small input force acting to shift the pilot valve results in a proportionately greater force being applied to the spool valve.

In order to pressurize inlet-outlet conduit **48***a* while exhausting conduit **48***b*, the pilot valve is shifted to the right with point **91***a* again acting as a fixed pivot. Control chamber **172** is communicated to tank via uncovered port **182** thereby dropping the pressure therein. The pressure in constantly pressurized chamber **138** will be sufficient to shift the spool **108** to the right relative to the pilot valve until the port **182** is again covered, during which time pressure will be transmitted to the hydraulic jack **48** via chambers **126** and **116**, port **120** and conduit **48***a*. Conduit **48***b* will be communicated to exhaust via line **122**, chambers **118** and **128** and line **130**. The feed back cable **90***a* will cause the spool **108** to shift back to the null and balanced position in the manner heretofore described.

In the event of a loss of hydraulic pressure, the spool **108** can be shifted manually to release fluid pressure from the hydraulic jack **48**. This is accomplished by means of an enlarged flange **101** attached to actuator rod **186** which is disposed within a chamber **103** in the spool **108**. The chamber has end walls **105** and **107** which are engaged by the enlarged flange upon movement of the yoke **68***a* to manually shift the spool **108**.

If desired, the feed means may be eliminated as shown in the embodiment of FIG. **3**. In this embodiment, only the input cable **66***a* is attached to the pilot valve **150**. In the embodiment of FIG. **1** and FIG. **2**, the valve will seek the null and balanced position for any position of the control handle. That is, if the control handle is pushed to the right in the direction of arrow X 1 inch and is held there, the corresponding element will swing to its angular movement a predetermined distance proportional to the movement of the control handle and will stop automatically without having to move the handle back to neutral since the feed back cable will cause the valves to return to the null and balanced position. In the embodiment FIG. **3**, the handle itself must be returned to the neutral position before the valve will return to the null and balanced position.

ALTERNATE PROPORTIONAL FORCE AMPLIFIER

A modified form of amplifier used to actuate the control valve of this invention is shown in FIG. **4**. The control valve comprises a conventional four-way valve, generally indicated by the numeral **200** having a spool valve **202**. In the embodiment of FIGS. **2** and **3** the pilot valve is mounted within a central bore in the spool

valve. In the modified form of FIG. 4 the pilot valve is mounted exteriorly of the spool valve and outside of the spool valve housing.

In this regard, an extension **204** is attached to one end of the spool valve **202**, is axially aligned therewith and is slidably received in a bore in a housing **208** mounted on the valve **200**. The housing **208** includes an inlet port or passage **248** connected to a source of fluid pressure and a counterbore **210** at the open end of the bore **206**. The extension **204** is shown threadably engaged with one end of the spool valve **202**. However, it is to be understood that the extension **204** may be an integral part of the spool valve **202** or otherwise attached thereto. Means are provided for sealing the extension within the counterbore **210**. Such means comprises a seal ring **205** having external O-ring seals **207** and an internal O-ring seal **209**.

The extension **204** includes a double faced actuator piston **212** which is positioned for sliding movement within the counterbore **210** and divides the counterbore **210** into chambers **214** and **216**. The total cross sectional area of surfaces **218** and **220** on the piston **212** adjacent chamber **216** is approximately half the cross sectional area of the surface **222** on the piston **212** adjacent to chamber **214**. The extenstion **204** is provided with an axial bore **236** which is connected to the chamber **216** through a passage **250** and to the chamber **214** through a passage **258** and a port **259**, the port **259** being closed by a plug **261**. The piston **212** is sealed in the counterbore **210** by means of an O-ring seal **213**.

The pressure of the fluid acting on piston **212** is controlled by means of a tubular pilot spool valve **224** having lands **226, 227** and **228** and a central passage **235**. The spool valve **224** is slidably received in an axial bore **232** in an insert **234** which is positioned within the axial bore **236** in extension **204**. The insert **234** is retained in the bore **236** by means of a plug **242** threadably received in the outer end of the bore **236** in extension **204** and is sealed therein by means of O-ring seals **233**. The insert **234** is provided with a flange **244** which abuts an inwardly directed shoulder **245** in the bore **236**. Annular chambers **246** and **247** are provided between the insert **234** and the extension **204**. The chamber **246** is in communication with inlet pressure passage **250** and the chamber **247** is in communication with port **259** and passage **258**.

The pilot spool valve **224** is positioned within the bore **232** in the insert with the lands **226** and **227** spaced to define an annular pressure chamber **254** and the lands **227** and **228** spaced to define a relief chamber **255**. The pressure chamber **254** is connected to the chamber **246** by means of a port **252**. The relief chamber **255** is connected to the open end of the bore **236** by means of flats **229** on land **228**. The chambers **254** and **255** are selectively connected to the chamber **247** through a port **252** by means of the land **227** as described below.

The pilot spool valve **224** as seen in FIGS. **5, 6** and **7** is provided with a counterbore **239** at each end of passage **235** and a cross bore **237** adjacent to land **228**. Means are provided for connecting the pilot valve **224** to an actuator rod **240** in the form of a rod **238** which extends through the passage **235** and is connected to the end of the spool valve **224** by means of a plug **257**. In this regard, the plug **257** is threadably connected to the rod **238** and is positioned within counterbore **239**. Side loads imparted to the pilot valve **224** by the movement of the rod **238** are compensated for by means of a spring **241** positioned between the plug **257** and a shoulder **243** between the bore **235** and the counterbore **239**. Since the side loads generally occur when the spool valve **224** is pulled by the rod **238**, the spring **241** is provided only on one side of the plug **257**. Movement in the other direction is achieved by the mechanical engagement of the plug **257** with an end cap **260** threadably received in the end of the counterbore **239**.

The spool valve **224** is pressure balanced within the passage **232** in order to eliminate any variation in forces acting on the ends of the valve **224**. This is accomplished by means of the passage **235** which extends through the center of the spool valve and the cross bore **237**. Since both ends of the spool valve are now connected the pressure acting on each end of the spool valve will be essentially equal except for the cross sectional area of rod **238** which is negligible. Further the passage **235** is connected to tank pressure through passage **262** in the spool valve **202**, the annular chamber **264** and passage **266** in the control valve **200**.

Means are provided for mechanically actuating the spool valve **202** in the event of a loss of power. Such means is in the form of a flange **270** provided on the actuator member **240** and positioned in a counterbore **272** in the end of the plug **242**. The flange **270** is retained in the counterbore **272** by means of a retainer ring **274**. On movement of the actuator rod to the right, the flange will engage the end wall **276** and move the plug **242** to the right. On movement of the actuator member **240** to the left, the flange **270** will engage the retainer ring **274** and move the plug **242** to the left.

Means are provided for sealing the extension **204** within the bore **206** of housing **208**. Such means is in the form of an O-ring seal **211** in the bore **206** and an O-ring seal **231** positioned to sealingly engage rod **238**. The seal **231** is retained in the end of plug **242** by means of a plate **230**.

In operation of the modified valve of FIG. **4** fluid under pressure is introduced into chamber **216** via passageway **248**. The fluid passes through passageway **250**, annular chamber **246** and passageway **252** to annular chamber **254** defined by the reduced portion of the spool valve **224** between the lands **226** and **227**. Chamber **216** is in constant communication with the pressure source and is therefore under constant static pressure, which tends to urge the piston and thereby the extension and spool valve to the left. The valve is shown in its null and balanced position with the forces tending to move the piston either to the ritht or left being equalized.

The force tending to urge the piston to the left is counterbalanced by the lower pressure in the chamber **214** acting on the larger cross sectional area **222**. Fluid flow to the chamber **214** to vary the pressure therein is controlled by the pilot valve **224**. As shown, land **227** covers port **256** which leads to port **259**, passageway **258** and chamber **214**. When the pilot valve **224** is shifted to the right fluid under pressure enters the port **256**, annular chamber **247**, port **259**, passageway **258** and chamber **214** to raise the pressure in the chamber **214** causing the piston **212** and extension **204** to move to the right relative to the pilot valve **224** until the port **256** is again covered by the land **227**. Of course, the movement of the piston **212** and extension **204** to the right causes the spool valve **202** to move to the right to

uncover the pressure and exhaust ports therein. In order to move the spool valve **202** to the left, the pressure in the chamber **214** is reduced by moving the pilot valve **224** to the left and communicating the chamber **214** with the tank T via passage **258**, port **259**, chamber **247**, port **256**, chamber **255**, passageway **262**, annular chamber **264** and passagewaY **266**. As in the embodiments of FIGS. **1** through **3**, the pilot valve of the embodiment of FIG. **4** may or may not be provided with a feed back means.

Means are provided for preventing the second land **227** from catching on the edges of the port **256**. Such means is in the form of the third land **228** which acts as a support for the spool valve **224**. On movement of the valve **224** in the bore **232**, the land **228** will clear the edges of the port **256**.

I claim:

1. A hydraulic control system for controlling the flow of hydraulic fluid from a fluid pressure source to a plurality of hydraulic piston and cylinder assemblies from a remote point comprising,

main valves for selectively connecting each of the cylinder assmeblies to the fluid pressure source,

a yoke pivotally connected to each of said valves,

first means including a manual input lever operably connected for moving each of said main valves to an open position, said first means including a fixed guide and a flexible cable passing through said fixed guide and being attached to one end of said yoke, and

second means connected to said piston and cylinder assemblies for moving each of said main valves in the reverse direction to the direction of movement imparted by said manual input lever a distance equal to the distance of movement of the lever to close the valves, said second means including a second fixed guide and a second flexible cable passing through said second cable and being attached to the other end of said yoke, whereby the amount of movement of the piston and cylinder assemblies is directly related to the amount of movement of the lever.

2. The control system of claim **1** wherein each of said main valves includes a spool valve slidably received in a housing having inlet-outlet ports communicating with one of said piston and cylinder assemblies, and pressure and tank ports, metering lands on said spool valve normally closing said ports, said spool valve having opposed first and second end surfaces defining first and second chambers respectively with the ends of said housing, the area of said first end surface being half that of said second end surface, said first chamber being in constant communication with said pressure source, a pilot valve coaxial with and slidably received in an axial bore in said spool valve and operably connected to said first and second means, first and second passageways communicating with second chamber with said pressure source and with a reservoir at tank pressure respectively, said pilot valve extending across said passageways and selectively communicating said second chamber with said pressure source and reservoir to cause movement of one of said piston and cylinder assemblies in response to movement of said first and second cables.

3. The control system of claim **2** wherein said pilot valve has third and fourth lands normally closing both said first and second passageways respectively when said spool is in the balanced or null position and wherein the axial spacing between said metering lands is equal to the axial spacing between said passageways, said lands defining a third chamber therebetween, a third passageway constantly communicating said second chamber with said third chamber, and whereby said pilot valve is shifted axially to uncover one of said passageways in response to movement of said first means thereby changing the pressure in said second chamber relative to said constantly pressurized first chamber and causing movement of said spool valve relative to said pilot valve until said first and second passageways are again covered by the lands of said pilot valve.

4. The system according to claim **1** including

a proportional force amplifier operatively connected to said main valve,

said amplifier including a pilot valve,

said yoke being connected to said pilot valve.

5. The system according to claim **1** including,

a proportional force amplifier operatively connected to said main valve, said amplifier including a housing having a cylindrical chamber, a double faced piston mounted for axial movement in said chamber and having a central passage, said piston separating said chamber into a pressure chamber and a control chamber,

first and second passages in said piston connecting said pressure and control chambers to said central passage, and a pilot valve mounted for axial movement in said central piston passage for selectively connecting said pressure chamber to said control chamber.

6. The system according to claim **5** wherein said pilot valve includes a central bore in communication with each end of said valve whereby the fluid pressure action on each end of the valve is equal.

7. A hydraulic control system for controlling the flow of fluid under pressure to a plurality of hydraulic piston and cylinder assemblies from a remote point comprising,

a normally closed main valve for each of said assemblies, each main valve including a housing having a central bore and a spool valve slidably received in said bore in said housing,

a proportional force amplifier connected to control said spool valve,

a universally movable manual input lever connected to actuate said amplifier and open said main valve to actuate the corresponding piston and cylinder assembly, and

means connected to said amplifier for returning said spool valve to the closed position, said returning means being connected to respond to the movement of the corresponding piston and cylinder assembly.

8. The control system of claim **7** wherein said spool valve includes first and second ends defining first and second chambers with the end walls of the bore in said housing, said first end being of approximately twice the cross sectional area of said second end, the fluid pressure source being in constant communication with said second chamber to provide static pressure therein, and said amplifier including a pilot valve selectively communicating said first chamber to the pressure source and reservoir to vary the pressure therein and to thereby cause the movement of said spool valve, the di-

rection of movement being a function of differential pressures in said chambers and the difference in areas of said surfaces.

9. The control system of claim **7** wherein said amplifier includes a double-faced actuator piston connected to said spool valve, a housing having a bore for receiving said piston, said bore being divided into first and second chambers by said piston, the faces of said piston being of different cross sectional areas such that the area of the face presented to said first chamber is approximately twice that of the face presented to said second chamber, a fluid pressure source in constant communication with said second chamber to provide static pressure therein, a pilot valve in said piston selectively communicating said first chamber to the pressure source to vary the pressure therein and to thereby cause the movement of said actuator piston and said main valve, the direction of movement being a function of the differential pressures in said chambers and the difference in areas of said piston faces.

10. The control system of claim **9** wherein said piston has an axial bore therein and said pilot valve is slidably received in said axial bore, a reservoir in communication with said axial bore, said piston has passageways for communicating said first chamber with said pressure source and reservoir through said pilot valve.

11. The system according to claim **7** including,

a yoke connected to said amplifier,

said lever being connected to one end of said yoke and said returning means being connected to the other end of said yoke.

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