Dec. 28, 1926. 1,612,118

E. M. HEWLETT ET AL

CONTROL SYSTEM FOR ORDNANCE

Original Filed Sept. 27, 1921 6 Sheets-Sheet 1

Fig. 13.

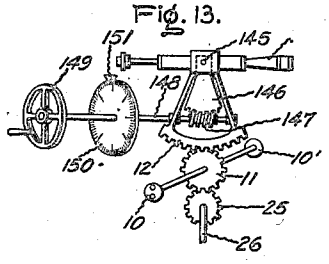


Fig. 1.

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Fig. 3.

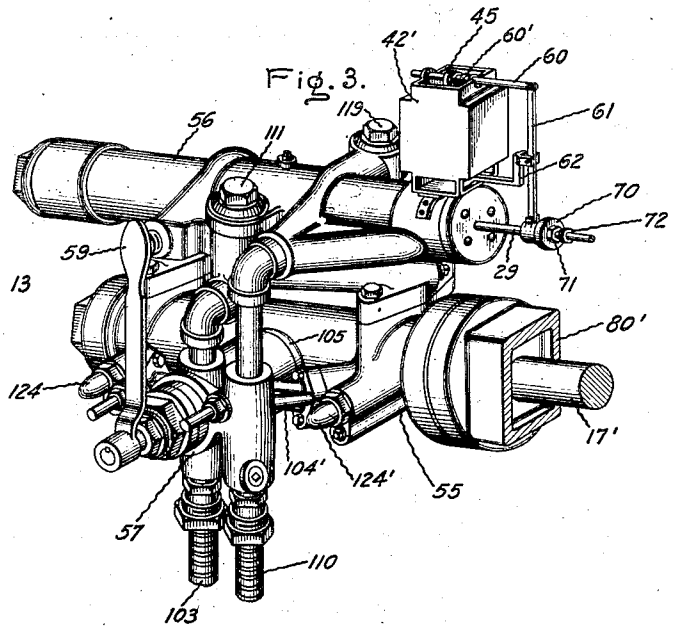
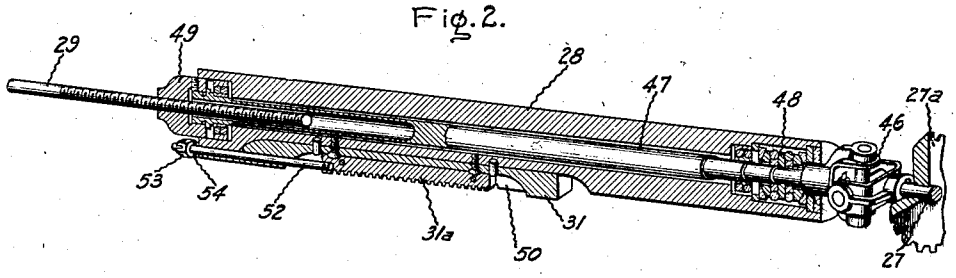


Fig. 2.



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CONTROL SYSTEM FOR ORDNANCE

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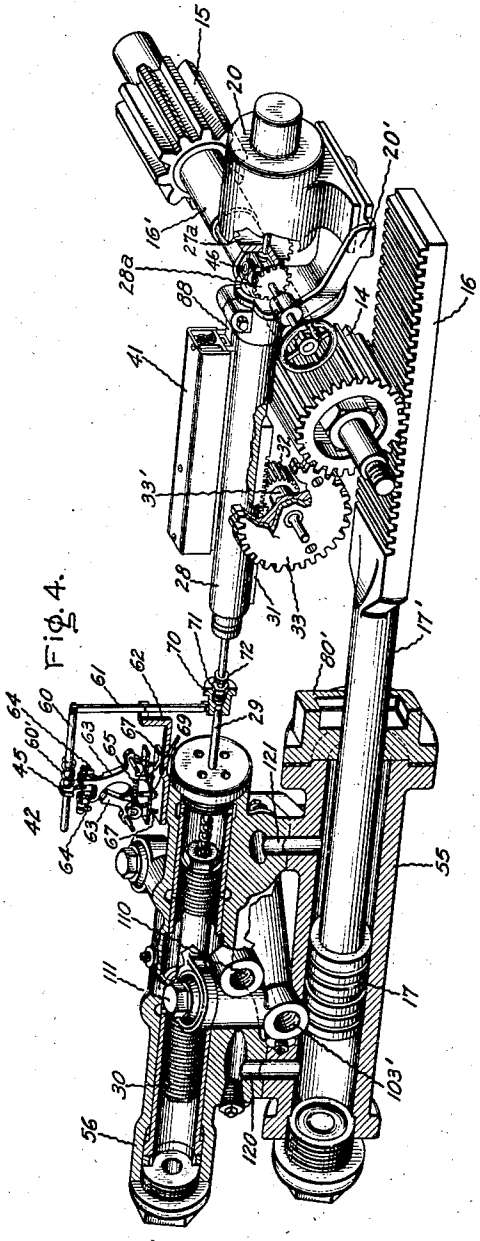


Fig. 4.

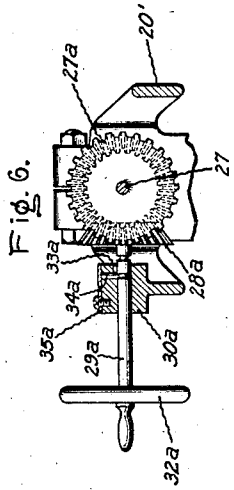


Fig. 6.

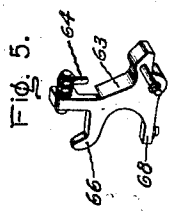


Fig. 5.

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CONTROL SYSTEM FOR ORDNANCE

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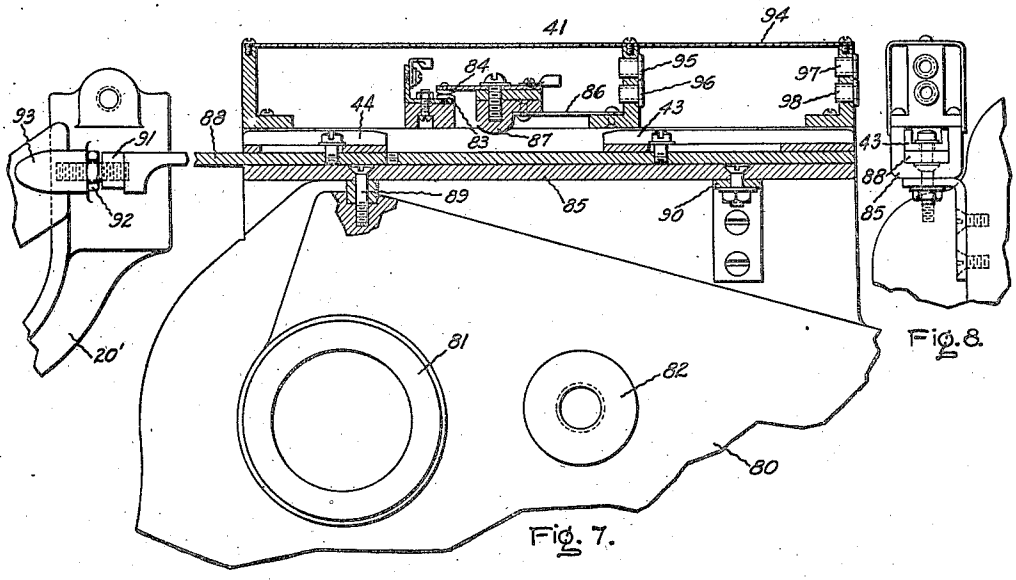


Fig. 8.

Fig. 7.

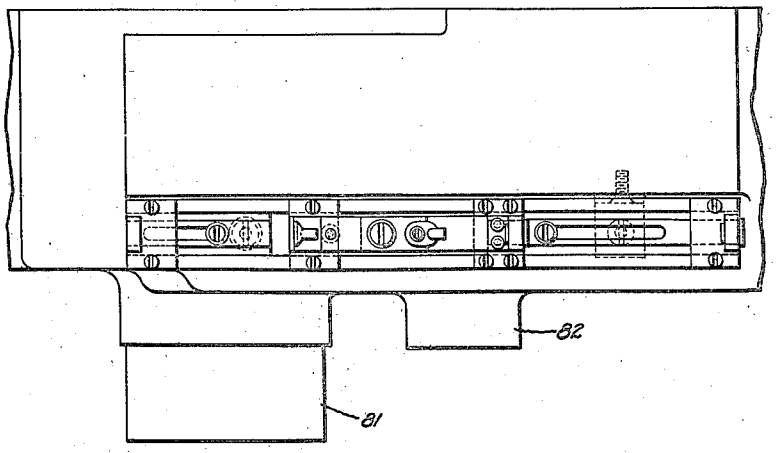


Fig. 9.

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CONTROL SYSTEM FOR ORDNANCE

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Fig. 10.

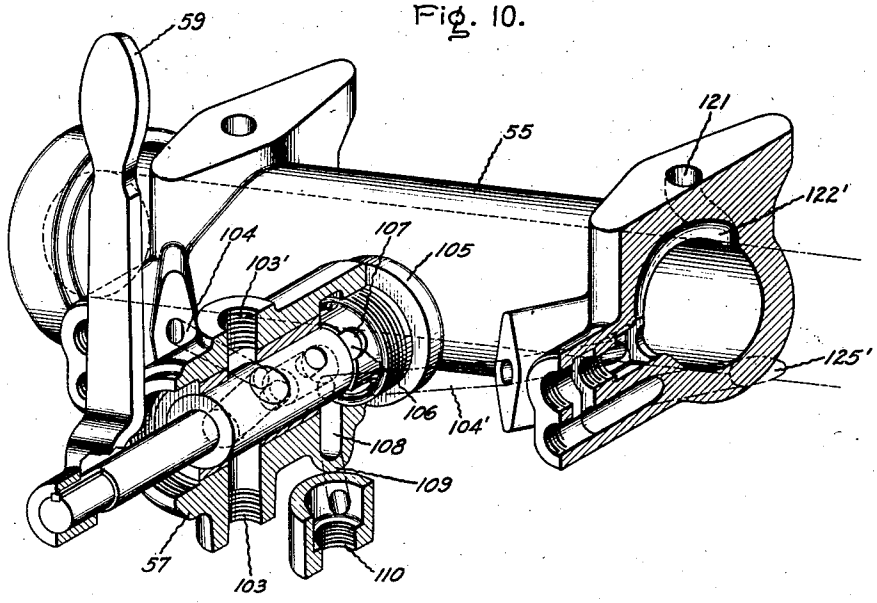
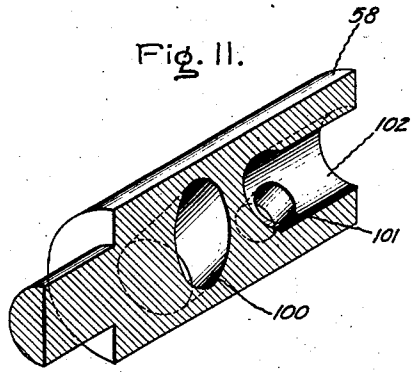


Fig. 11.



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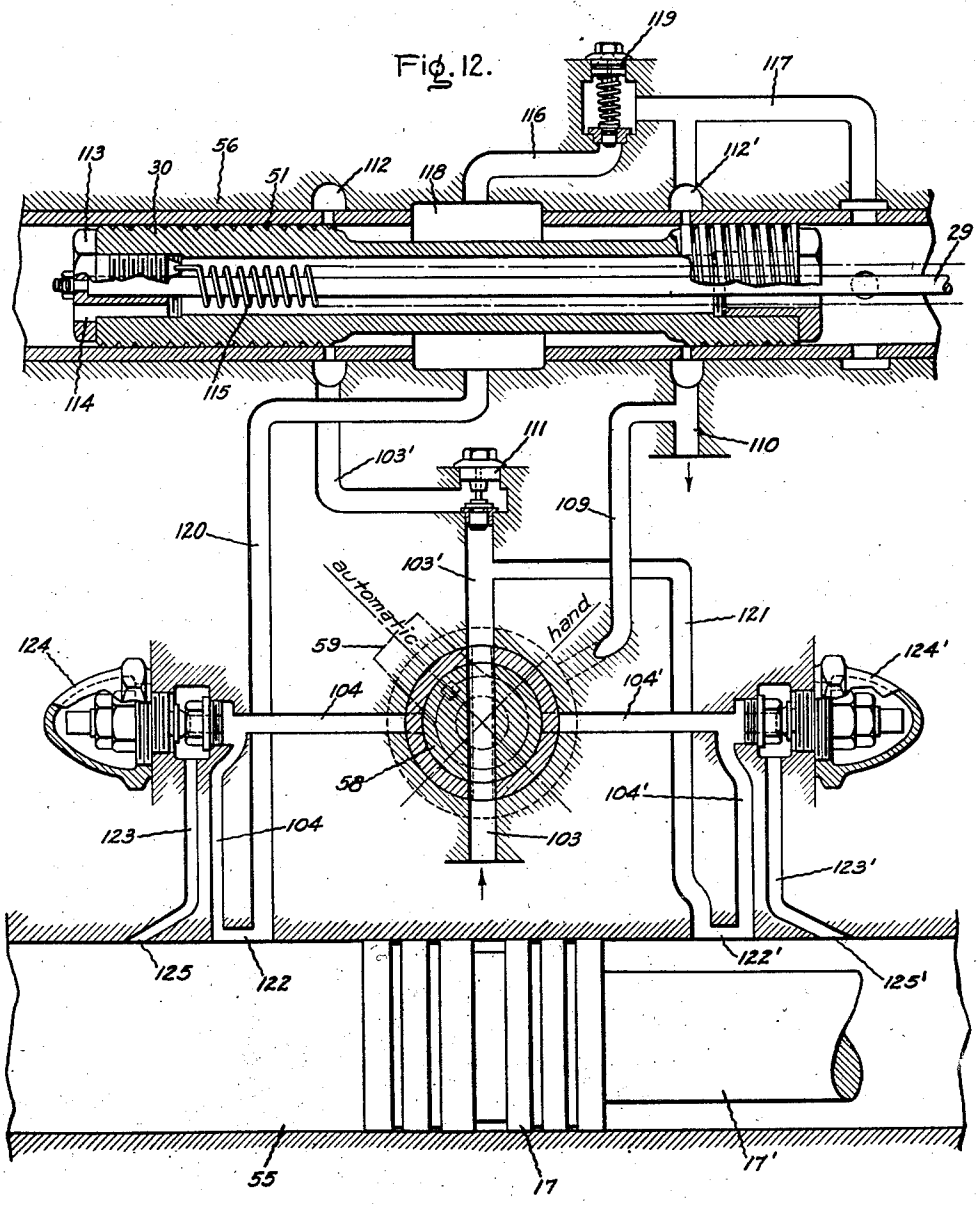
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CONTROL SYSTEM FOR ORDNANCE

Original Filed Sept. 27, 1921 6 Sheets-Sheet 6

Fig. 12.



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Patented Dec. 28, 1926. 1,612,118

UNITED STATES PATENT OFFICE.

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CONTROL SYSTEM FOR ORDNANCE.

Application filed September 27, 1921. Serial No. 503,545. Renewed May 21, 1926.

This invention relates to control systems for ordnance and has for its object the provision of improved means whereby a gun or like device may be controlled from a remote point.

More specifically, this invention relates to a control system whereby a gun is automatically maintained in a predetermined angular relation with respect to a remote telescope or sighting device. By means of one form of our invention, when firing from a ship the gun may be adjusted on a distant target and kept on the target regardless of the movements of the ship by holding the telescope on the target, or on some fixed point of reference such as the horizon. The gun is, in effect stabilized automatically in a predetermined angular position in altitude by holding the telescope in a predetermined angular position in altitude.

In carrying out our invention, we employ a hydraulic motor for adjusting the gun and control the hydraulic motor from a remote telescope by means of a self-synchronous system, now known as the selsyn system, for transmitting the angular movement of the telescope. The angular movement of the telescope is transmitted with respect to the ship or other body on which it is mounted, and the resulting movement of the gun is also with respect to the ship or other body on which it is mounted. Movement of the telescope opens the control valve of the hydraulic motor, the resulting follow up movement of the hydraulic motor gradually closing the valve until when the gun has followed the telescope, the valve is closed and the gun brought to rest. By means of a hand-operated valve the hydraulic motor can be disconnected from the source of hydraulic supply so that the gun can be adjusted independently of the automatic control means. We have also provided means for adjusting the angular relation between the gun and the telescope and limit switches in the firing circuit of the gun which are automatically controlled in such manner that the gun can be fired only when it is in a predetermined angular relation with the telescope and within predetermined limits of its angular movement.

For a more complete understanding of our invention reference should be had to the accompanying drawings in which Fig. 1 is a simplified diagrammatic representation of a control system for ordnance embodying our invention; Fig. 2 is a view in section of the connection between the synchronous receiver and the control valve for the hydraulic motor; Fig. 3 is a perspective view of the hydraulic motor; Fig. 4 is a simplified view partly in section of the hydraulic motor mechanism; Fig. 5 is a perspective view of a limit switch contact arm; Fig. 6 is an end view partly in section showing the hand control means; Fig. 7 is an elevation view partly in section of a limit switch; Fig. 8 is an end view of Fig. 7; Fig. 9 is a plan view of Fig. 7; Fig. 10 is a perspective view partly in section of the hand-operated valve control; Fig. 11 is a view in section of the hand-operated valve; Fig. 12 is a diagrammatic view of the hydraulic motor; while Fig. 13 is a diagrammatic view of a modification of our invention.

We shall first describe a control system for ordnance embodying our invention as a whole, and then point out more in detail the specific features of our invention.

Referring to Fig. 1 of the drawings, the gun B is controlled in elevation automatically in response to angular movement in altitude of a telescope A located at a convenient point of observation remote from the gun. The telescope is adjusted manually by means of handles 10 and 10′ through a gear 11 actuated thereby which cooperates with a gear sector 12 on the telescope. The gun is actuated by a hydraulic motor 13 which is controlled automatically in response to movement of the telescope. A suitable gear train consisting of gears 14 and 15 connects rack 16 actuated by hydraulic piston 17 of the motor to a gear sector 18 on the gun.

Angular movement of the telescope is transmitted for the control of the hydraulic motor by means of a self-synchronous or selsyn system consisting of a selsyn transmitting generator 19 and a selsyn receiving motor 20 in synchronism therewith. The transmitting generator is operated at a suitable ratio with respect to the telescope by means of spur gear 25 meshing with spur gear 11 and secured to the drive shaft 26 of the gen-

erator. Rotor shaft 27 of the receiving motor is in screw and nut relation in a quill 28 with an actuating rod 29 of an automatic control valve 30 for the hydraulic motor. Secured to quill 28 is a rack 31 which is connected through spur gears 32 and 33 to spur gear 14. The generator and motor are similar in construction, having single phase field windings 21 and 22 on their rotors and three phase armature windings 23 and 24 on their stators. The field windings are energized from a suitable source of alternating current supply, while like points of the armature windings are interconnected, a selsyn transformer 130 which will be described hereinafter being interposed in the armature connections.

The operation of systems of this general character for the transmission of angular movement is well known in the art. Voltages are induced in the three-phase stator windings of the generator and motor by the single-phase field windings on the associated rotors. When the rotors of the generator and motor are in the same angular positions with respect to their stators, the induced voltages in the armature windings are equal and opposite and consequently no current is set up in the armature windings. If the rotor of the generator is turned and held in its new position, the voltages no longer counterbalance, whereby equalizing currents are caused to flow in the armature windings. The equalizing currents exert a torque on the rotor of the motor causing it to take up a position corresponding to the position of the generator rotor. Angular movement imparted to generator 19 is therefore reproduced by receiving motor 20.

When shaft 27 is rotated by receiving motor 20 in response to movement of the telescope, valve 30 is moved to the right or left, as the case may be, causing piston 17 to move the gun in the direction in which the telescope was moved. Quill 28 is at the same time moved longitudinally through the gear train connecting spur gear 14 with rack 31 in the direction to return valve 30 to closed position. Motor 20 is mounted on a suitable support 20′ (Fig. 4) attached to quill 28 so as to move therewith. When the gun has followed the movement of the telescope, it is brought to rest by the movement of valve 30 to closed position.

The hydraulic liquid, which may be oil or water, is supplied at constant pressure to the hydraulic motor by a suitable pump 34 driven by an electric motor 35. Pump 34 is connected to the hydraulic motor through pipe 36, the hydraulic liquid being exhausted from the hydraulic motor through pipe 37 to pump well 38.

In the firing circuit 39 of the gun is a switch 40 mounted in handle 10 and is closed by the operator when the telescope is on the target, a switch 41 governed by the position of quill 28, and a switch 42 governed by the position of valve 30. In the positions shown in the drawing, switches 41 and 42 are closed. Should the gun be elevated or depressed more than a predetermined amount with respect to the ship, switch 41 will be opened by one of cams 43 and 44 movable with the quill 28, as the case may be. In this way, the hydraulic mechanism is protected from damaging shocks due to firing the gun when the driving piston 17 is near either limit of its stroke. The range of the angular movement of the gun in which it can be fired can be varied as desired by adjusting the position of cams 43 and 44. Contact 45 of switch 42 is moved to open the firing circuit when valve 30 is moved more than a predetermined amount in either direction from closed position. Switch 42 is therefore closed and the gun can be fired only when the gun is within a predetermined angular relation with the telescope. Switches 41 and 42 are not indispensable parts of our invention, since the system is obviously operable without them. These switches may be used, however, to provide protection for the apparatus and to facilitate firing only at proper times.

Referring to Fig. 2 showing a section of quill 28, shaft 27 of motor 20 is connected through a universal joint 46 to one end of a shaft 47 extending through the quill and journaled therein. Shaft 47 is also provided with a double thrust bearing 48 for holding it in a fixed longitudinal position relative to the quill. Rigidly secured to the other end of shaft 47 is a nut 49 which cooperates with the threaded end of valve rod 29. Rack 31 secured to the lower side of the quill is provided with a longitudinal central groove 50 in which is a rack 31ª in adjustable relation therewith. Rack 31ª is adjusted by means of rod 52 and nut 53 so that it is biased slightly out of alinement with rack 31 by a flat spring 54 underneath nut 53. The object of this arrangement is to take up lost motion between the rack and driving gear 32 meshing therewith.

In Fig. 3 is shown the hydraulic motor 13 in perspective. Sscured to the top of the hydraulic cylinder 55 is a casing 56 containing the automatic valve 30, while attached to the side of the cylinder is a casing 57 containing a hand-operated valve 58 (Fig. 10) provided with an actuating handle 59. By means of the hand-operated valve, the hydraulic motor can be entirely cut off from the source of hydraulic supply for independent control of the gun. Limit switch 42 is mounted in a casing 42′ secured on the right-hand end of valve casing 56.

Referring to Fig. 4, the shaft 16′ carrying spur gears 14 and 15 and the shaft 33′ carrying spur gears 32 and 33 are journaled in a suitable frame or housing 80, (Fig. 7) a

portion of which showing bearings 81 and 82 for shafts 16′ and 33′ is shown in Fig. 7. Suitable guides are provided in the housing for slidably supporting quill 28 and rack 16, and a projection 80′ (Figs. 3 and 4) forms a head for hydraulic cylinder 55 and a support for the hydraulic motor. The housing 80 is secured to the carriage of the gun mount so as to maintain the hydraulic motor and operating mechanism in operative relation to the gun. Spur gear 33 is made in two halves yieldably connected for the purpose of taking up lost motion in the gear train.

The cross-sectional area of piston rod 17′ of driving piston 17 is equal to one half the area of the piston face. Hydraulic pressure is constantly applied to the reduced piston face, and by regulating the pressure on the opposite face, the piston is moved to any desired position in a well known manner.

Referring to Figs. 3, 4 and 5, the movable contact 45 of limit switch 42 is carried on a rod 60 which is supported in casing 42′ so as to be longitudinally movable. The rod 60 is moved longitudinally in response to movement of valve rod 29 by means of a link 61 pivoted on a stationary arm 62 and pivotally attached at its ends to rods 29 and 60. By means of a spiral spring 60′ on rod 60, engaging contact 45 and casing 42′, rod 60 is biased toward the left to take up any lost motion in the link 61. Adjacent opposite sides of contact 45 are pivotally mounted arms 63 carrying insulated contacts 64 cooperating with contact 45. The arms 63 are biased toward each other by a spring 65 attached thereto so that when valve 30 is in closed position the contacts 64 rest against opposite sides of contact 45 and close the firing circuit. When contact 45 is moved in either direction upon movement of valve 30 from closed position, it moves away from one contact 64 and moves the opposite contact 64 with it. The firing circuit is thus held open through switch 42 as long as the valve 30 is open more than a predetermined amount. A projection 66 on each arm 63 is engaged by contact 45 on the return movement and serves as a positive means in addition to the bias of spring 65 for returning the arms to their inner positions. Suitable connection terminals 67 for contacts 64 are provided in the bottom of casing 42′. The terminals 67 are made accessible at all times by providing a skeleton supporting base for the casing. A projection 68 on each contact arm 63 rests on an adjustable screw 69 extending through the bottom of casing 42′ and limiting the movement of the contact arms toward each other and hence the position of contacts 64. Screws 69 are accessible from the bottom of the casing for adjustment, whereby the range of movement of contacts 64 toward contact 45 can be adjusted to cause the firing circuit to be opened through the contacts after a predetermined movement of the valve 30 in either direction from closed position.

Valve rod 29 is provided with a coupling 70 which can be loosened by unscrewing collar 71 to permit the right hand section to be turned by means of knurled knob 72. This arrangement provides a means for actuating the valve 30 independently of the telescope since longitudinal movement is imparted to the valve rod 29 when knob 72 is turned by reason of the threaded engagement of the valve rod with nut 49. By turning knob 72 in the necessary direction, valve 30 can be moved to cause the hydraulic motor to make the desired adjustment of the gun. Knob 72 is used, however, only in the initial adjustment to bring the gun in parallel relation with the telescope.

Referring to Figs. 2, 4, and 6, adjacent universal joint 46 is a bevel gear 27^a secured to the drive shaft 27 of the selsyn motor 20. A bevel gear 28^a movable into engagement therewith is secured on one end of a shaft 29^a which is supported at right angles to shaft 27 in a bearing 30^a secured to the selsyn motor support 20′. On the other end of shaft 29^a is a hand wheel 32^a. As shown in Fig. 6, bearing 30^a is provided with an opening 33^a in which is a movable pin 34^a. The lower end of pin 34^a is yieldably held against shaft 29^a by a flat spring 35^a secured to the bearing 30^a and engaging the upper end of the pin. On the shaft 29^a are two annular grooves. The shaft can be moved longitudinally by means of the hand wheel to cause gear 28^a to engage or disengage gear 27^a as desired, and the annular grooves are so positioned that the gear 28^a is yieldably held in either position by the engagement of pin 34^a with one of them. By means of this arrangement, the hydraulic motor can be readily controlled by hand in case of a failure of the selsyn system, and also in any case where such control is desirable. It is contemplated that ordinarily the selsyn motor will be disconnected electrically from the generator when this hand control is used, although it need not necessarily be disconnected, since the torque exerted by the selsyn motor in opposition to movement of the hand wheel will not be prohibitive. When hand control is used, hand wheel 32^a is pushed inwardly until gear 28^a engages gear 27^a. The hand wheel is then turned in a direction to give the desired movement of the gun, movement of the hand wheel being transmitted through gears 28^a and 27^a to shaft 27 for the control of the hydraulic motor.

Referring to Figs. 4, 7, 8 and 9, limit switch 41 is mounted on the stationary supporting frame or housing 80. The limit switch consists of two normally engaging

insulated contacts 83 and 84 which are secured to a member 85 having a central, longitudinal channel. One end of member 85 rests on the frame 80 and is secured thereto by means of a screw 89, while the other end is supported by an angle iron 90 secured to the frame 80. Contact 84 is yieldably supported by spring 86 which also carries on its free end a projection 87. A bar 88 fits slidably in the channel of member 85 and carries the two adjustable cam members 43 and 44. The left hand end of bar 88 is secured by means of a threaded interconnecting member 91 provided with a lock nut 92 to a projection 93 on the supporting base 20′ for selsyn motor 20. It will be seen that bar 88 moves with quill 28, and when the quill is moved beyond a certain predetermined limit in either direction, contact 84 is lifted by the engagement of one of cam members 43 and 44 with projection 87 to open the firing circuit through switch 41. The limits of movement of quill 28 within which switch 41 is closed can be varied by adjusting the position of cams 43 and 44. A cover 94 encloses the switch parts. Insulating bushings 95, 96, 97 and 98 are provided to support the conductors (not shown) connecting the contacts 83 and 84 in the firing circuit.

The hand-operated valve 58, as shown in Figs. 10 and 11, is cylindrical in form and rotatable to either one of two positions, "automatic" or "hand", by means of the handle 59. The valve is provided with two transverse, parallel passages 100 and 101, of which passage 100 is the larger. A longitudinal passage 102 extends from the inner end of the valve to intersect with passage 101. In the valve casing 57 are two pairs of transverse alined passages 103, 103′ and 104, 104′ at right angles to each other. When the handle 59 is turned to "automatic" position, passages 104 and 104′ are obstructed by the valve, while passages 103 and 103′ are connected through passage 100. When the handle is in "hand" position the reverse is true, passages 103 and 103′ being obstructed, and passages 104 and 104′ open through passage 101. The inner end of the valve casing is closed by a plug 105 against the inner end of which the valve is seated. In the inner end of the plug is a depression 106 in alinement with passage 102 in the valve. Portions of the edge of the plug are cut away to form ports 107 which connect depression 106 with an annular chamber 108 in the valve casing. The annular chamber is deeper at its lower side where it is connected through passage 109 with exhaust passage 110. Passages 104 and 104′ lead to the right and left-hand ends of the hydraulic cylinder 55. It will be observed that when the handle 59 is in "hand" position the ends of the cylinders are connected together and also connected to exhaust through passage 102, ports 107, chamber 108 and passage 109. Passage 103 is connected to the pressure side of pump 34 through pipe 36 (see Fig. 1). Passage 103′ leads through a check valve 111 (see Fig. 12) to an annular pressure chamber 112 in the left-hand end of valve casing 56. For the sake of clearness, in Figs. 3 and 10 the handle is shown in mid-position between "automatic" and "hand" position, although it is not contemplated that the handle will be in this position at any time during the operation of our invention.

The automatic piston valve 30 is cylindrical, hollow, and has a central portion of reduced size as shown in Fig. 12. An actuating rod 29 extends loosely through the valve and is rigidly secured to the left end thereof in a plug 113. Several holes 114 (only one of which is shown) are provided in plug 113 so as to maintain a free opening through the valve, whereby the pressure at the ends of the valve are balanced. The end bearing portions of the valve are provided with a fine helical groove 51 which permits a slight leakage and overcomes any tendency of the valve to stick to its seat due to greater pressure on one side. By thus balancing the pressures, acting on it, the valve is maintained freely movable at all times. By means of a spiral spring 115 on rod 29 attached at one end to plug 113 and at the other end to the right-hand end of the valve casing, the valve is biased toward the right to take up lost motion.

In the valve casing 56 and connected to the valve chamber through suitable ports are two annular chambers, a pressure chamber 112 and an exhaust chamber 112′. The pressure chamber is supplied through passage 103′, as previously described. Communicating with the exhaust chamber 112′ are two passages 116 and 117, passage 116 leads from a central annular chamber 118 in the valve seat through a releif valve 119 and has for its object to relieve excessive pressures, in chamber 118, while passage 117 leads directly to the valve chamber at one end of the valve so that the ends of the valve are maintained at atmospheric pressure. The valve is constructed to have a slight negative lap to permit a small amount of leakage when it is in closed position; this prevents the sudden application of pressure which would otherwise result from closing the valve suddenly while the piston is in motion, and also makes the hydraulic motor very sensitive to small movements of the valve 30. It will be observed that when the valve is in the closed position as show in Fig. 12, this leakage takes place from the pressure chamber 112 past valve 30 to chamber 118 and from chamber 118 past valve 30 to the exhaust chamber 112′. Since the

drop in pressure is substantially the same at both points of leakage it will be observed that the pressure in chamber 118 will be substantially one half the pressure of the supply source and consequently the piston 17 will be stationary. Under these conditions it is obvious that any movement, however slight, of the valve 30 will cause either an increase or a decrease of pressure in the lefthand end of the hydraulic cylinder which will result in movement of the piston.

The variable pressure end of the hydraulic cylinder 55 is supplied by passage 120 from chamber 118. Constant pressure is applied to the other end of the cylinder through passage 121 from passage 103'. In opposite ends of the hydraulic cylinder are arc-shaped grooves 122 and 122' (see Fig. 10). Groove 122 extends between the inner ends of passages 104 and 120, while groove 122' extends between the ends of passages 104' and 121.

In each end of the hydaulic cylinder is a slow closing valve arrangement consisting in the left-hand end of a passage 123 connecting passage 104 through an adjustable needle valve 124 to the cylinder at a point nearer the end of the cylinder than the opening of passage 104, and in the right-hand end of a similarly arranged passage 123' and needle valve 124'. These passages intersect the cylinder at an angle and at points below the center line of the cylinder so that openings 125 and 125' in the shape of an ellipse with one end flattened are formed in the cylinder, the pointed ends being toward the outer ends of the cylinder (see Fig. 10).

The action of the slow closing valves is as follows: Assuming that piston 17 is approaching the right-hand limit of its travel and has covered groove 122' and the openings of passages 104' and 121, it will be observed that the pressure in the end of the cylinder must be relieved through passage 123' and needle valve 124' through passage 104', groove 122', and passage 121 against the pump supply. The needle valve is adjusted to a restricted opening to give a predetermined slow movement of piston 17. As the piston covers the opening 125' of passage 123' the outlet to the entrapped hydraulic liquid is still more restricted. Due to its shape the opening is covered at a gradually decreasing rate, which gives a fine "wire drawing" effect as the pointed end of the opening is covered, thus gradually bringing the piston to rest without shock or strain on the mechanism. The piston is brought to rest in a similar manner at the left hand extreme of its movement. It is therefore impossible to bring the piston to rest suddenly through carelessness or otherwise at either extreme of its movement. This is a very important feature inasmuch as the hydraulic motor is geared to a heavy gun, the moving parts of which have great inertia.

Referring to Fig. 1 of the drawings, for the purpose of introducing range adjustment between the telescope and the gun we have interposed a selsyn transformer in the armature connections between the transmitting generator 19 and the receiving motor 20. This selsyn transformer is described and claimed in our copending application, Serial No. 501,007, filed Sept. 15, 1921, assigned to the same assignee as this invention. It consists of two three-phase distributed armature windings 131 and 132, winding 131 being mounted on a stator member and winding 132 being rotatably mounted on a shaft 133 in inductive relation to the winding 131. Secured to the shaft 133 is a worm gear 134 in engagement with which is a worm 135 secured to the shaft of a handwheel 136. By means of the handwheel the winding 132 may be adjusted with respect to winding 131 to any desired angular position. A dial 137 calibrated in range is secured to shaft 133, and cooperating with the dial is a stationary pointer 138. Like points of windings 131 and 23 are interconnected by conductors 139, 140 and 141, while like points of windings 132 and 24 are interconnected by conductors 139', 140', and 141'.

It will be observed that when windings 130 and 132 are in corresponding angular positions, the voltages induced in the winding 23 of the generator are transmitted through the transformer in their true phase relation to the receiving motor 20. Should winding 132 be displaced with respect to winding 131, the voltages transmitted to the receiving motor will be shifted in phase with relation to the voltages induced in winding 23 and in a direction depending on the directions of displacement of the winding 132. The motor 20 will therefore be caused to lead or lag with respect to the generator 19 by an amount depending on the amount of displacement given to the winding 132. In this manner the hydraulic operating mechanism of the gun can be controlled independently of the telescope to give the gun the desired angular relation with the telescope for the range of the target. The dial 137 is suitably calibrated in range so that the range adjustment can be made by turning handwheel 136 until the range of the target is indicated on the dial by the stationary pointer 138. It will be observed that after the range adjustment has been introduced the gun follows synchronously the movement of the telescope.

The operation of our invention is as follows: When it is desired to control the gun from the telescope, the hand-operated valve 58 is moved to "automatic" position, as

shown in Figs. 1 and 12, the automatic valve 30 then assuming entire control of the hydraulic motor. Hydraulic pressure is supplied from pump 34 through pipe 36, passages 103, 100 and 103′, through check valve 111 to pressure chamber 112; and from passage 103′ through passage 121 to the right-hand end of the hydraulic cylinder 55. With the automatic valve 30 in closed position, as shown in the drawings, the driving piston 17 is held balanced by reason of the pressure of the hydraulic liquid entrapped at the left hand of the piston acting to counterbalance the pressure supplied to the right hand of the piston, the pressure of the entrapped liquid being one-half the pressure supplied by the pump. Assuming that the automatic valve 30 is moved to the right by selsyn motor 20 in response to movement of the telescope, or of handwheel 136 when introducing the range adjustment, in the manner previously described, the ports leading from the automatic valve chamber 118 to exhaust chamber 112′ are uncovered, and the left-hand end of cylinder 55 connected to exhaust through passage 120, chamber 118, around the reduced portion of the automatic valve, through the ports to chamber 112′, through passage 110 and pipe 37 to the pump well 38. Piston 17 is thereby caused to move to the left to adjust the gun at the same time moving valve 30 back toward closed position through the gear mechanism previously described until when the predetermined angular relation between the gun and the telescope has again been established, the valve is close and driving piston 17 brought to rest. In the event that valve 30 is moved to the left, the ports leading from pressure chamber 112 will be uncovered and hydraulic pressure supplied around the reduced portion of the valve to chamber 118, thence through passage 120 to the left-hand end of cylinder 55. Piston 17 is then caused to move to the right until brought to rest by the moving of valve 30 to closed position.

The firing circuit switch 40 is closed by the telescope operator when he has adjusted the telescope on the target, and limit switches 41 and 42 in the firing circuit are controlled automatically, as previously described, so that when the telescope is on the target, and the gun in a predetermined angular relation with the telescope and within a predetermined range of its angular movement, the firing circuit is closed and the gun fired.

The relief valve 119 is set to withstand a pressure somewhat greater than the pressure supplied by the hydraulic pump. The function of the relief valve is to cushion the shock on the hydraulic mechanism due to jump of the gun muzzle when the gun is fired.

Piston 17 is moved to the left with great force by the jump of the gun, the resulting excessive pressure in the left hand end of cylinder 55 being releived through passage 120, chamber 118, passage 116, and the relief valve to exhaust. At the same time valve 30 moves slightly to the left uncovering the ports leading from chamber 118 to pressure chamber 112. The check valve 111 is provided to prevent this excessive pressure from being applied from chamber 112 through passage 103′ against the hydraulic pump, and also to prevent the gun from "squatting" due to the escape of liquid through passage 103′ while the pressure in the variable end of the cylinder is higher than the operating pressure of the pump due to the very greatly unbalanced weight of the gun during recoil. Movement of piston 14 to the right due to downward "whip" of the gun muzzle is cushioned, however, directly in the hydraulic motor, since the pressure generated in this case is not great enough to endanger the hydraulic supply system.

Should it be desired to control the gun position by the usual manually operated or manually controlled means independently of the telescope, the hand-operated valve is turned to "hand" position. In this position of the valve, the ends of cylinder 55 are connected together through passages 104 and 104′ and passage 101 in the valve, and also to exhaust through passage 109. Piston 17 is, therefore, freely movable to permit the gun to be moved to any desired angular position.

In Fig. 13 of the drawings, we have shown a modification of our invention in which the range adjustment is made by mechanical means on the telescope. The telescope A is pivotally mounted on the gear sector 12 to move about the fixed transverse horizontal axis 145 of the gear sector. Secured to the telescope is a worm gear sector 146 in engagement with which is a worm 147 carried by a shaft 148. The shaft 148 is rotatably mounted on the gear sector 12 and is held against longitudinal movement with respect thereto by any suitable means not shown. The worm 147 can be rotated to elevate or depress the telescope about its axis 145 with relation to gear sector 12 by means of a handwheel 149 secured to the shaft 148. A dial 150 suitably calibrated in range is secured to shaft 148. A stationary pointer 151 cooperates with the dial 150.

When using this modification of our invention the generator winding 23 is connected directly to the receiving motor winding 24, the transformer 130 being omitted. It will be observed that by suitably calibrating the dial 150 in range, the gun can be given the range adjustment by turning

handwheel 149 until the range of the target is indicated on dial 150 by the pointer 151 and then adjusting the telescope about its axis 145 until it is again on the target by moving gear sector 12 by means of handles 10 and 10'. In this case the desired angular relation between the gun and the telescope is made by adjusting the telescope independently of the gun and the gun given the necessary elevation by moving the gun and the telescope in synchronism when the telescope is again brought on the target.

Various methods may be used in operating the system. The telescope may be held on the target or on some fixed point of reference, such as the horizon, the gun automatically following the telescope through the roll and pitch of the ship, or the telescope may be held at a convenient elevation and the gun fired when the telescope rolls on the target. Although we have shown our invention applied to the control of guns in altitude, it is contemplated that the invention can also be applied to the control of guns in azimuth. Obviously any suitable self-synchronous system for the transmission of angular movement may be used for transmitting the movements of the telescope.

In accordance with the provisions of the patent statutes, we have described the principle of operation of our invention together with the apparatus which we now consider to represent the best embodiment thereof, but we desire to have it understood that the apparatus shown is only illustrative and that the invention can be carried out by other means.

What we claim as new and desire to secure by Letters Patent of the United States, is:—

1. A system of ordnance control comprising a gun, hydraulic operating means for the gun, a control valve for the hydraulic operating means, a sighting device remote from the gun, operating means for said control valve responsive to movement of the sighting device, and a movable support for said operating means responsive to movement of the gun whereby said valve is differentially controlled so as to maintain a predetermined angular relation between the gun and the sighting device.

2. A system of ordnance control comprising a gun, hydraulic operating means for the gun, a control valve for the hydraulic operating means a sighting device remote from the gun, operating means for said control valve responsive to movement of the sighting device, a slidable support for said operating means, a rack carried by said support, and a gear train connecting said rack to the gun, whereby said valve is differentially controlled so as to maintain a predetermined angular relation between the gun and the sighting device.

3. A system of ordnance control comprising a gun, operating means for the gun, a sighting device remote from the gun, a system of control associated with said sighting device and said operating means, a firing circuit for the gun, and a switch in said firing circuit automatically controlled in accordance with the angular position of the gun, so that the firing of the gun is limited to a predetermined range of its movement.

4. A system of ordnance control comprising a gun, hydraulic operating means for the gun, a control valve for the hydraulic operating means, a sighting device remote from the gun, a system of control associated with said sighting device and said control valve, a firing circuit for the gun, and a switch in said firing circuit automatically controlled to maintain the firing circuit open when the gun is in a predetermined extreme of its angular movement in either direction.

5. A system of ordnance control comprising a gun, a hydraulic motor for operating said gun comprising a driving piston, a valve for controlling said piston a sighting device remote from the gun, means responsive to the position of the sighting device for controlling said valve, a firing circuit for the gun, a switch in said firing circuit, and means responsive to the angular position of the gun cooperating with the switch so as to maintain the firing circuit open when the piston is near either limit of its movement.

6. A system of ordnance control comprising in combination with a gun, a hydraulic motor operatively connected to the gun, an automatic control valve for said motor, a source of hydraulic supply for said motor, a sighting device remote from the gun, a system of control associated with said sighting device and said automatic valve, and a hand operated selective valve in series with said automatic valve movable to one position for automatic operation under the control of said sighting device and to another position to shut off the hydraulic supply and connect the hydraulic motor to the exhaust.

7. A system of ordnance control comprising in combination with a gun, a cylinder, a hydraulic driving piston in said cylinder operatively connected to the gun, an automatic control valve for said piston, a sighting device remote from the gun, a system of control associated with said sighting device and said automatic valve, a source of hydraulic fluid pressure supply, a pipe connecting said source with said automatic valve, a selective valve in said pipe, and ports leading from the ends of said cylinder to said selective valve, whereby when said selective valve is turned to admit fluid through said pipe said ports are closed, and when turned to shut off the fluid supply said ports are connected to exhaust.

8. A system of ordnance control compris-

ing a gun, a sighting device remote from the gun, a transmitting generator actuated thereby, operating means for said gun, a receiving motor for controlling the same, alternating current field and armature windings for said motor and generator, and electrical connections between said armature windings whereby the motor is caused to be in synchronism with the generator.

9. A system for ordnance control comprising a gun, a sighting device remote from the gun, a transmitting generator actuated thereby, hydraulic operating means for said gun, control means for said hydraulic operating means, a receiving motor for actuating the same, alternating current field and armature windings for said motor and generator, and electrical connections for equalizing currents between said armature windings whereby the motor is caused to be in synchronism with the generator.

10. A system of ordnance control comprising a gun, a sighting device remote from the gun, a transmitting generator actuated thereby, a hydraulic motor for operating said gun, a control valve for the hydraulic motor, a receiving motor for actuating said control valve, alternating current field windings for said motor and generator, a source of alternating current supply for said field windings, polyphase armature windings for said motor and generator, and electrical connections between said armature windings whereby the motor is caused to be in synchronism with the generator.

11. A system of ordnance control comprising a gun, a sighting device remote from the gun, a transmitting generator actuated thereby, operating means for the gun, a receiving motor associated with said gun, differential control means for said operating means responsive jointly to movement of the gun and the receiving motor, alternating current field and armature windings for said motor and generator, and electrical connections between said armature windings whereby the motor is caused to be in synchronism with the generator and maintain a predetermined angular relation between the gun and the sighting device.

12. A system of ordnance control comprising a gun, operating means for the gun, a sighting device remote from the gun, an electrical system of control associated with said sighting device and said operating means, and electrical means interposed in said system of control for introducing changes in angular relation between the gun and the sighting device.

13. A system of ordnance control comprising a gun, operating means for the gun, a sighting device remote from the gun, an electrical system of control associated with said sighting device and said operating means, and electrically inductive means interposed in said system of control for controlling said operating means independently of the telescope.

14. A system of ordnance control comprising a gun, hydraulic operating means for the gun, a control valve for said hydraulic operating means, a sighting device remote from the gun, an electrical system of control associated with said sighting device and said control valve, and electrically inductive means interposed in said system of control for controlling said valve independently of the sighting device.

15. A system of ordnance control comprising a gun, a sighting device remote from the gun, a transmitting generator actuated thereby, operating means for the gun, a receiving motor for controlling said operating means, said receiving motor being responsive to movement of the generator so as to maintain a definite angular relation therewith, and means interposed in the electrical connections between said generator and motor for controlling said angular relation.

16. A system of ordnance control comprising a gun, a sighting device remote from the gun, a transmitting generator actuated thereby, operating means for said gun, a receiving motor for controlling the same, alternating current field and armature windings for said motor and generator, electrical connections between said armature windings whereby the motor is caused to be in synchronism with the generator, and means interposed in said connections for controlling the synchronous relation between the motor and generator.

17. A system of ordnance control comprising in combination with a gun, a hydraulic motor operatively connected to said gun, a control valve for said hydraulic motor, means permitting leakage between the valve and its seat whereby said valve is maintained freely movable, a sighting device remote from the gun, and operating means for said valve responsive to movement of said sighting device.

18. A system of ordnance control comprising in combination with a gun, a hydraulic motor operatively connected to the gun, a cylindrical control valve for said hydraulic motor, said valve being provided with a peripheral groove permitting leakage of hydraulic fluid between the valve and its seat whereby said valve is maintained freely movable, a sighting device remote from the gun, and operating means for said valve responsive to movement of said sighting device.

19. A system of ordnance control comprising in combination with a gun, a hydraulic motor operatively connected to the gun, a sighting device remote from the gun, and operating means for said valve responsive to movement of said sighting device, said

valve being arranged to permit leakage when the motor is at rest whereby the motor is responsive to small movements of said sighting device.

20. A system of ordnance control comprising a gun, a cylinder, a driving piston in said cylinder operatively connected to said gun, said piston having different pressure areas on its opposite sides, a source of hydraulic fluid supply, a connection between said source and said cylinder on the side of said piston of lesser area, a valve for controlling the fluid supply to the other end of said cylinder to control the movement of said piston, a sighting device remote from the gun, and a system of control associated with said sighting device and said valve, said valve being arranged to permit leakage from said source to said cylinder and from said cylinder to exhaust when the piston is at rest whereby the piston is responsive to small movements of said sighting device.

21. A system of ordnance control comprising in combination with a gun, a cylinder, a driving piston in said cylinder operatively connected to said gun, said piston having different pressure areas on its opposite sides, a source of hydraulic fluid supply, a connection between said source and said cylinder on the side of said piston of lesser area, a valve for controlling the fluid supply to the opposite end of said cylinder, a seat for said valve provided with a chamber connected to said opposite end of the cylinder and with ports controlled by said valve connected to the source of hydraulic fluid supply and exhaust respectively, a sighting device remote from the gun, and operating means for said valve responsive to movement of said sighting device, said valve being arranged to permit leakage of fluid from said source to said chamber and from said chamber to exhaust when the piston is at rest whereby the piston is responsive to small movements of said sighting device.

22. A system of ordnance control comprising in combination with a gun, a cylinder, a driving piston in said cylinder operatively connected to said gun, said piston having different pressure areas on its opposite sides, a source of hydraulic fluid supply, a connection between said source and said cylinder on the side of said piston of lesser area, a cylindrical valve for controlling the fluid supply to the opposite end of said cylinder, said valve having a central portion of reduced size and its end bearing portions grooved to permit leakage, a tubular seat for said valve, said seat being provided with a chamber corresponding to the central portion of said valve and ports controlled by the end portions of said valve, a connection between said chamber and said cylinder on the side of said piston of larger area, connections between one of said ports and the source of hydraulic fluid supply and between the other port and exhaust, a sighting device remote from the gun, and operating means for said valve responsive to movement of said sighting device, said valve being arranged to permit leakage of fluid from said source to said chamber and from said chamber to exhaust when the piston is at rest whereby the piston is responsive to small movements of said sighting device.

In witness whereof, we have hereunto set our hands this 26th day of September, 1921.

EDWARD M. HEWLETT.
WALDO W. WILLARD.