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ELECTRICALLY CONTROLLED VALVE MEANS  
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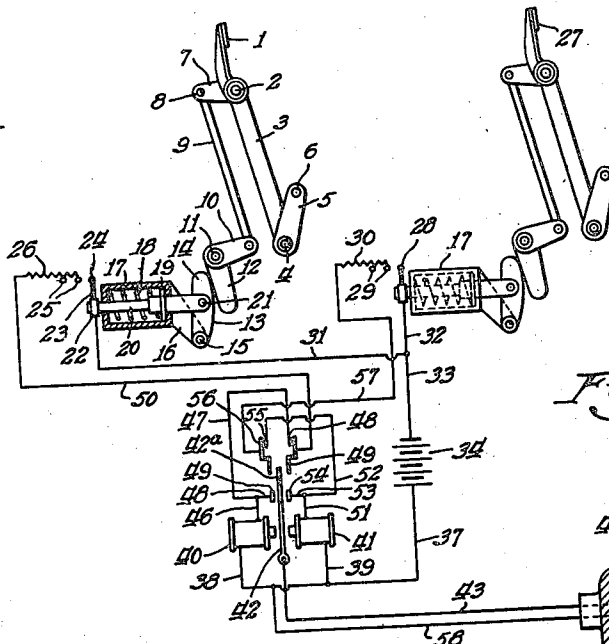
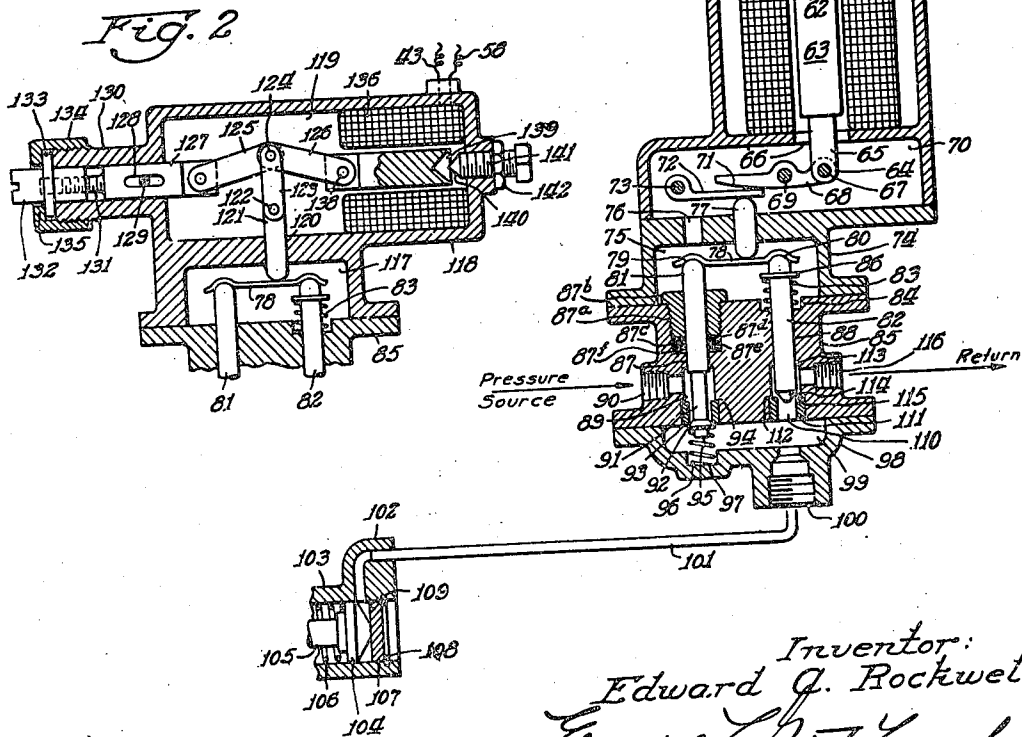


Fig. 1



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Att.

## UNITED STATES PATENT OFFICE

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## ELECTRICALLY CONTROLLED VALVE MEANS

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mesne assignments, to Borg-Warner Corpora-  
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My invention relates particularly to an apparatus for controlling the movement of any device for performing work by means of an electric control connection which operates the device hydraulically, and while my invention is applicable to the control of devices of any desired character, it is particularly applicable to the controls in the operation of aircraft.

The object of my invention is to provide an electric-hydraulic control apparatus, by means of which any device to be moved may be operated thereby and in which an electric control device is arranged to operate a hydraulic mechanism accurately and with at least the same effectiveness as in a completely hydraulic control apparatus. Another object of my invention is to provide an arrangement of this character which, while the device that is to be controlled may be located at a considerable distance from the electric controlling mechanism for the same, substantially the same effective control is obtained as if the parts were entirely hydraulic and located in proximity to one another. A further object is to provide an apparatus of this character in which the delivery pressures are effectively co-related to the manual forces applied for operating the electric control apparatus therein. Another object is to provide, in an apparatus of this character, an electrical valve operating mechanism having a progressively decreasing leverage to compensate for changes in position of the electrical actuating means therefor. Still another object is to provide a manual control means which is coordinately pressure-responsive to the hydraulic pressures delivered thereby. A further object is to provide a compact, self-contained, powerful, efficient and light weight power unit which can be placed wherever desired with simple tubing and electrical connections. A further important object is to provide the same for effectively operating airplane wheel brakes. Another object is to provide a quick-acting release control mechanism. A further object is to translate manual pressures from the pilot and co-pilot to the servomotor by a single line to the brakes. Still another object is to conserve the amount of high pressure fluid utilized to operate the control apparatus by means of modulator valves. Accordingly, a relatively small lightweight apparatus can be used for this purpose. Further objects of my invention will appear from the detailed description of the same hereinafter.

While my invention is capable of embodiment in many different forms, by way of illustration

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I have shown only certain forms thereof in the accompanying drawing, in which—

Fig. 1 is a diagrammatic elevation, partly in section, of an apparatus constructed in accordance with my invention; and

Fig. 2 is a diagrammatic vertical section of a modified form of the valve actuating mechanism therein.

In the drawing, referring first to the form of my invention as shown in Fig. 1, I have shown a pedal 1 for operation by the pilot of an airplane, the same being mounted on a pivoted shaft 2 carried in the end of a rudder lever 3, which is fastened to a shaft 4 having a stationary pivot on the airplane. To this shaft 4 there is attached an arm 5 which is connected by a link socket 6 to the rubber or rudders of the airplane (not shown). Secured to the pedal 1, furthermore, there is an arm 7 having a pivotal connection 8 to a link 9 which is connected to an arm 10 secured on a shaft 11 carried in fixed pivots by the airplane. Also secured to the shaft 11 there is an arm 12 which operates on a curved outer surface 13 of a lever 14 having a pivotal support 15 in brackets 16 secured to a spring housing 17 having provided therein a reaction means in the form of a helical spring 18, one end of which is seated on the spring housing 17 and the other end of which presses against a flange member 19 which is secured on a plunger rod 20 having a pivotal connection 21 to the middle portion of the lever 14. The other end of the plunger rod 20 extends out through the end of the spring housing 19 and is provided with a sleeve 22 having a switch arm 23 thereon. The arm 23 is provided with a contact 24 so as to make contact in succession with a series of terminals 25 connected to a rheostat resistance 26.

A co-pilot pedal 27 is provided in the same airplane with connecting parts the same as just described, as being provided for the pilot and connected to the pedal 1, so that thereby the co-pilot may operate rheostat connections 28 and 29 connected to a rheostat resistance 30 in the same manner as previously described in connection with the pilot pedal 1. The sleeve 22 is connected by a wire 31 to a wire 32 leading from the co-pilot rheostat terminal 28 and these two wires are, accordingly, both connected by a wire 33 to one terminal of a storage battery 34, the other terminal of which leads by a wire 37 to branch wires 38 and 39 connected, respectively, to electromagnets 40 and 41 which are located on opposite sides of an armature switch arm 42 arranged to be magnetically attracted by either

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one or the other of the magnets 40 and 41, depending upon the closing of one of the circuits including the same. The switch arm 42 has an insulated end 42a and is connected by a wire 43 to the field winding of a valve-operating solenoid 44 within a casing 45. Furthermore, the electromagnet 40 is connected by a wire 46 to a wire 47 having a branch 48 leading to a terminal 48a, the circuit through which can be completed by the movement of the arm 42, and the wire 47 thence leads to a contact 48 which is connected to a spring arm terminal 49 which is capable of being moved by the armature 42 so as to break the circuit between the contact 48 and the spring arm 49, the latter being connected by a wire 50 to one end of the rheostat resistance 26. Similarly, the electromagnet 41 is connected by a wire 51 to a wire 52 which has a branch 53 leading to a contact 54 which is provided for completing a circuit through the armature 42 when moved by the electromagnet 41. The said wire 52, in a similar manner, leads to a contact 55 which completes the circuit with a spring arm 56 so that the circuit between the same and the contact 55 can be broken by pressure from the end of the armature 42 when moved by the electric magnet 40. This spring contact 56 is, furthermore, connected by a wire 57 to one end of the rheostat resistance 30.

The wires 38 and 39 leading to the electromagnets 40, 41 are also connected by a wire 58 to the solenoid 44. Within the casing 45 of the solenoid 44 there is a centering screw 59 having a lock nut 60 thereon, the said screw being provided with a conical end 61 for acting as a centering means within a conical recess 62 in an iron core 63 of the solenoid 44. The core 63 is provided with a yoke 64 on a reduced extension 65 passing through an opening 66 which leads to the chamber in which the solenoid 44 is carried. The yoke 64 is attached at its lower side by a pivot 67 to a rocker arm 68 carried on a pivot 69 in the sides of the casing 45, within a chamber 70 beneath the opening 66. It will be noted that the lower face of the lever arm 68 has a curved surface 71, the curvature of which is selected to accord with the characteristics of the windings of the solenoid, for contacting with the outer end of an arm 72 carried on a fixed pivot 73 in the casing 45 within the said chamber 70. This casing 45 is secured in any desired manner to the top of an intermediate casing 74 which has a chamber 75 therein connected by a port 76 to the chamber 70. Furthermore, the said arm 72 is supported upon the rounded upper end of a plunger rod 77 which passes through the top of the intermediate casing 74 into the chamber 75. Also, the lower end of the plunger rod 77 has a rounded end contacting with the upper surface of a rocker plate 78 having two hemispherical recesses 79 and 80 for receiving in the under face of said plate 78 an inlet valve rod 81 and an outlet valve rod 82. The valve rod 82 has a helical retracting spring around the same, the lower end of which is received in a recess 84 in the top of a valve casing 85, the upper end of the spring 83 being located against a spring retaining ring 86 in the chamber 75 fastened to the rod 82. The valve casing 85, which may be secured to the intermediate casing 74 in any desired manner, is provided with vertical passages 87 and 88 to receive the rods 81 and 82, respectively. At the top of the passage 87 there is a screw-threaded recess 87a to receive a screw plug 87b which exerts a predetermined pinch on the rod 81 by a compres-

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sible gasket 87c between washers 87d, of substantially rectangular cross-section, and 87e located above a dished washer 87f. By this means the normal friction is minimized and the friction exerted on the plunger 77 will be the same when increasing forces as well as decreasing forces are applied to the rod 81. The rod 81 extends downwardly through an inlet chamber 89 for receiving a high pressure liquid from any desired source through a screw-threaded inlet opening 90 which has any desired tubular connection for this purpose. Within the chamber 89 the rod 81 has a reduced end 91 carrying a conical valve 92 thereon which is arranged to seat against a removable annular valve seat 93 supported by a shoulder 94 adjacent to the chamber 89. Furthermore, beneath the valve 92 the rod 81 has a boss 95 to act as a guide for the helical spring 96, the upper end of which rests against the conical valve 92 while the lower end is supported in a recess 97 in a cover plate 98 provided with a chamber 99 therein and having a screw-threaded outlet port 100 which may be connected by any suitable tubular means 101 to a passageway 102 in a casing 103 of a work-performing piston 104 on a piston rod 105 normally moved to the right, in Fig. 1, by a helical spring 106 against a movable disc 107 held in place by a supply ring 108 located in a recess 109. Furthermore, the chamber 99 has a discharge port 110 within a valve seat ring 111 supported against a shoulder 112 in the valve casing 85 adjacent to a chamber 113 which receives the lower end of the outlet valve rod 82 where said rod is provided with a conical valve 114 to cooperate with a valve seat 115 on the upper portion of the valve seat ring 111. Also, the chamber 113 is connected with an outlet or discharge port 116 which is screw-threaded to receive any desired tubular connection for receiving the liquid when being discharged. It will be understood that the piston 103 may be a valve operating piston, as for instance the valve operating piston such as is shown in Fig. 2 of my co-pending application Ser. No. 534,503, filed May 6, 1944, upon Electrical hydraulic power unit, Patent No. 2,443,642.

As shown in Fig. 2, I may provide a modification of the valve actuating mechanism in which it will be noted that the valve casing 85 is provided with the inlet valve rod 81 and outlet valve rod 82 as previously described. Also, these rods 81 and 82 are operated by the same kind of rocker plate 78 as in the preceding form in Fig. 1, as well as the spring 83 shown therein. However, in this instance the upper ends of the rods 81 and 82 are received in a chamber 117 in a solenoid casing 118, having a chamber 119 therein and a passageway 120 which receives a valve operating plunger 121 resting on the upper face of the rocker plate 78. In this instance, furthermore, the upper end of the plunger 121 is connected by a pivot 122 to a link 123, the other end of which is provided with a pivotal connection 124 to a pair of toggle levers 125 and 126. The toggle lever 125 is provided with an adjusting rod 127 having a slot 128 cooperating with a stop pin 129 passing through an extension 130 of the solenoid casing 118. The outer end of the rod 127 has secured thereto a screw 131 around the outside of which there is an adjusting sleeve nut 132 provided with a flange 133 resting against the outside end of the extension 130. A lock nut 134 has an annular shoulder 135 fitting against the outside of the flange 133 for securing the same in adjusted position. Within the chamber 119, furthermore,

there is a solenoid field coil 136 which is connected by the wires 43 and 58 to the other parts of the control mechanism, as in Fig. 1. The field coil 136 has within the same an iron core 137 which carries a pivot 138 for connection to the toggle levers 125 and 126. The other end of the core 137 is also provided with a conical recess 139 for cooperating with a conical end 140 of a guiding screw 141 having a lock nut 142 and which is screw-threaded in the solenoid casing 118.

In the operation of my invention, referring first to Fig. 1, the pilot may operate the pedal 1 or the co-pilot may operate the pedal 127 for controlling the movement of the work-performing piston 104, the latter being provided for operating any of the desired parts of the aircraft to be controlled, as for instance the wing flaps or elevating surfaces of the same. Each of the pedals 1 and 27 operates in the same manner and the operation of only one thereof will be described in detail accordingly. When operating the pedal 1 it will be understood, of course, that by means of the arm 5 the rudder of the aircraft may be controlled by moving the rudder lever 3 about this fixed pivot 4. As this occurs, however, it will be noted that the rudder lever 3 and the link 9 will be mounted in parallel to each other. In this way, by the rotation of the pedal 1 around the pivot 2 the lever arms 10 and 12 can be rotated so as to move the pivoted arm over the outer curved surface 13 of the plunger rod operating lever 14. In this manner the rheostat terminals 24 and 25 can be closed so that by the successive advance of the contact 24 over the contacts 25 the resistance of the rheostat will be successively decreased so as to increasingly energize the solenoid 44. The closing of the rheostat connections 24 and 25 will energize the electromagnet 40 through the wires 33, 31, contacts 24, 25, wire 80, contacts 49, 48, wires 47, 46, magnet 40 and wires 38 and 37, thus attracting the armature 42 and completing the circuit between the armature 42 and the terminal 49 to energize the solenoid 44 while at the same time pushing the spring 56 away from the contact 55 and thus preventing the control of the apparatus being altered by the operation of the co-pilot pedal 27 during the operation from the pedal 1. The circuit through the solenoid 44 is completed through the wires 33 and 31, contacts 24, 25, wire 50, contacts 49, 48, wire 47, terminal 48a, armature 42, wire 43, wire 58 and wire 37. The same will take place in the reverse order, when the co-pilot pedal 27 is operated by energizing the magnet 41 instead of the pilot pedal 1. Thus, in the operation of the pedal 1, as the contact 24 is advanced over the series of contacts 25 an increased energizing of the solenoid 44 takes place, thus moving to the desired extent the cam surface 71 of the lever 68 downwardly against the lever arm 72. It may be noted that the cam surface 71 on the bottom of the lever arm 68 is accurately convexly formed and constitutes a curve from one end of the arm to the other, the curve gradually extending upwardly from the portion thereof beneath the pivot 69 to the left extremity of the arm 68. Upon increasingly energizing the solenoid 44 and a consequent movement of the core 63 in an upward direction, the movable pivot 67, connecting the arm 68 and core 63, is also moved upwardly and the arm 68 is rotated in a counterclockwise direction about its fixed pivot 69 whereby rotation of the curved surface 71 of the arm 68 will cause the lever arm 72 to engage the surface at a varying distance

from the pivot 69 or axis of rotation of the lever arm 68 and thereby shift the point of application of force between the lever arms 68 and 72 whereby the mechanical advantage is gradually decreased between the core 63 and valve-actuating plunger 77 to thus compensate for the change in position of the core 63 with regard to the field coil of the solenoid 44. Initially, however, due to the plunger 77 being nearer to the outlet valve rod 82, the outlet valve 114, 115 is closed, after which the valve 92, 93 is opened to the desired extent, thus admitting high pressure liquid from the inlet port 90 which enters the chamber 99 and thence passes downwardly by the pipe 101 to move the piston 104 against the force of the spring 106, to act as a servomotor. As fluid pressure builds up in the chamber 99 and port 110 and exceeds the mechanical force or pressure applied by the energized solenoid core 63 to the discharge valve rod 82 and with which force the rod 82 is thrust down, the fluid pressure reacts to move the valve rod 82 upward to open the discharge passage 110 to permit the pressure fluid to enter the chamber 113 and discharge port 116, upward movement of the valve rod 82 also rocks the plate 78 upwardly on the conical upper end of the inlet valve rod 81 as a fulcrum to thereby cause the plunger 77 to move upwardly and rotate the lever 72 upwardly about its pivot 73. Due to the engagement of the lever 72 with the cam surface 71 of the lever 68, the lever 68 will be rotated in a clockwise direction about its fixed pivot 69 and, through its pivotal connection at 67 to the solenoid core 63, will exert a downward pull on the core 63 in opposition to the upward pull on the core exerted by the field coil of the solenoid 44. According to the extent of the movement of the piston 104 a corresponding reaction is produced on the pedal 1 due to the increasing opposition of the spring 18 to the further movement of the pedal 1. When the manual pressure on the pedal 1 or 27 is being relaxed the same corresponding reaction or "feel" will be experienced by the pilot or co-pilot correspondingly with the pressure produced against the piston 104, the opposition of the spring 18 to movement of the pedal 1 or 27 being varied according to the pressure against the piston 104 inasmuch as the pressure of the spring increases as the contact 24 is moved along the resistance 26 to decrease the resistance with increased energization of the solenoid 44 whereby the core 63 thereof is operative to control the modulating valve to permit increasing fluid pressure on the piston 104. While the pressure is being relaxed from the pedal 1 or the pedal 27 the pressure liquid will be allowed to discharge past the valve 114, 115 to the discharge port 116. At any point where the pedal is stopped, however, the valves 92, 93 and 113, 114 will be in lap position. This action will continue to the extent desired or until all of the high pressure liquid has been released from the pipe 101 to be discharged through the discharge port 116 and until the parts have thus been restored to their initial positions.

In the modified form of my invention as shown in Fig. 2, the operation is the same as that already described except that in this instance the decreasing mechanical advantage is secured by the toggle levers 125, 126 in connection with the link 123 and the plunger 121. Also, in this instance it will be noted that the extent of this decreasing mechanical advantage can be adjusted or set to any desired proportion by means of the sleeve nut 132 which, when adjusted, is main-

tained in its adjusted position by the lock nut 134. More particularly, the adjustment for securing the decreasing mechanical advantage of the toggle lever connection to the plunger 121 may be readily obtained by rotating the lock nut 134 to free the same from the flange 133 of the sleeve nut 132 to permit rotation of the nut 132 which will, due to its threaded engagement 131 secured to the rod 127, cause movement of the rod 127 to the left thereby moving the levers 125 and 126 and the core 139 in the same direction. Due to these movements afforded by the pivotal connections of the lever 125 with the rod 127, the lever 126 to the core 139, and the connection of the levers at the pivot 124, the levers and core will be shifted to the left and with them the upper portion of the link 123 connected thereto effecting an inclination of the link to the left, due to its pivotal connection 122 to the plunger 121 which is maintained in its vertical position between the walls of the opening 120. Upon energization of the solenoid 118 and movement of the core 139 to the right the angle of inclination of the link 123 will be such as to dispose the angular inclination of the levers 125 and 126 in almost coplanar relationship which will result in decreasing the mechanical advantage of the levers 125 and 126 in connection with the link 123 and plunger 121. Upon energization of the solenoid and movement of the core 139 to the right, the approach of the pivot 124 and the levers to a common horizontal plane by the aforesaid adjustment will decrease the amount of travel of the levers toward said plane and thereby the travel of the link 123 and plunger 121 effecting operation of the rocker plate 78 and thereby the valve rods 81 and 82.

By this means, therefore, modulating valve control of the movement of the work-performing device may be readily secured with substantially the same effectiveness of control as if the apparatus were entirely hydraulic, but in this instance any desired remote position can be provided for the manual controls without thereby in any way altering the speed or effectiveness of the work-performing hydraulic fluid. This is accomplished, also, by securing a degree of travel of the solenoid in each of the forms of my invention described which is coordinate to the extent to which the control mechanism has been operated and according to the hydraulic pressure delivered for the operation of the work-performing device.

While I have described my invention above in detail I wish it to be understood that many changes may be made therein without departing from the spirit of the same.

I claim:

1. In combination, a source of fluid pressure, a modulating valve controlling the delivery of increasing pressures to a device to perform work, and an electrical control mechanism remote from said modulating valve and connected thereto by an electric circuit having a valve-operating solenoid therein provided with a lever connection to said valve arranged to control the operation of said valve and affording a decreasing mechanical advantage between said valve and solenoid, said control mechanism having a manually operated reaction device in said circuit for effecting energization of said solenoid and adapted to produce a reaction corresponding to the pressures delivered.

2. In combination, a source of fluid pressure, a modulating valve controlling the delivery of in-

creasing pressures to a device to perform work, and an electrical control mechanism remote from said modulating valve and connected thereto by an electric circuit having a valve-operating solenoid therein provided with a lever connection to said valve arranged to control the operation of said valve, said lever connection having a cam affording a decreasing mechanical advantage between said valve and solenoid, said control mechanism having a manually operated reaction device in said circuit for effecting energization of said solenoid and adapted to produce a reaction corresponding to the pressures delivered.

3. In combination, a source of fluid pressure, a modulating valve controlling the delivery of increasing pressures to a device to perform work, and an electrical control mechanism remote from said modulating valve and connected thereto by an electric circuit having a valve-operating solenoid therein provided with a toggle lever connection to said valve arranged to control the operation of said valve and affording a decreasing mechanical advantage between said valve and solenoid, said control mechanism having a manually operated reaction device in said circuit for effecting energization of said solenoid and adapted to produce a reaction corresponding to the pressures delivered.

4. In combination, a source of fluid pressure, a modulating valve controlling the delivery of increasing pressures to a device to perform work, and an electrical control mechanism, having alternately operable dual controls therein, remote from the modulating valve and connected thereto by an electric circuit having a valve-operating solenoid therein, arranged to control the operation of the said valve, said control mechanism having an electro magnet arranged to close the circuit with the solenoid when one of the controls is operated and a circuit connection operated by the magnet to disconnect the other control from operating the solenoid, said control mechanism having manually operated reaction devices associated with respective controls and selectively operable thereby to energize said electro magnet and adapted to produce a reaction corresponding to the pressures delivered.

5. In combination, a source of fluid pressure, a modulating valve controlling the delivery of increasing pressures to a device to perform work, and an electrical control mechanism, having alternately operable dual controls therein, remote from the modulating valve and connected thereto by an electric circuit having a valve-operating solenoid therein, arranged to control the operation of the said valve, each of said controls having a reaction device operatively connected to said control mechanism to effect energization of said solenoid producing a mechanical reaction corresponding to the pressures delivered, said control mechanism having a pair of electro magnets and a pair of switches having a switch arm forming the armature of the electro magnets, arranged to close the circuit with the solenoid when one of the reaction devices is operated and a circuit connection operated by the magnets to disconnect the other reaction device from operating the solenoid.

6. In combination, a source of fluid pressure, a modulating valve controlling the delivery of increasing pressures to a device to perform work, and an electrical control mechanism having alternately operable dual controls therein, remote from the modulating valve and connected thereto by an electric circuit having a valve-operating

solenoid therein, arranged to control the operation of the said valve, each of said controls having a reaction device operatively connected to said control mechanism to effect energization of said solenoid and producing a mechanical reaction corresponding to the pressures delivered, said solenoid having a leverage connection to the valve providing a decreasing mechanical advantage upon energization of said solenoid, said control mechanism having a pair of electro magnets and a pair of switches having a switch arm forming the armature of the electromagnets, arranged to close the circuit with the solenoid when one of the reaction devices is operated and a circuit connection operated by the magnets to disconnect the other reaction devices from operating the solenoid.

7. In combination, a source of fluid pressure, a modulating valve controlling the delivery of increasing pressures to a device to perform work, and an electrical control mechanism, having alternately operable dual controls therein, remote from the modulating valve and connected thereto by an electric circuit having a valve-operating solenoid therein, arranged to control the operation of the said valve, each of said controls having a reaction device operatively connected to said control mechanism to effect energization of said solenoid and producing a mechanical reaction corresponding to the pressures delivered, said solenoid having a leverage connection to the valve, said connection having a cam providing a decreasing mechanical advantage upon energization of said solenoid, said control mechanism having a pair of electromagnets and a pair of switches having a switch arm forming the armature of the electro-magnets, arranged to close the circuit with the solenoid when one of the reaction devices is operated and a circuit connection operated by the magnets to disconnect the other reaction device from operating the solenoid.

8. In combination, a source of fluid pressure, a modulating valve controlling the delivery of increasing pressures to a device to perform work, and an electrical control mechanism, having alternately operable dual controls therein, remote from the modulating valve and connected thereto by an electric circuit having a valve-operating solenoid therein, arranged to control the operation of the said valve, each of said controls having a reaction device operatively connected to said control mechanism to effect energization of said solenoid and producing a mechanical reaction corresponding to the pressures delivered, said solenoid having a toggle leverage connection to the valve, providing a decreasing mechanical advantage upon energization of said solenoid, said control mechanism having a pair of electromagnets and a pair of switches having a switch arm forming the armature of the electromagnets, arranged to close the circuit with the solenoid when one of the reaction devices is operated and a circuit connection operated by the magnets to disconnect the other reaction device from operating the solenoid.

9. In combination, a source of fluid pressure, a modulating valve controlling the delivery of increasing pressures to a device to perform work, and an electrical control mechanism, remote from the modulating valve and connected thereto by an electric circuit having a valve-operating solenoid therein, arranged to control the operation of the said valve, said control mechanism having manually operable reaction device in-

serted in said circuit to effect energization of said solenoid and a reaction device producing a reaction corresponding to the pressures delivered, said solenoid having leverage connection to the valve providing a decreasing mechanical advantage upon energization of said solenoid and means for adjusting the effective positions of the levers forming the connection to effect the decreasing mechanical advantage.

10. In a pressure modulating valve arrangement including electrical operating means for said modulating valve, controlled remotely, and simulating manual operation of said valve, said modulating valve communicating with a source of pressure and having means balancing the same against being affected in its operation by said pressure, said electrical means comprising a solenoid motor for moving said valve in the opening direction and connecting means between said solenoid and said valve including a cam driven by said solenoid and a lever effective to transmit force from said cam to said valve, and means including a manually operated rheostat for remotely adjusting the degree of energization of said solenoid in proportion to the pressure exerted on said manual means for effecting the opening of said modulating valve in proportion to said manual pressure.

11. In a pressure modulating valve arrangement including manually operated remote electrical control means therefor, a solenoid motor for operating said valve, under the influence of said control, means defining a lever and cam assembly connecting said solenoid with said modulating valve, said last named means comprising a first lever pivoted intermediate the ends thereof on a fixed pivot, one terminal portion of said first lever being drivingly connected to said solenoid, one of said levers having a convex surface thereon, a second lever having a fixed pivot and engageable with said convex surface positions varying in distance from the pivot of said first lever depending upon the operative position of said solenoid and means connecting said second lever with said valve.

12. In a pressure modulating valve arrangement including remotely controllable electrical operating means for said valve effective to substantially simulate manual movement of said valve, said arrangement including means placing said valve in communication with a source of pressure, a solenoid motor for moving said valve in the opening direction including a field winding and a reciprocable armature, the pulling force of said armature varying in accordance with the relative position of said armature with respect to said field and in accordance with the degree of energization of said field, connecting means disposed between said armature and said modulating valve effective to compensate for said variation in pull on said armature particularly that variation due to change in the relative position between said armature and said field, said means including a first lever formed with a convex cam surface thereon, said cam lever being connected in driving relation to said armature, a second follower lever effective to follow said cam and to engage said cam at varying distances from the pivot axis of rotation of said cam lever in accordance with the position of said armature with reference to said field, and means drivingly connecting said second lever with said valve and means including a manually operated rheostat for adjusting the degree of energization of said

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field in proportion to the manual pressure exerted on said last named means.

13. In a pressure modulating valve arrangement including remotely controllable electric means for operating the same to approximately simulate manual operation, said arrangement including an on-modulating valve communicating with a source of pressure and having means balancing the same against being affected in its operation by said pressure, an off-modulating or relief valve position adjacent said on-modulating valve, resilient means normally urging said relief or return valve to the open position, a solenoid motor for first moving said relief valve into closed position and subsequently moving said modulating valve in the opening direction, the pulling force of said solenoid varying in accordance with the operative position thereof, connecting means between said solenoid and said valves effective to compensate for said variation in the pulling force of said armature, said means including a first cam lever, a second follower lever for following said cam and effective to engage said cam at a varying distance from the axis of rotation of said cam in accordance with the position of said solenoid, a walking beam-like lever engaging both of said valves, and connecting means between said second lever and said walking beam intermediate said terminal portions of said walking beam whereby upon energization of said solenoid said relief valve is first closed and said modulating valve is subsequently moved in the direction of opening thereof, and means including manually operated rheostat for remotely adjusting the degree of energization of said solenoid in proportion to the manual pressure exerted thereon.

14. In a system for pressure utilization, an inlet for hydraulic fluid, a servo motor having a pressure responsive device receiving fluid therefrom, a pressure chamber means adapted to be connected to a pressure-responsive device to con-

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trol the servo motor, said chamber having an inlet port and an outlet port, an inlet valve adapted to seat in said inlet port, having an area exposed to the pressure in said chamber in a direction tending to seat said inlet valve, an outlet valve adapted to seat in said outlet port and having an area exposed to pressure in said chamber in a direction tending to unseat said outlet valve, resilient means tending to seat said inlet valve, resilient means tending to unseat said outlet valve, means including a plunger exerting a varying pressure for operating the valves reactively to the pressures applied thereby and a resilient annular sealing washer of substantially rectangular cross section, around the inlet valve, the said seal comprising a spring means for providing a predetermined pinch so that the pressure from the pressure-exerting means acts on the inlet valve while minimizing the normal friction of the seal so that the varying force acting on the plunger will be substantially the same when increasing amounts of pressure are applied as when decreasing amounts of pressure are applied.

EDWARD A. ROCKWELL.

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