July 7, 1959 R. E. BAUER 2,893,355

HYDRAULIC CONTROL SYSTEM

Filed Jan. 12, 1953 5 Sheets-Sheet 1

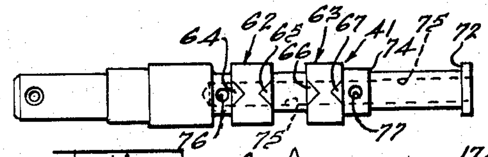

FIG. 1 A.

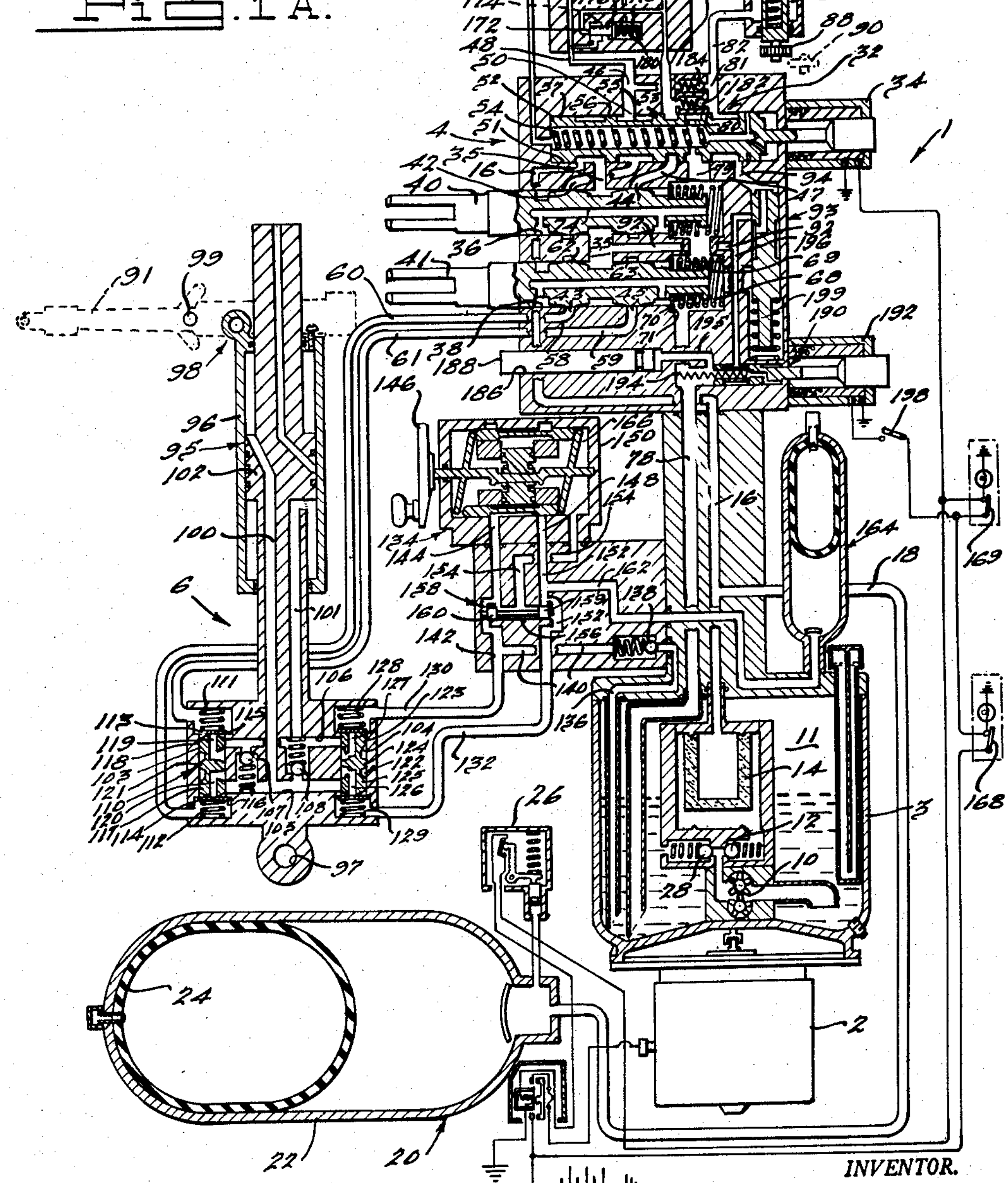

FIG. 1.

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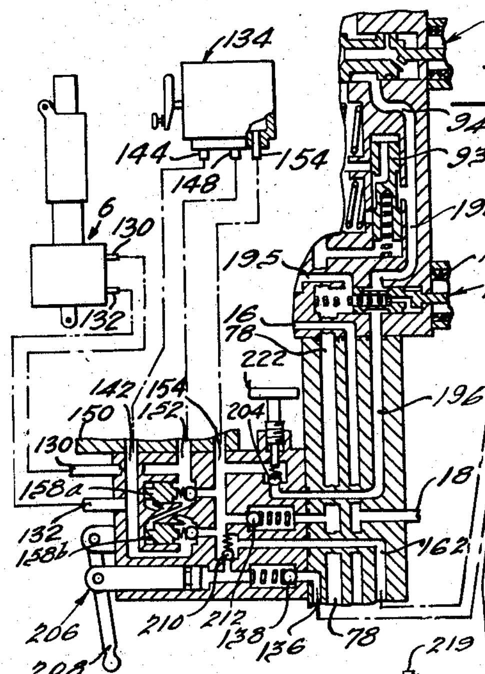

FIG. 4.

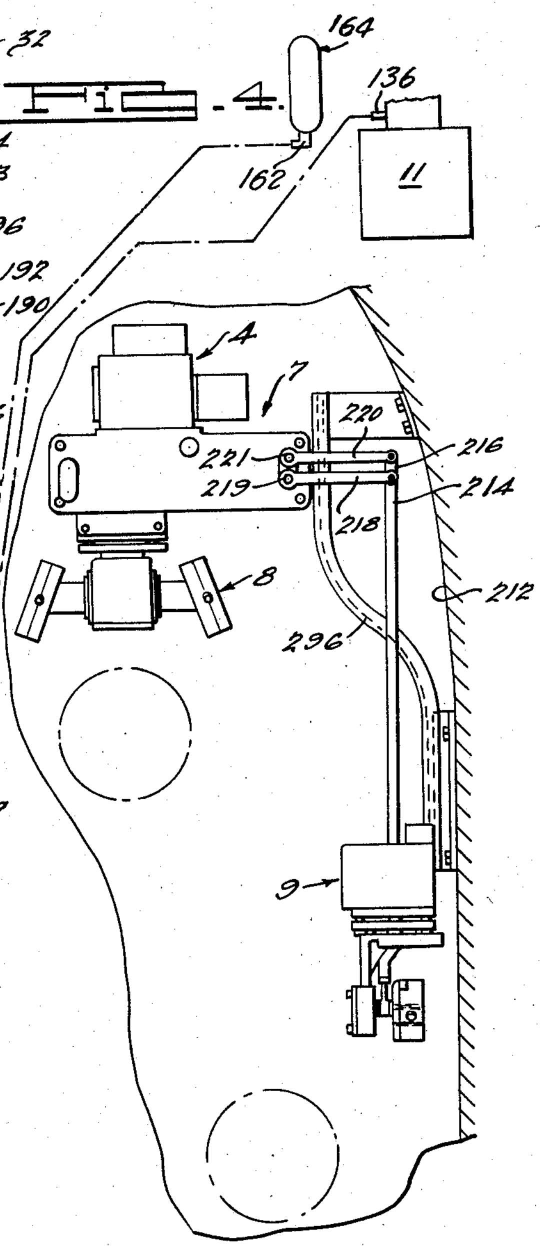

FIG. 3.

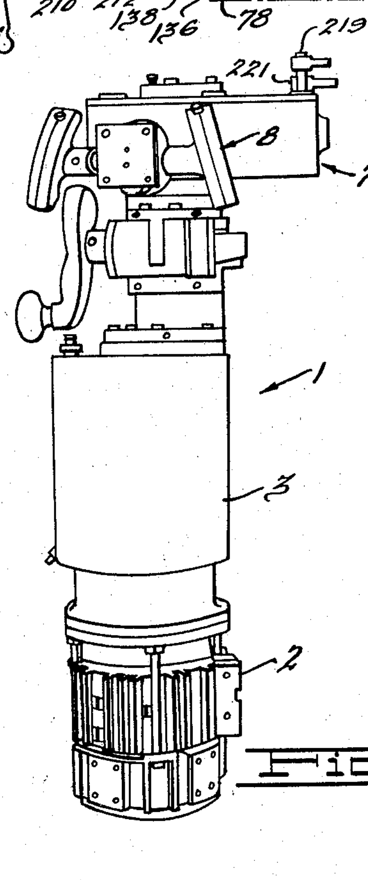

FIG. 2.

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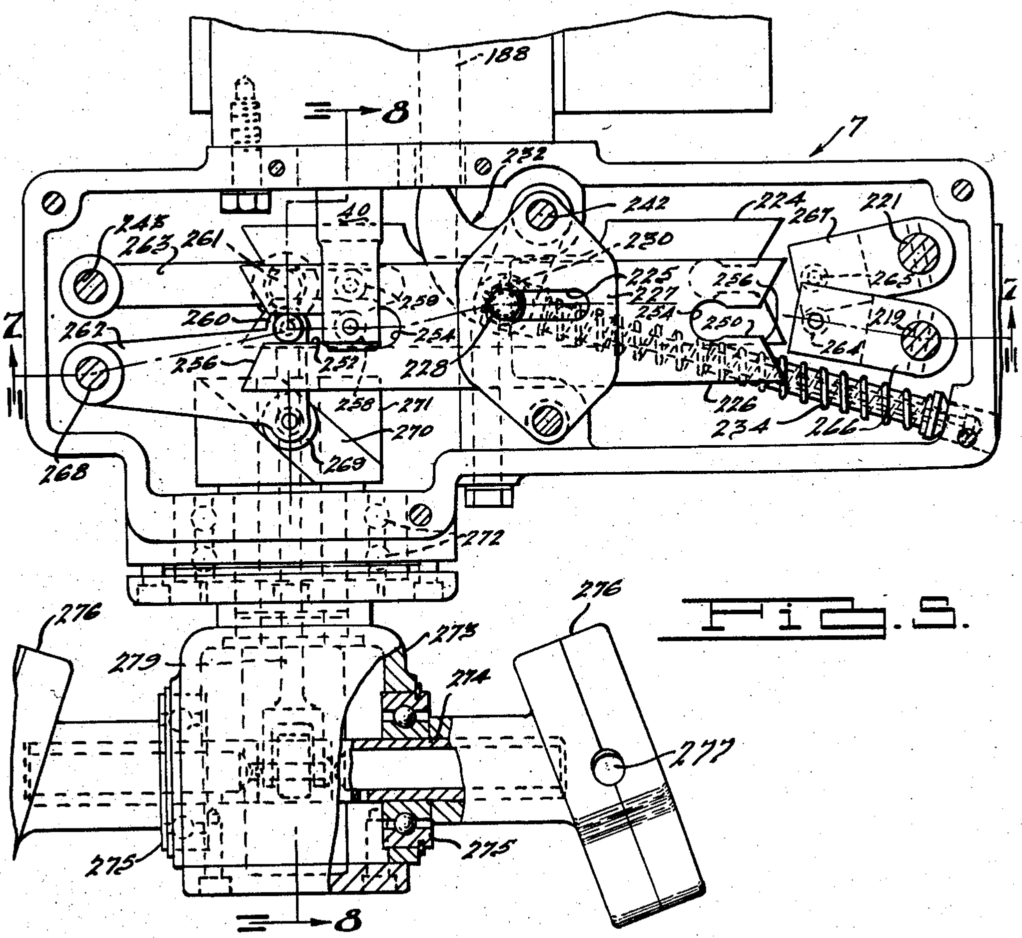

FIG. 5.

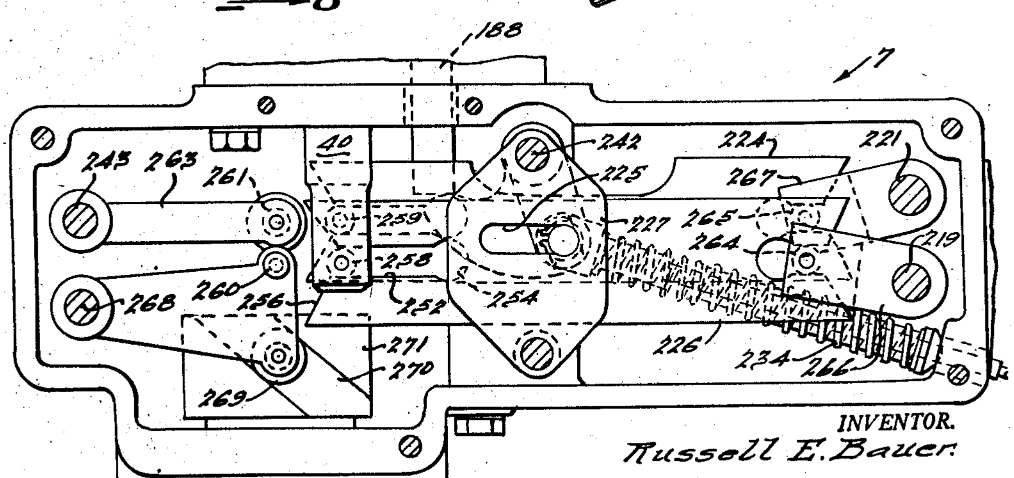

FIG. 6.

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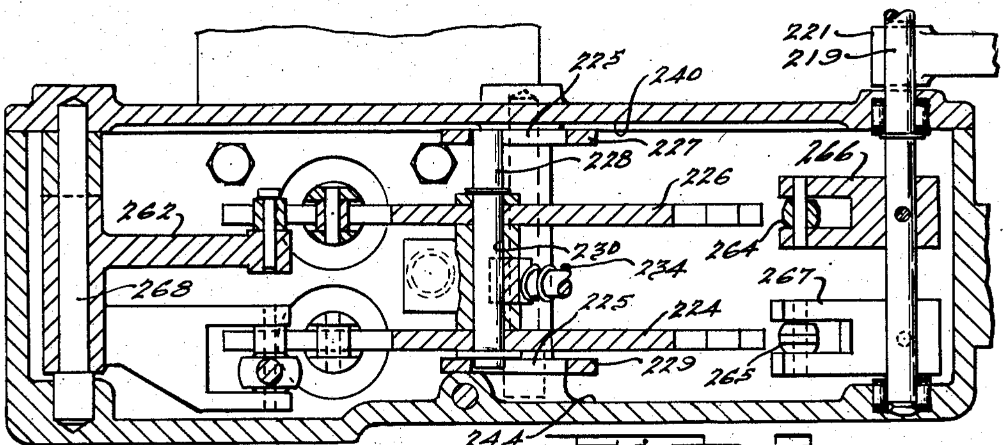


FIG. 7.

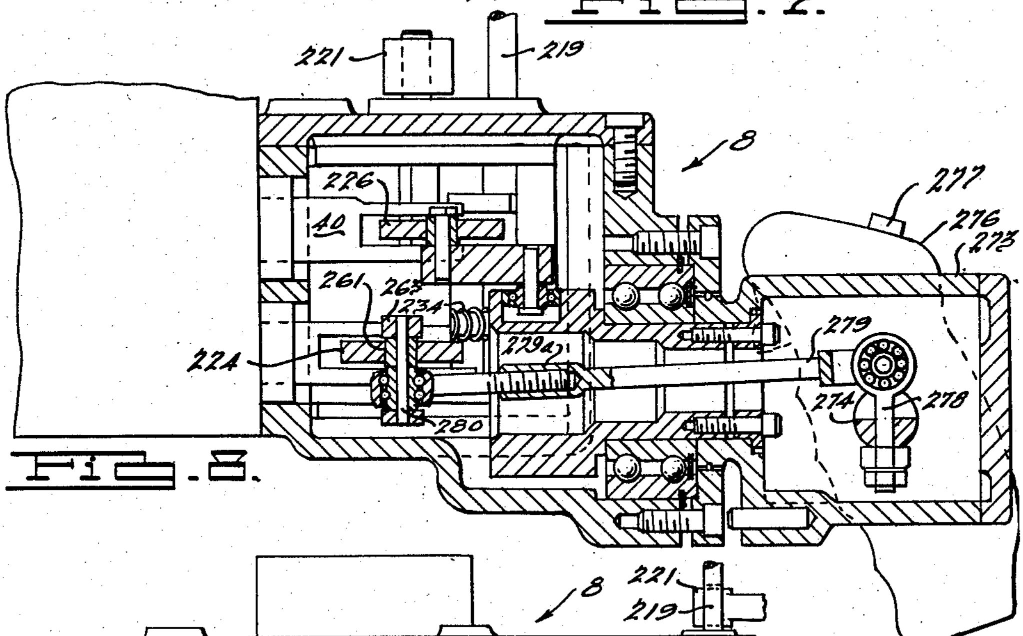
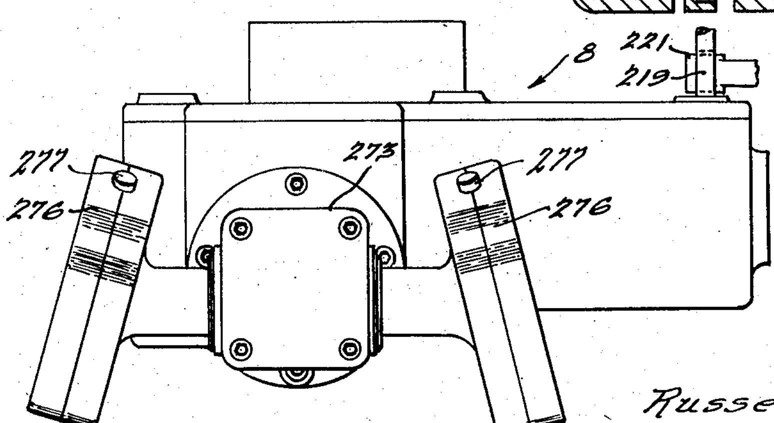


FIG. 8.



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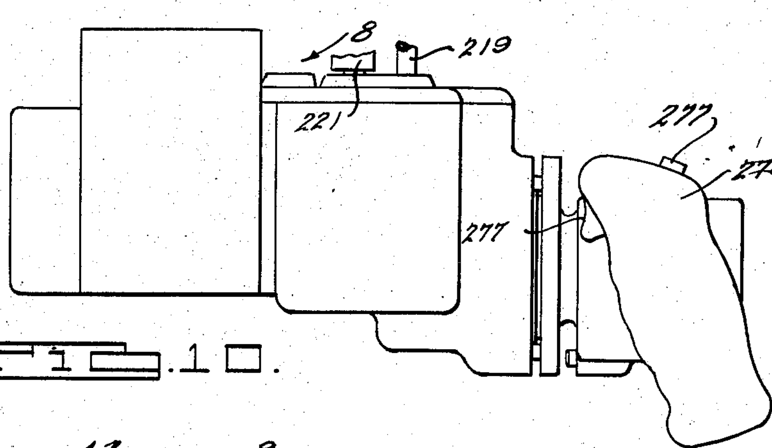

FIG. 10.

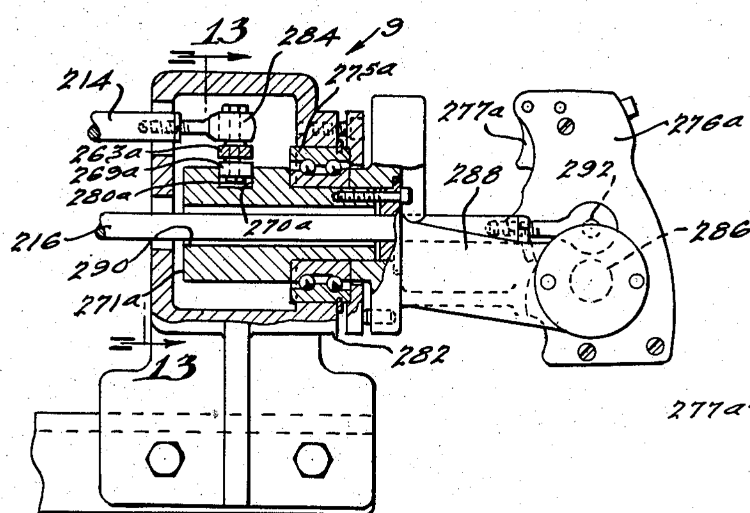

FIG. 11.

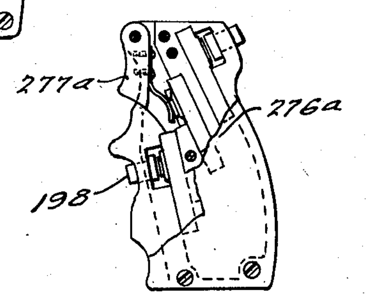

FIG. 12.

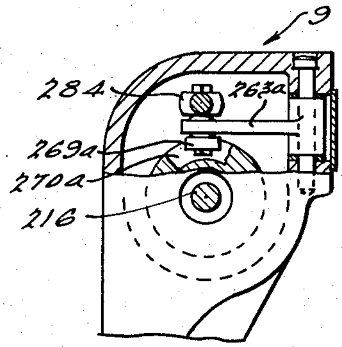

FIG. 13.

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2,893,355

HYDRAULIC CONTROL SYSTEM

Russell E. Bauer, Grosse Pointe Woods, Mich., assignor to Cadillac Gage Company, Roseville, Mich., a corporation of Michigan

Application January 12, 1953, Serial No. 330,871

3 Claims. (Cl. 121—39)

This invention relates generally to hydraulic control systems and more particularly to apparatus for aiming the cannon of a combat vehicle.

An object of this invention is to provide an improved control system for controlling elevation and rotation of a device such as a cannon.

Another object is to provide a system of this nature which is extremely compact and which is simple and efficient in its operation.

Another object of this invention is to provide such an apparatus in which there are a minimum of parts interconnected by conduits which might be ruptured during combat.

Another object of this invention is to provide such an apparatus which may be manually operated in the event of damage to the power system.

Another object of this invention is to provide such an apparatus that the drain on the electric power supply will be low when in operation and will be nil when in standby operation.

Another object of this invention is to provide such an apparatus that will be silent in operation to minimize the chance of detection by the enemy when the vehicle on which it is installed is in ambush.

Another object of this invention is to provide such an apparatus in which there is a minimum of lag between operation of the controls and actual movement of the cannon.

Another object of this invention is to provide such an apparatus which will permit very accurate tracking of targets.

Another object of this invention is to provide such an apparatus which will permit rapid and accurate laying of cannon on fixed targets.

Other objects of this invention will be apparent from the description and the drawings, in which drawings:

Fig. 1 is a diagrammatic representation of one form of the controlling apparatus embodying the invention;

Fig. 1A is an enlarged view of one of the spool valves shown in Fig. 1;

Fig. 2 is a view in side elevation showing a commercial form of the apparatus;

Fig. 3 is a plan view of the apparatus of Fig. 2 showing the commander's override control attached thereto;

Fig. 4 is a modified form of a portion of the hydraulic control system shown in Fig. 1;

Fig. 5 is a plan view of the valve control box, the cover being removed, and the associated gunner's control;

Fig. 6 is a partial view similar to Fig. 5 showing the valve control box in a position to respond to the commander's control;

Fig. 7 is a view taken substantially along the line 7—7 of Fig. 5;

Fig. 8 is a view taken substantially along the line 8—8 of Fig. 5;

Fig. 9 is a front elevation view of a portion of the apparatus shown in Figs. 6, 7 and 8;

Fig. 10 is a side elevational view of the apparatus shown in Fig. 9;

Fig. 11 is a side elevational view partly in section of the commander's override control;

Fig. 12 is a view of the commander's control handle with certain of the parts broken away to show the switch structures thereof; and,

Fig. 13 is an end view of the commander's control with a portion of the housing broken away.

Controls for the aiming of a tank cannon have been heretofore designed and have been heretofore used but have been subject to certain disadvantages which my apparatus completely overcomes. For example, prior art controls involve a complicated combination of electrical and hydraulic systems and therefore include a number of costly relays and other equipment which, while from many standards are fast operating, are not sufficiently fast when cannons are being aimed under combat conditions. For example, a very appreciable time lapse will occur between operation of the controls by the gunner and response thereto in the aiming of the cannon. Such delay, of course, is not desirable since under combat conditions it may mean the difference as to whether the enemy or the gunner is able to obtain the first crucial shot. The present invention provides a system for directing fire from tanks or other combat vehicles with extreme accuracy and speed and permits the accurate tracking of moving targets or laying on a fixed target.

Generically, the aiming is effected by manual operation of a pair of valves which meter the flow of oil or other hydraulic fluid to control the cannon elevating cylinder and the traversing motor for rotating the turret. The present embodiment is of durable but light construction and is small in over-all size which particularly adapts it to any of the light, medium or heavy tanks and gun motor carriages. The elimination of much intermediate control mechanism, such as feedbacks, dither devices, servo devices, electronic valves, accessory pumps, gyros, inverters, differentials, etc., found in many of the prior art systems, not only reduces the time lags in the control system but also reduces the power consumption to a small fraction of that required by systems presently being used by the armed forces.

The hydraulic pressure fluid for operation of the traversing motor and the elevating cylinder is obtained from a main power fluid accumulator tank which is periodically charged from a fluid reservoir and is of such size that normal tracking and laying on target can be conducted over long periods of time without the necessity of operating the main tank engine or auxiliary generator.

The system is further arranged so that the combat vehicle will not be put out of commission by the failure of any one conduit which might be ruptured during combat. In the event of the rupture of any line of the power system, the cannon may be aimed by the hand system and if any line of the hand system is ruptured, the cannon may still be aimed by power. The hydraulic fluid from one system cannot be lost through failure of any part of the other system. Further, all internal hydraulic fluid passages are drilled or manifolded in solid metal to lessen the chance of rupture during operation.

In the past, the thinking has been that hydraulic controls based on a pressure metering system were impractical since the hydraulic motor actuated thereby would be jerky in operation, tending first to bind up and then to go at uncontrollable speeds, and for that reason the more complicated variable displacement pumps were employed for controlling the volume of the hydraulic fluid in the motor. Also, past systems have required a variable displacement pump for traversing the cannon, and one for elevating the gun, as well as a system charging pump.

In accordance with this invention, however, the speed of operation of such fluid motor is controlled by metering the hydraulic fluid on both the inlet and the outlet or return sides of the fluid motor whereby sudden surges of pressure are eliminated, and smooth operation is achieved at all tracking speeds or times of laying on target regardless of variations in torque due to improperly fitted gears or tight and loose spots in the turret. Also, only one simple hydraulic pump is required.

Referring now to Figs. 1, 2, and 3 of the drawings wherein there is illustrated a preferred embodiment of the invention, 1 designates generally a hydraulically actuated combat vehicle cannon aiming apparatus comprising a vertically mounted electric motor **2**, a hollow casing **3** mounted above the motor and providing a hydraulic fluid reservoir **11**, within which a liquid pump **10** and filter **14** are enclosed. A valve block **4** is mounted above the casing **3** for controlling the admission of hydraulic fluid to a hydraulic motor **5** which rotates the cannon and to a cannon elevating cylinder **6**. A valve control box **7**, which may be controlled either from the gunner's control mechanism **8** or the commander's control mechanism **9** is mounted adjacent to the valve block **4** for actuating a pair of spool valves **40** and **41** contained within the valve block **4**.

The electric pump motor **2** drives the liquid pump **10** which may be a simple gear pump as shown. The pump **10** forces hydraulic fluid from the fluid reservoir **11** through a check valve **12** and filter **14**, a vertically extending passageway **16**, and a conduit **18** into the main hydraulic power accumulator **20** to provide a ready and steady source of high pressure hydraulic fluid of, for example, 1000 pounds p.s.i. for actuating the motor **5** and the cylinder **6**. The accumulator **20** may be of any usual construction, and as herein shown comprises a sealed tank **22** containing an expansible-contractible gas filled bladder **24** which provides the required pressure above the liquid and serves to prevent intermingling of the pressure maintaining gases contained therein with the hydraulic liquid of the hydraulic system. A pressure actuated switch **26** normally controls the energizing circuit of the motor **2** to maintain the fluid pressure in the accumulator between predetermined pressure limits. The check valve **12** prevents back flow of hydraulic fluid into the reservoir **11** during standby periods of the pump **10**. As a safety precaution a relief by-pass valve **28** is provided to by-pass at least some of the fluid pumped by the gear pump **10** in the event its discharge pressure becomes excessive.

The passageway **16** extends from its junction with the accumulator passageway **18** upwardly into the valve block **4**, which is mounted on top of the unit rearwardly of the valve control box **7**. As shown in Fig. 1, the valve block **4** is provided with a spool type master valve **32**, which during normal operation is actuated to open position by an electric solenoid **34**. The valve **32** is shown in its open, or energized position in which the passageway **16** is in open communication with the center sections **35** of the valve chambers **36** and **38**. Spool type traverse and elevation controlling valves **40** and **41** are respectively positioned within the chambers **36** and **38**. They are shown in their normal, or closed positions in which they act to prevent any passage of pressure fluid from the passageway **35** to either of the outlet ports **42–44** of chamber **36** or **43–45** of the chamber **38**. The ports **42** and **44** control fluid supplied to passageways **46** and **47** and conduits **48** and **49** of the hydraulic traversing motor **5**. The passageways **46** and **47** lead through a central section **50** of the chamber **51** housing the spool element **52** of the master valve **32**. In the open position of the master valve **32** the passageways **46** and **47** are separated from each other by a land **53** of the element **52**. In the de-energized, or closed position of the valve **32** the spool element **52** thereof moves to the right under the force of a spring **54** whereby the land **53** moves to the right of the passageway **47**, and a reduced diameter portion **55** of the element **52** which is intermediate the land **53** and a second land **56** interconnects these two passageways **46** and **47** to permit fluid from the motor to circulate freely during manual rotation of the turret. This is necessary since the motor **5** in present tank practice is continually connected through gearing (not shown) with the tank ring gear (not shown), and therefore rotation of the turret is accompanied by rotation of the motor **5** which then acts as a pump. When the master valve **32** is closed, third land **57** of the element **52** closes the passageway **16** to prevent flow of high pressure fluid from the accumulator **20** to the four-way control valves **40** and **41**.

The elevation controlling valve **41** in its closed, or centered position prevents passage of fluid from the passageway **35** to either of the outlet ports **43** or **45**, which are connected by passageways **58** and **59** and conduits **60** and **61** respectively to the cannon elevating cylinder **6**. The spool valves **40** and **41** are each normally held in their closed, or centered positions. Since each of the valves **40** and **41** is substantially identical, a detailed description of but one thereof is deemed to be sufficient to understand the construction of both and valve **41** will therefore be described. Valve **41** is provided with a pair of spaced lands **62** and **63** which are each provided with flattened tapered surfaces **64**, **65**, **66** and **67** (Fig. 1A), the taper of the surfaces **64** and **67** preferably being the same and the taper of the surfaces **65** and **66** being the same. In many instances the taper of each pair of surfaces may be the same, but in other instances it may be desirable to form them slightly differently depending upon the particular operating characteristics of the motor to be controlled.

Valve **41** is normally held in its centered position by springs **68** and **69** so that the intermediate portion of the lands **62** and **63** completely close the ports **43** and **45** respectively of the chamber **38**. One end of the spring **68** seats against the right-hand end wall of the chamber **38** and its other end seats against and normally urges an annular abutment **70** against a shoulder **71** of the chamber. One end of the second spring **69** seats against the annular abutment **70** and its other end seats against a shoulder **72** of the valve **41** and urges a second shoulder **74** of the valve **41** in engagement with the annular abutment member **70**. Valve **41** is provided with a longitudinally extending central passageway **75** opening outwardly through the end thereof having the shoulder **72** and having a first radially extending portion **76** which opens outwardly thereof to communicate with the left-hand end of the valve chamber **38** and a second radially extending passageway portion **77** which opens outwardly of valve **41** intermediate the valve land **63** and shoulder **74**.

The right-hand ends of the valve chambers **36** and **38** are connected together and to the reservoir **11** by means of a drain passageway **78**. The passageway **75** therefore acts to connect the left-hand groove of the spool valves **40** and **41** to the respective right-hand ends of the chambers **36** and **38** whereby each end thereof is connected to the drain passageway and any fluid leaking by the lands **62** and **63**, as well as return fluid from the motor **5** and cylinder **6**, is returned to the reservoir **11**.

The right-hand end of the chamber **36** is connected by a drain passageway **79** to the master valve **32**. In the energized position of the master valve **32** a land **80** of the element **52** closes communication between the passageway **79** and a passageway **81** and conduit **82** which lead to a piston chamber **83** below a piston **84** in a traverse gear box shifter **86**.

During power operation of the aiming apparatus **1**, the piston **84** of the gear box shifter is maintained in its upper position against the force of the return spring **87** by fluid pressure in the chamber **83**. In this position the pinion gear **88** disconnects the manually rotatable gear 90 from the gear train driven by the motor 5. This disconnection of the hand cranking device is desirable to disconnect the "no-back" construction usually embodied in such a cranking device. Such "no-back" construction would otherwise prevent movement of the turret by motor 5. In types of tanks such as the M–48, the piston 84 could be used to insert and remove the usual hydraulic motor lock used in this type of tank. The fluid pressure for the chamber 83 is supplied from passageway 35 through a passageway 92, pressure reducing valve 93, and passageway 94 which when the master valve 32 is in its open position is communicatively connected to passageway 81. When valve 32 moves to closed position, communication between passageways 94 and 81 is interrupted by the land 80 and passageway 81 is connected to the reservoir 11 through passageways 79 and 78. This connection relieves the fluid pressure in chamber 83 when the master valve 32 is closed and permits spring 87 to place the gear 88 in mesh with gear 90 whereby rotation of gear 90 by a suitable crank (not shown) is effective to rotate the turret.

The cannon elevating cylinder 6 includes a piston 95 positioned within a cylinder 96. The lower end of the piston 95 is held against vertical movement by a pin (not shown) extending through an eye 97 in its lower end portion. The upper end portion of the cylinder is suitably attached as at 98 to the cannon 91 which is mounted on trunnions 99. The piston is provided with a pair of passageways 100 and 101 opening at their upper ends within the cylinder 96 above and below, respectively, the head portion 102 of the piston 95. The lower end of the elevating piston 95 is enlarged and provided with a pair of vertically extending cylindrical valve chambers 103 and 104. The lower end portions of these chambers are interconnected by means of a lower transversely extending passageway 105, and their upper end portions are interconnected by an upper transversely extending passageway 106. The passageway 105 is in open communication with the passageway 100 and passageway 106 is in open communication with passageway 101. A pair of pressure relief valves 107 and 108 interconnect the passageways 105 and 106 and by-pass fluid therebetween whenever the pressure difference therebetween exceeds a desired value, thereby preventing excessive shock to the system when the vehicle is crossing rough terrain.

A spool valve 110 is provided in the valve chamber 103 and is normally held in its shown centered position by means of centering springs 111 and 112. More particularly, one end of the spring 111 is located between the upper end wall of chamber 103 and an annular member 113. The spring 112 similarly is located between the lower end wall of the chamber and a lower annular member 114. The chamber 103 is provided with a pair of outwardly facing shoulders 115 and 116 which are spaced apart substantially the length of valve 110. These annular members 113 and 114 are urged by their respective springs against the shoulders 115 and 116 respectively and thereby normally maintain the valve 110 centered with the passageways 105 and 106 isolated from the chamber 103. When, however, fluid under pressure is admitted to conduit 60 the fluid moves the valve 110 upwardly against the force of the spring 111. This upward movement moves land 117 upwardly to place the conduit 60 in fluid flow communication with the lower transverse passageway 105. The upper land 118 of this valve 110 moves upwardly to a position in which an upper internal passageway 119, separated from a lower internal passageway 120 by land 121, communicatively connects the passageway 106 to the conduit 61 through the annular member 113. In order to insure that the valve 110 will close as a consequence of closure of the valve 41, the land 121 may be arranged to permit a small leakage flow thereby, so that any remaining differential in pressure across the valve 110 may be equalized.

If pressure fluid is admitted to conduit 61, the valve 110 moves downwardly and land 118 permits fluid to flow into passageway 106 from conduit 61 and in this position of valve 110 the passageway 105 communicates with the conduit 60 through passageway 120. Upon the admission of pressure fluid to the conduit 60, the valve 110 will move upwardly admitting pressure fluid through the passageways 105 and 100 to the upper end portion of the cylinder 96. Since the piston 95 is fixedly held, the cylinder 96 will be moved upwardly to tilt the cannon 91 to lower the elevation thereof. As the cylinder 96 moves upwardly, fluid exhausts from the lower end portion of cylinder 96 through the passageways 101 and 106 and passageway 119 of the valve member 110 to the conduit 61.

Conversely, when pressure fluid is admitted to the conduit 61 the valve 110 moves downwardly to open the conduit 61 into the passageway 106 and to connect the passageway 105 through passageway 120 to the conduit 60 to admit fluid to the lower portion of cylinder 96 and to exhaust fluid from the upper portion of the cylinder 96. A similar valve 122 with lands 123, 124 and 125 and internal passageways 126 and 127, normally held in centered position by springs 128 and 129, is located in the valve chamber 104 and cooperates with conduits 130 and 132, similarly as does valve 110 with conduits 60 and 61. As will be subsequently described, conduits 130 and 132 are used for conducting fluid to and from the cylinder 96 when the elevating cylinder 6 is operated manually from the hand operated pump 134.

The manual system for controlling the cylinder 6 includes the above mentioned valve 122, conduits 130 and 132 and a reversible hand pump 134. Fluid for the manual system is derived directly from the reservoir 11 through passageway 136, check valve 138 and passageway 140 which opens into a passageway 142 which connects one of the pump ports 144 with the conduit 130. The pump 134 can be of any bi-directional type which will upon rotation of the hand crank 146 provide the required fluid pressure between its ports 144 and 148. As shown, the pump 134 is of the piston type having a casing 150 enclosing the pistons and swash plate actuated valves. The port 148 is connected by passageway 152 with the conduit 132 while the interior of the casing 150 is connected to passageway 154 which is selectively in communication with the passageways 142 and 152. More specifically, the passageway 154 opens into a central portion of a transversely extending passageway 156 opening into the passageways 142 and 152.

A shuttle valve 158 has opposite head portions or lands 159 and 160. The lands are spaced relative to each other and relative to the distance between the outlets of passageway 156 into the passageways 142 and 152 so that the lands will always prevent flow between the passageways 142 and 152 but will selectively render the passageway 154 in communication with the one of the passageways 142 and 152 in which the hydraulic pressure is lower.

The passageway 152 is provided with a branch passageway 162 which opens into a manual elevation system accumulator 164 which is similar to but preferably smaller than the accumulator 20. Accumulator 164 acts as a source of supercharging pressure fluid for facilitating the manual operation of cylinder 6. The accumulator 164 is charged from the reservoir 11 by the pump 134 by rotating its crank 146 in a direction to pressurize the right-hand passageway 152. With the cannon 91 located in its extreme downward position against any suitable stop (not shown), the pump 134 will draw fluid from the reservoir 11 through passageways 136, 140 and 142 and the check valve 138 and discharge fluid through port 148. Once the elevating cylinder 6 is driven to the limit of its extension and thus prevented from further depressing the cannon 91, the pumped fluid will be forced through passageway **162** into the accumulator **164**.

At this time, the shuttle valve **158** will be in its leftward position, causing the pressure of the interior **166** of the pump casing **150** to be the same as the inlet pressure of the pump. The pump **134** is actuated to charge the accumulator **164** to any desired pressure such as, for example, about 300 pounds p.s.i., for supercharging the manual system. When the pump **134** is released, the fluid pressure equalizes throughout the manual system including the pump **134** and the conduits **130** and **132** which lead to the elevation cylinder. Thereafter, the crank **146** may be rotated in one direction or the other to establish a desired fluid flow through the conduits **130** and **132** to elevate or depress the cannon **91**. The accumulator **164** will insure a sufficient amount of supercharging fluid pressure for proper operation of the manual system. Fluid which may escape from this system may be replaced by recharging the accumulator as described above.

The operation of the fluid systems so far described is as follows:

Upon closure of the loader's safety switch **168** and main power switch **169**, operation of the motor **2** is placed under control of the pressure switch **26** which thereupon acts to start and stop the motor **2** to maintain the desired pressure in the accumulator **20**. Closure of the switches **168** and **169** also energizes the solenoid **34** to place the master valve **32** in its shown open position whereby pressure fluid is supplied to the passageway **35**. Fluid under pressure regulated by the pressure controlling valve **93**, and passing through master valve **32** fills the chamber **83** of the gear box shifter **86** to uncouple gear **90** from the gear box controlling rotation of the turret.

When it is desired to rotate the turret, the spool valve **40** is longitudinally moved either inwardly or outwardly depending upon the desired direction of rotation which for purposes of description will be outwardly for counterclockwise and inwardly for clockwise rotation. The specific mechanism for controlling the valves **40** and **41** is the valve control box **7** actuated either by the gunner's control mechanism **8** or the commander's mechanism **9** as will be described more fully below. Assuming that valve **40** has been moved outwardly (to the left as viewed in Fig. 1), fluid now flows from the accumulator **20**, through passageway **16**, master valve **32**, port **42**, passageway **46**, conduit **48**, motor **5**, conduit **49**, passageway **47**, port **44** and passageways **77**, **75** and **78** to the reservoir **11**. As shown, the angle of taper of land portion **65** is substantially the same as that of the land portion **67** and the flow of fluid is regulated at both ports **42** and **44** so that surge of pressure through the motor **5** is prevented. A regulated rate of fluid then flows through the fluid motor **5** which then drives the gear train (not shown) at a regulated speed to rotate the turret in a counterclockwise direction. Return of the valve **40** inwardly to neutral position stops all fluid flow by sealing off the ports **42** and **44**.

This stops further rotation of the motor **5** which then is locked in its stopped position by the fluid trapped in the motor fluid system. If, however, an unduly great rotative force were applied to the turret, such as the cannon **91** hitting an obstruction, safety pressure relief valve **172** will permit flow of fluid between the conduits **48** and **49** and thereby permit rotation of the turret without damage to the fluid system and other mechanism. The stem of valve **172** is provided with a slot **174** and a piston **176** in a piston chamber **178**. A spring **180** normally holds valve **172** closed. If the pressure within the conduit 49 exceeds a predetermined value, the pressure acting on the end of valve **172** will overcome the force of spring **180** and the valve will open. If the obstruction is such as to increase the pressure in conduit **48**, fluid pressure will act on the piston **176** through slot **174** and move the valve **172** to permit flow from conduit **48** to conduit **49**.

Traverse circuit keep-full valves **182** and **184** are provided to supercharge the motor circuit, and permit fluid flow from the passageway **81** into passageways **47** and **46** respectively. This improves the response of the motor **5** and keeps it in condition to lock the turret against rotation except when fluid is supplied to motor **5** by the valve **40** or when the master valve **32** is in its de-energized position and the turret is being manually controlled. The valves **182** and **184** comprise spring pressed balls moved toward open position when the pressure in passageway **81** exceeds that in passageways **47** and/or **46** by a predetermined amount.

Movement of the spool valve **41**, which is similar in construction to valve **40** and cooperates similarly with the ports **43** and **45**, acts to provide a controlled fluid flow through the conduits **60** and **61** to elevate or depress the cannon **91**. Movement of the valve **41** outwardly (to the left as viewed in Fig. 1) permits fluid to flow from passageway **35** through port **43** and conduit **60** to move valve **110** upwardly. Fluid then flows from conduit **60** through passageways **105** and **100** into the upper portion of the cylinder **96**. This causes cylinder **96** to move upwardly to depress the cannon **91**. As the cylinder **96** moves upwardly, fluid is expelled from the lower portion thereof through passageways **101**, **106** and **119**, conduit **61**, passageway **59**, port **45** and passageway **78** to the reservoir **11**. Return of the valve **41** in an inwardly direction to its normal centered position closes the ports **43** and **45** and locks the elevating cylinder in its adjusted position, with valve **110** returning to its normal centered position by the springs **111** and **112** as the pressure equalizes thereacross either through the cylinder **6** or by the leakage past land **121**. Movement of the valve **41** inwardly causes fluid to flow from passageway **35** through conduit **61** to move valve **110** downwardly and therethrough and through passageways **106** and **101** to the lower end portion of cylinder **96** moving the cylinder **96** downwardly to elevate the cannon **91**. Fluid from the upper portion of the cylinder **96** flows through passageways **100**, **105**, and **120**, conduit **60**, passageway **58**, port **43**, the passageway within the valve **41**, and passageway **78** to the reservoir **11**.

The construction by which the spool valves **40** and **41** act to throttle both the inlet and outlet passageways to the fluid powered units, which may be either motor **5** or cylinder **6**, is an important part of this invention. When both ports of one of the valves are closed, the power unit associated therewith and its connecting passageways are maintained full of liquid. When the valve is initially moved to a throttling position and the inlet and outlet ports are initially opened for fluid flow therethrough, a full supply pressure is applied to the power unit. Just as soon, however, as the power unit moves and fluid flow starts, a pressure drop appears across both the inlet and outlet ports of the valve. If the power unit tends to move more rapidly than the position of the valve would justify, there is an immediate build up in pressure across both the inlet and outlet ports with a consequent reduction in pressure drop across the power unit. If, on the other hand, the power unit tends to move less rapidly, then there is a consequent lowering of the pressure drop across each of the ports which results in a greater pressure available for movement of the power unit. Since the liquid lines are always fully charged, any slight tendency of the power unit to vary its rate of movement will immediately result in a compensating change in the pressure drop across the power unit. If only a single valve on the inlet side of the power unit were used, then a slowing down of the power unit would permit a rapid build up of pressure across the power unit and when the unit did finally start to increase its rate of movement it would tend to accelerate to a more rapid rate than was desired since there would be no braking force on the outlet of the power unit. This would be particularly true in instances in which the force required to drive the apparatus powered by the power unit was of a variable nature. Certain of my advantages could be obtained by merely valving only the outlet of the power unit, but in such event the fluid pressure in the power unit would be at the elevated fluid pressure of the source. With certain types of power units this might not be too objectionable.

With types of power units such as fluid motors which are commonly used for rotating tank turrets, certain of the parts would be subject to a difference in pressure between that of the source and that in its surrounding casing which for obvious reasons is normally maintained at atmospheric pressure. At slow speed operation this unnecessarily great pressure difference across these parts tends to cause them to bind and give a jerky movement to the turret. By throttling the inlet as well as the outlet pressure to such a fluid motor, the pressure of the admitted fluid is substantially reduced and the tendency of the motor to operate jerkily is greatly reduced if not completely eliminated without, at the same time, resulting in a tendency for the motor to change in speed as a consequence of variations in power required to rotate the turret or other mechanism driven thereby.

With the piston cylinder type of power unit, the double throttling prevents jump which might result if full pressure differential were suddenly admitted across the piston due to the compressibility of the fluid therein.

When manual operation of the turret and cannon elevating cylinder is desired, switch **169** is opened to de-energize the solenoid **34** whereby spring **54** moves the master valve **32** to closed position. Movement of valve **32** to off position disconnects the passageway **81** from the pressure supplying passageway **94** and connects passageway **81** to drain passageways **78** and **79**. Piston **84** then moves downwardly under the force of spring **87** to connect the gear **90** with the gear train (not shown) for revolving the tank turret. Closing of the master valve **32** also disconnects passageway **35** from the main supply passageway **16** leading to the accumulator **20** and interconnects the motor circuit passageways **46** and **47.** With the gear **90** so connected manual rotation thereof by a crank (not shown) acts to revolve the turret and cannon **91.** Elevating and depressing of the cannon **91** is accomplished by manually rotating the handwheel **146** of the hand operated pump **134** in one direction or the other to pump fluid into one or the other of the conduits **130** and **132** depending on the direction of pump rotation. Fluid so pumped then acts through the valve **122** in a similar manner to that described in connection with power operation through conduits **60** and **61,** and valve **110.** The shuttle valve **158** will shuttle to a position in which the interior of the pump housing **150** is connected to the inlet side of the pump **134** to always maintain the pressure in the housing interior the same as that of the inlet pressure to the pump.

The valve block **4** is provided with an additional piston chamber **186** having a piston **188** which actuates the valve control box **7** to permit the tank commander to assume control of the apparatus **1.** Flow of fluid for controlling the piston **188** is under control of a valve **190** actuated by a solenoid **192.** Normally the solenoid **192** is maintained de-energized thereby permitting spring **194** to hold this valve in the illustrated position in which a passageway **195** opening into the end portion of the chamber **186** behind the piston **188** is opened to the drain passageway **78.** Upon energization of the solenoid **192,** the valve **190** is moved to the left, as viewed in Fig. 1, against the force of the spring **194** to seal off the connection of the passageway **195** to the passageway **78** and place it in communication with a branch passageway **196** of the pressure fluid supplying passageway **35.** The energization of the solenoid **192** is under control of a normally open switch **198** available for operation by the tank commander.

In Fig. 4, in which like parts to Fig. 1 are identified by the same numerals, there is shown a somewhat modified form of a manually operated cannon elevating system in which fluid for charging the manual system accumulator **164** and the fluid for operating the piston **188** are normally supplied from the pressure reducing valve **93** so that the accumulator **164** is continually maintained charged from the main hydraulic fluid system and the operating force on the piston **188** is reduced. In this instance the passageway **196** is made a branch of passageway **94** instead of passageway **35.** Passageway **196** then connects the valve **93** through a manually operated power charging cut-off safety valve **202** to the passageway **154** which in this form is in open communication through passageway **162** with accumulator **164.** The valve **202** is normally maintained in its shown position in which the spring pressed ball valve **204** thereof acts as a check valve to permit fluid flow into the manual system but prevents flow therefrom. Valve **202** may however be turned so that the stem thereof positively holds the ball **204** against its seat to isolate the manual system.

In the event that it is desired to manually charge the manual system, a hand pump **206** is provided. Operation of pump **206** is by means of a manually operated lever **208.** The pump **206** is connected through check valve **138** and passageway **136** to the reservoir **11.** When operated, the hand pump **206** withdraws liquid from the reservoir **11** and pumps it through check valve **210** into the passageway **154** and passageway **162** to accumulator **164.** The passageway **154** is connected through a pressure relief valve **212** to the drain passageway **78.** This pressure relief valve **212** controls the maximum pressure which is permitted within the housing **150** of the manual actuating pump **134.**

In this form the shuttle valve **158** has been replaced by a pair of pressure actuated valves **158*a*** and **158*b*** which serve as check valves to permit charging of the manual fluid systems. When the pump **134** is operated, the pressure in the passageway **142** or **152** may be reduced below that in the accumulator **164.** If the manual system is completely filled it would be undesirable to add further fluid since upon discontinuance of the operating of the pump **134** pressure in the system might be greater than the desired pressure. Valves **158*a*** and **158*b*** are therefore provided with pressure sensitive plungers which are respectively sensitive to the difference in pressure between the passageways **142** and **152.** When the pressure in passageway **152** exceeds that in **142** by a predetermined amount, the piston associated with valve **158*b*** is moved to the right to hold the ball valve associated therewith tightly against its port to prevent a flow of liquid from the passageway **154** into the passageway **142.** Conversely, when the pressure in passageway **142** exceeds that in passageway **152** by a predetermined amount, the piston associated with the valve **158*a*** is moved to the right to hold its respective ball valve tightly against its port to prevent liquid to flow from passageway **154** into passageway **152.**

Fig. 3 diagrammatically shows the commander's override control **9** attached to the inner wall of the tank turret **212** and operatively connected by means of a pair of rods **214** and **216** with the arms **218** and **220** for rotation of the rotatable rods **219** and **221** respectively pivoted for oscillating movement in the valve controlling box **7.**

The valve control box **7** as shown in Fig. 5 houses a pair of pivoted blades **224** and **226** which connect the elevating and traversing valves **41** and **40** respectively with either the gunner's control **8** or the commander's control **9.** The blades **224** and **226** are pivoted on opposite ends of a stub shaft **228** which in turn is mounted at opposite ends within slots **225** of guide plates **227** and 229 carried by the box 7. A swivel arm 232 is provided with a slot 230 through which the shaft 228 extends. As shown, the swivel arm 232 is normally urged by a compression spring 234 into its clockwise position in which the blades 224 and 226 of the valve control box are actuatable by the gunner's control mechanism 8. The swivel arm 232 is pivotally mounted on a stub shaft 242 which is held at its end portions within suitable bosses carried by the top and bottom walls 240 and 244 of the box 7. When the solenoid 192 is energized, the fluid pressure operated piston 188, which is engageable with the arm 232, will rotate the arm 232 counterclockwise against the force of spring 234 from its position shown in Fig. 5 to the position shown in Fig. 6 in which the blades 224 and 226 will be under control of the commander's control 9 and entirely disconnected from the gunner's control 8.

The blades 224 and 226 are of similar construction, and are each provided with a slot 250 and 252 opening outwardly through opposite end surfaces. If desired, each of these slots may have a clearance hole 254 in their inner end portion for convenience of manufacture and to relieve stresses. The end walls of the blades are provided with tapering walls 256 tapering inwardly toward the slots 250 and 252 for a purpose which will be made clear below.

The blades 224 and 226 and the slots 252 are preferably of such length that the roller abutments 258 and 259 carried by the traversing valve 40 and elevating valve 41 are always within the respective slot 252 irrespective of the rotative position of the swivel arm 232. When the swivel arm 232 is in its clockwise position (Fig. 5) the roller 260 carried by the arm 262 and the roller 261 of the arm 263 are located within the respective slots 252, and the rollers 264 and 265 of the arms 266 and 267 mounted on the shafts 219 and 221 are without the slots 250. When the swivel arm 232 is in its counterclockwise position as shown in Fig. 6, the rollers 260 and 261 are without the slots 252 while the rollers 264 and 265 are within the slots 250. It will therefore now be appreciated that the rotative positions of the blades 224 and 226 continually control the positioning of the valves 40 and 41 but that the blades 224 and 226 will be controlled by the arms 262 and 263 at one rotative position of swivel arm 232 and by the arms 266 and 267 at a second rotative position of swivel arm 232.

The arms 262 and 263 are moved by the gunner's control 8 while the movement of the arms 266 and 267 are under control of the commander's control 9. More specifically, the arm 262 is pivotally secured to the box 7 on a fixed pin 268 and is provided with a second roller 269 which is received within a helical cam slot 270 carried by a hollow cylindrical sleeve 271. The sleeve 271 is held against movement longitudinally but is journaled for rotation in bearings 272. One end of the sleeve extends outwardly of the box 7 and has a hollow casing 273 secured thereto. A hollow ended shaft 274 extends transversely of the axis of rotation of the sleeve 271 and is suitably journaled in bearings 275 for rotation of the shaft 274 about its longitudinal axis. Gunner's handles 276 are secured to opposite ends of the shaft 274 and provide means for rotating the sleeve 271 and the shaft 274. The two handles 276 are mirror copies of each other and each may be provided with manually operable control switches 277 for firing of the cannon and/or other guns by means not shown. Rotation of the sleeve 271 causes the roller 269 to be moved longitudinally of the sleeve 271 and the arm 262 is rocked about its pivot pin 268 to pivot the blades 226 when the swivel arm 232 is in a position as shown in Fig. 5. Pivoting of the blade 226 moves the traversing spool valve 40 to control the admission of fluid to the traversing motor 5 and the rotation of the turret 212.

A crank arm 278 is secured to a mid-section of the shaft 274 and is journaled to one end of a rod 279 which extends upwardly through the hollow interior of the casing 273 and sleeve 271. The other end of the rod 279 is journaled to a pin 280 carried by the arm 263 and which pin 280 may also serve as the support for the roller 261. With this arrangement rotation of the shaft 274 acts to pivot the arm 263 to pivot the blade 224 to control the position of the elevating spool valve 41. The rod 279 is journaled as at 279*a* intermediate its ends which permits the outer end of the rod 279 to rotate with the sleeve 271.

The commander's control 9 is quite similar in construction to the gunner's control in that it comprises a cylindrical member 271*a* held against axial movement but journaled for rotational movement on bearings 275*a* mounted in a housing 282. The member 271*a* is provided with a diagonally extending peripheral cam slot 270*a* which receives a roller 269*a* carried by an arm 263*a* pivotally mounted on the housing 282 similarly to the way in which arm 263 is mounted in the gunner's control 8. A pin 280*a* carried by the arm 263*a* serves as the pivot for roller 269*a* and a bearing 284 which is secured to one end of the shaft 214 which connects with the arm 218 of the valve control box 7. A commander's handle 276*a* is pivotally mounted on a bearing 286 carried on a bracket 288 which in turn is carried by the member 271*a* externally of the housing 282. The shaft 216 which has one end pivotally secured to the arm 220 extends through a longitudinally extending central aperture 290 of the cylindrical member 271*a* and has its other end pivotally secured to the commander's handle 276*a* as at 292. In addition to the cannon firing switch 277*a*, the handle 276*a* is provided with a switch 198 by which the commander is enabled to control the energization of the solenoid 192 and consequently the operation of the valve 190. When the commander closes his hand about the handle 276*a* and actuates the switch 198, the solenoid 192 is energized to actuate the valve 190 to cause pressure fluid to force the piston 188 outwardly to rotate the swivel arm 232 and move the blades 224 and 226 into the position thereof shown in Fig. 6 so that movement thereof and of the valves 40 and 41 is under control of the commander's control 9. Having thusly assumed control, the commander may now rotate his handle 276*a* about the longitudinal axis of the member 271*a* to rotate the member 271*a* to control the traversing controlling valve 40, and may pivot the handle 276*a* in a vertical sense to control the elevating controlling valve 41 independently of any movement of the gunner's control 8 since at this time the blades 224 and 226 are free of the rollers 260 and 261.

The commander's control 9 is maintained in fixed position with respect to the valve control box 7 by suitable means and which may if desired include an angle bar 296. Lateral rotation of the handle 276*a* rotates the cylindrical member 271*a* causing the roller 269*a* to move longitudinally of the member 271*a* and to longitudinally move the shaft 214 which through the arm 218 pivots the shaft 219 of the valve control box 7. Pivoting of the shaft 219 pivots the arm 266 to rock the blade 226 to control the traversing valve 40. Likewise, fore and aft rotation of the handle 276*a* will move the shaft 216 which through arm 220 pivots the shaft 221. Pivoting of shaft 221 pivots the arm 267 to rock the blade 224 to control the elevating valve 41.

While illustrative embodiments of the invention have been shown, they should not be understood as limiting the scope of the invention but merely as illustrating the best presently known embodiment of the invention in accordance with the patent statutes.

What is claimed and is desired to be secured by United States Letters Patent is as follows:

1. A hydraulic control system for interconnection between a pressure fluid source and a bi-directional fluid actuatable motor in apparatus of the type wherein a load is arranged to be driven alternatively by the motor

and by a manually operatable device, said system comprising a four-way valve having first and second ports for connection to a pressure fluid source and to a drain, respectively, and third and fourth ports for connection to the motor, a master valve having a closable passage connected in series flow between said first port and the source and two other passages connected in series flow between said third and fourth ports, respectively, and the motor, said master valve being selectively movable between an On position and an Off position and being effective when in its On position to open all of said passages as separate fluid flow paths, said master valve being arranged when in its Off position to close said closable passage thereby cutting off pressure fluid from said control valve, and to open communication between said two other passages, a manually operatable device for driving the load, a releasable coupling device for coupling and decoupling said manually operatable device to and from the load, a fluid pressure actuatable device for actuating said coupling and decoupling device, and means defining an auxiliary hydraulic passage for energizing said fluid actuatable device, said master valve also being connected in and including valve means for admitting pressure fluid into said auxiliary passage from the source when said master valve is in its On position and for connecting said auxiliary passage to the drain when said master valve is in its Off position.

2. A hydraulic control system for interconnection between a pressure fluid source and a bi-directional fluid actuatable motor comprising a four-way valve having first and second ports for connection to a pressure fluid source and to a drain, respectively, and third and fourth ports for connection to the motor, a master valve having a closable passage connected in series flow between said first port and the source and two other passages connected in series flow between said third and fourth ports, respectively, and the motor, said master valve being selectively movable between an On position and an Off position and being effective when in its On position to open all of said passages as separate fluid flow paths, said master valve being arranged when in its Off position to close said closable passage thereby cutting off pressure fluid from said control valve, and to open communication between said two other passages, means defining an auxiliary hydraulic passage, check valve means connecting said auxiliary passage with said two other passages for supercharging said two other passages, means for pressurizing said auxiliary passage at a pressure lower than the pressure of said source, said master valve being arranged to connect said auxiliary passage to the fluid source when said master valve is in its On position and to connect said auxiliary passage to the drain when said master valve is in its Off position.

3. A hydraulic control valve assembly for interconnection between a pressure fluid source and a bi-directional fluid actuatable motor comprising a compact valve body having a master valve, a control valve, and a pressure reducing valve therein and passageways interconnecting said valves with each other and with external ports, said control valve being a four-way valve having first and second ports for connection to a pressure fluid source and to a drain, respectively, and third and fourth ports for connection to the motor, said master valve being a spool valve having a first passage connected in series flow between said first port of the control valve and the source and second and third passages connected in series flow between said third and fourth ports, respectively, and the motor, said pressure reducing valve having an inlet port connected to said first passage on the opposite side of said master valve from the source and having an outlet port for connection to said second and third passages for supercharging them at a pressure below the full working pressure at the inlet of said master valve, said master valve having a fourth passage in series flow between said reducing valve outlet port and said second and third passages, check valve means between said fourth passage and said second and third passages for permitting fluid flow from said fourth passage to said second and third passages and blocking fluid flow in the back direction from said second and third passages to said fourth passage, said master valve being selectively actuatable between an On position and an Off position and being operative when in its On position to open said first, second, third and fourth passages as separate fluid paths, said master valve being operative when in its Off position to close said first and fourth passages and to interconnect said second and third passages.

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