Jan. 15, 1957 C. E. ADAMS ET AL 2,777,425

ELECTRONIC CONTROL SYSTEM FOR HYDRAULIC MOTOR

Filed Sept. 16, 1953

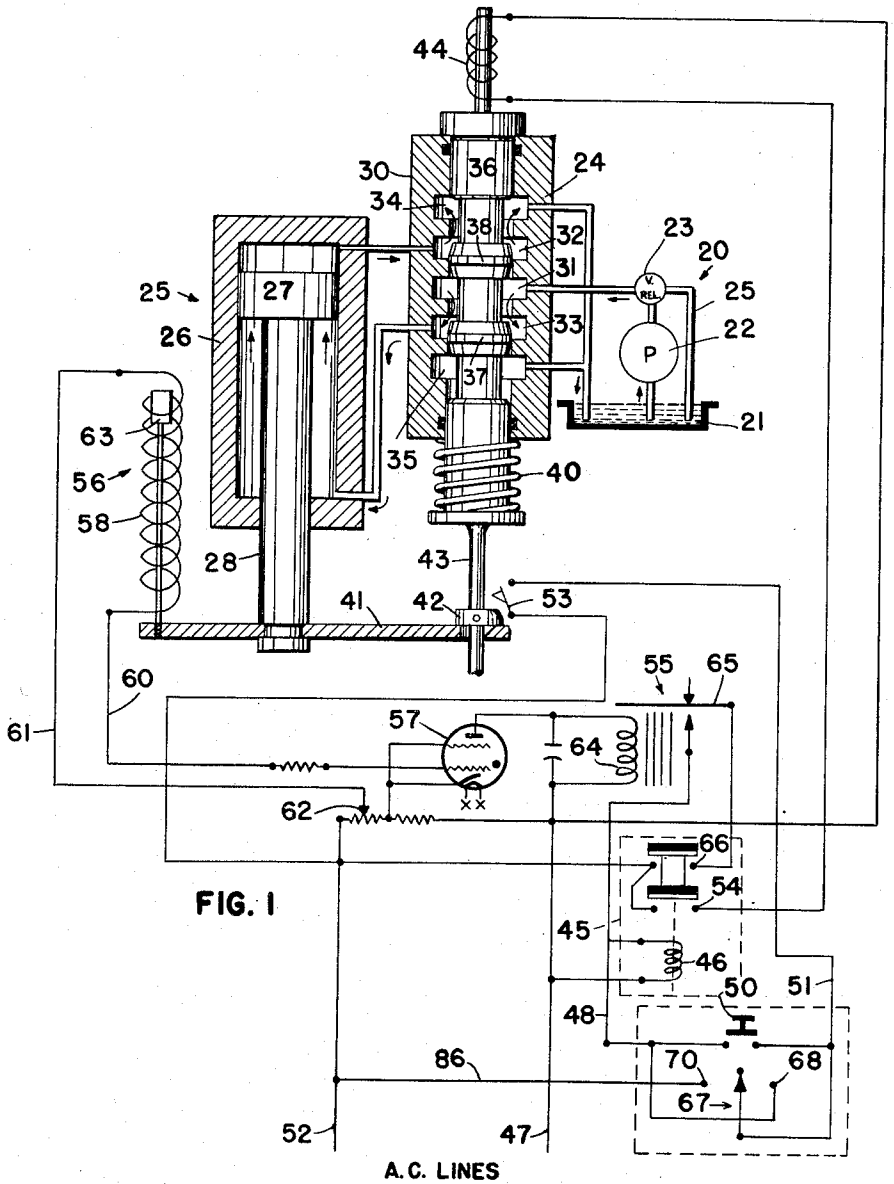

FIG. 1

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United States Patent Office 2,777,425
Patented Jan. 15, 1957

2,777,425

ELECTRONIC CONTROL SYSTEM FOR HYDRAULIC MOTOR

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Application September 16, 1953, Serial No. 380,578

12 Claims. (Cl. 121—38)

This invention relates generally to hydraulic apparatus and more particularly to control mechanism for hydraulically powered devices, especially those having lineally movable elements although the invention is also applicable to devices having rotary movable elements.

The invention is also related to control mechanism having electrically operated or electro-responsive elements and has as an object the provision of an electronic control system by which certain desirable features of hydraulic motor operation will be secured.

It is an object of the invention to provide fluid pressure operated apparatus having an electronic control system which will cause a ram or other movable element of a fluid motor, to continue to move in a desired direction, after the motion has been initiated, until a predetermined distance has been traversed or a resistance of predetermined force is encountered then automatically reverse and return to the starting point.

It is an object of this invention to provide control mechanism for a hydraulically operated device which control mechanism will operate substantially independently of the hydraulic system of the device, in that it will only require a minimum of the hydraulic power for its operation and yet it will be responsive to effect certain desired operations when predetermined conditions exist in the hydraulic system.

More specifically, it is an object of this invention to provide an electronic control system for a hydraulically operated device, such as a press, which system will cause the ram of the press to advance to and exert a predetermined force on an article disposed in its path and then be retracted to its initial or starting position.

A further object of the invention is to provide an electronic control system for a hydraulic press, the system having means for generating an electrical current when the press ram is advancing, such current being employed to maintain the flow of operating current to an electro-responsive device which, in turn, maintains the flow of hydraulic fluid to the ram until a predetermined pressure is reached after which the system operates to cause the ram to retract, the control system being devoid of pressure switches or any direct connection with the hydraulic system of the press.

A still further object of the invention is to provide a hydraulic press with an electronic control system having a coil through which a magnetized element is moved by the ram to generate an electric current which is employed to keep an electronic switch, such as a thyratron tube, in condition to direct an operating current from a source to a solenoid valve thus holding the valve in position to direct fluid pressure from a source to a port in the cylinder of the press to cause the ram to continue its advancing movement, the cessation of ram movement, due to reaching the end of its stroke or engaging an obstruction which offers sufficient resistance to cause the relief valve in the hydraulic system to open, serving to discontinue the current generation and interrupt the flow of current

to the solenoid valve permitting the same to shift to a position in which fluid pressure will be directed to a different port in the press cylinder to cause the ram to return to a starting position.

Another object of the invention is to provide a hydraulic press or similar device with an electrical control system having a motion sensing device which is responsive to the movement of the press ram to maintain a relay in the control system in a closed or current supplying condition so that an electro-responsive control valve for the press will continue to direct fluid from a pressure source to the press ram, the hydraulic system for the press having a relief valve which by-passes the fluid to the reservoir, when the press ram meets a predetermined resistance, and permits the ram to stop moving; the motion sensing device then permits the relay to assume an open position and the control valve will shift to a different position to cause reverse movement of the press ram. The effect secured by the control is that known in the trade as "pressure reversal" although pressure responsive switches or the like are not employed.

Further objects and advantages of the present invention will be apparent from the following description, reference being had to the accompanying drawings wherein a preferred form of embodiment of the invention is clearly shown.

In the drawings:

The sole figure in the drawing shows a combination diagrammatic view of the hydraulic apparatus and system forming a part thereof and the electronic control system.

In carrying out the invention, use is made, in the form of the invention illustrated, of a hydraulic press. The control system is adaptable to other types of hydraulic devices, the press shown being selected for illustrative purposes only. This press includes a source of fluid pressure **20** having a reservoir **21**, a pump **22**, and a relief valve **23**, a fluid line leading from the reservoir to the pump, from the latter to the relief valve, and from this member to a control valve of the reversing type indicated generally by the numeral **24**. A return line **25** leads from the relief valve back to the reservoir to conduct fluid from the pump to the latter when the relief valve opens due to the pressure in the source increasing beyond that for which the relief valve has been adjusted.

The reversing valve **24** controls the flow of fluid from the pressure source to a reversible fluid motor, indicated generally by the numeral **25**, which, in this instance, has been illustrated as a cylinder **26** and piston **27**, a ram **28** projecting from the piston. The reversing valve **24** includes a body **30** having inlet, forward and reverse cylinder and tank ports **31** to **35**, respectively. The inlet port **31** receives fluid directly from the pressure source. The forward and reverse cylinder ports are connected by lines with the upper and lower ends of the cylinder **26** while the tank ports **34** and **35** are suitably connected with the reservoir **21**. Valve body **30** receives a spool member **36** which is provided with spaced heads **37** and **38** so arranged to form grooves which establish communication between certain of the ports in the body depending upon the longitudinal position of the spool. This spool is urged in one direction by a coil spring **40** to cause the grooves in the spool to establish communication between the inlet port **31** and the reverse motor port **33**. When the spool is in the position to establish this communication, the ports **32** and **34** will also be connected and fluid from the pressure source will flow into the lower end of the power cylinder to cause the piston **27** to move in an upward or reverse direction. In so moving, the piston will discharge fluid from the upper end of the power cylinder through ports **32** and **34** to the reservoir.

As the piston nears the upper end of its travel, a bar **41** carried by the ram will engage a collar **42** provided on an extension **43** of the valve spool and will move the valve spool, in opposition to the spring **40**, to a position wherein the fluid pressure from the source will be directed into the tank port **35** from which it will flow to the reservoir **21**. At this time, the ram will stop in its elevated or retracted position.

The reversing valve is provided with a solenoid **44** for moving the spool to a further extent in opposition to the spring **40**. When the spool is moved by the solenoid, communication will be established between the inlet port **31** and the upper end of the power cylinder **26**. Fluid from the pressure source will then flow to the upper end of the power cylinder and will cause the piston and the ram to advance or move in a downward direction. Fluid displaced by the piston will be exhausted from the lower end of the power cylinder through ports **33** and **35** to the reservoir **21**. In the event the ram should meet an obstruction which offers sufficient resistance to prevent further movement thereof, the relief valve **23** will open to permit fluid from the pump to be by-passed back to the reservoir. At this time, the ram will be exerting the force for which the relief valve has previously been adjusted.

The invention herein relates to a control mechanism for the reversible fluid motor. The solenoid **44** forms a part of this control mechanism. As pointed out in the objects, a feature of this invention is to secure a reversal of the ram when a pressure, determined by the relief valve **23**, has been reached in the portions of the hydraulic system communicating with the upper end of the power cylinder; in other words, when the ram is exerting a predetermined force. It is also a feature of the invention to secure this reversal without the use of pressure switches. The electrical control system, illustrated in the drawing, makes this operation possible.

This control system includes relay mechanisms for controlling the flow of current to the solenoid **44**. A plurality of sections are included in the relay mechanisms, one of the sections, designated by the numeral **45**, having a field coil **46**, one end of which is connected with one of the current supply lines **47** while the other is connected with line **48**, this line leading to one side of a push-button switch mechanism indicated by the numeral **50**. The other side of this switch mechanism is connected by a line **51** with the other current supply lead **52**. Line **51** also contains a limit switch **53** which is disposed in the path of the bar **41** carried by the ram. When the ram is fully retracted, switch **53** will be closed to provide for current flow when the switch **50** is operated. This switch may be manually actuated or actuated in any other manner depending upon the desires of the manufacturer. When switch **50** is closed while the ram is fully retracted, current flow through coil **46** will be initiated. When coil **46** is energized, it will effect the closing of two switches controlled by the armature of the relay. One of the switches, designated by the numeral **54** controls the flow of current to the solenoid **44** and, when coil **46** is energized, switch **54** will be closed to provide for the flow of current to the coil **44**. The energization of this coil causes spool **36** to move, as previously described, in opposition to the spring **40** to a position in which the inlet port **31** of the valve **24** is connected with the forward cylinder port **32** and fluid from the pressure source will be directed to the upper end of the power cylinder to cause the ram to advance. It will be obvious that initial movement of the ram will cause the bar **41** to move away from switch **53**. Since this switch is of the normally open type, the movement of the bar will permit the switch to open interrupting current flow to the control switch **50**. The flow of current to the relay coil **46** will not be interrupted, however, due to the provision of the relay section **55** and a motion sensitive mechanism designated generally by the numeral **56**.

The control mechanism also includes an electronic switch **57** which may be of any suitable type, a thyratron

tube having been found to perform the operation desired satisfactorily. The motion sensing mechanism has a coil **58** stationarily supported adjacent the power cylinder and having its ends connected by lines **60** and **61** with one element in the tube **57** and with the control mechanism **62** for the tube, this control mechanism being connected with lead **52** of the power source. The motion sensing mechanism also includes a permanent magnet **63** which is disposed for movement in the coil **58** and is connected with the ram by the bar **41**. When the ram moves in a forward direction, the magnet **63** moves in the coil **58** causing a current to be generated which is conducted to the element in the tube **57**. When this element is excited in this manner, current will flow from the supply source **47**, **52** to the field coil **64** of the second section of the relay mechanism. When coil **64** is energized, a switch arm **65** forming part of this relay will be moved to a position to close the circuit for the coil **46**. In this manner, coil **46** will be energized to maintain the switch **54** in condition to continue the flow of current to the solenoid **44**. It will be obvious that, as long as the ram is moving, solenoid **44** will hold the spool **36** in position to connect the upper end of the power cylinder with the source of fluid pressure. The switch including arm **65** is arranged in series with a second switch **66** forming a part of the relay mechanism **45**.

When the ram meets an obstruction which will offer sufficient resistance to interrupt the movement of the ram, the relief valve **23** will open to bypass fluid from the pump directly back to the reservoir. At this time, the ram will be exerting the maximum force for which the relief valve has previously been set. Due to the interruption of the forward motion of the ram, the motion sensing mechanism **56** will cease to generate current and the tube **57** will no longer permit current to flow to the coil **64**. Arm **65** will then move to a switch-open position permitting coil **46** to be de-energized. When this condition exists, switch **54** will open and solenoid **44** will be de-energized. Spring **40** will then move the valve spool to the position in which the source of fluid pressure will be directed to the lower end of the power cylinder. As previously described, the direction of fluid to this end of the power cylinder causes the ram to move upward, which motion will normally be continued until the bar **41** engages the collar **42** and shifts the valve spool to a position in which the fluid pressure source will be connected with the reservoir. The ram will then come to rest. As previously pointed out, when the ram reaches this position, switch **53** will be closed and a new cycle of operation of the ram may again be initiated through the closing of switch **50**.

In some instances, it may be desirable to cause the cycle of ram operation to be automatically repeated. To provide for this type of operation, a selector switch **67** has been included. In this position shown, switch **67** is ineffective and the initiation of a cycle of operation will be controlled solely by the switch **50**. If switch **67** is moved into engagement with contact **68**, the switch **67** will then be in parallel with switch **50** and, when switch **53** is closed due to the complete retraction of the ram, coil **46** will be automatically energized without the closing of switch **50** to initiate a new cycle of ram operation. These cycles will be repeated as long as contact **68** is engaged.

In some instances, it has been found desirable to cause the ram to resume forward movement prior to the completion of a cycle of operation; in other words, before the switch **53** is closed. When this form of operation is desired, the switch arm **67** is moved into engagement with contact **70** and switch **53** is then shunted out. It will be observed that, at this time, switch **50** may be closed when desired to complete the circuit for the coil **46** and the activation of the solenoid **44**. If the ram is moving in a reverse direction at this time, the spool **36** will be operated to interrupt the reverse movement and cause the ram to move in a forward direction. If the switch **50** is held in a closed position, the ram will continue to move downward-

ly and, when this motion stops, it will continue to exert a downward force determined by the setting of the relief valve until the switch 50 is again released. Normal operation may be resumed by returning the switch 67 to the position indicated in the drawing wherein neither of the contacts 68 or 70 are engaged.

While the form of embodiment of the present invention as herein disclosed constitutes a preferred form, it is to be understood that other forms might be adopted, all coming within the scope of the claims which follow:

We claim:

1. Control mechanism for hydraulic apparatus of the type having a reversible fluid motor with a movable element, a source of fluid pressure and a reversing valve between said pressure source and said fluid motor comprising electro-responsive means for actuating said valve to cause the operation of said fluid motor in one direction; means responsive to the movement of the movable element of said fluid motor when operating in said one direction to maintain a flow of electrical energy to said electro-responsive means to hold the same in position to cause the continuation of the operation of said fluid motor in said one direction, said movement responsive means serving to reduce the flow of electrical energy to said electro-responsive means when the movement of the movable element of said fluid motor ceases; and means for actuating said reversing valve to cause reverse operation of said motor when the flow of electrical energy to said electro-responsive means is reduced.

2. Control mechanism for hydraulic apparatus of the type having a reversible fluid motor with a movable element, a source of fluid pressure and a reversing valve between said pressure source and said fluid motor comprising electro-responsive means for actuating said valve to cause the operation of said fluid motor in one direction; relay means for controlling the flow of electric energy from a source to said electro-responsive means; and means responsive to the movement of the movable element of said fluid motor when operating in said one direction to energize said relay means and direct electric energy to said electro-responsive means to hold said reversing valve in position to continue the operation of said fluid motor in said one direction.

3. Control mechanism for hydraulic apparatus of the type having a reversible fluid motor with a movable element, a source of fluid pressure and a reversing valve between said pressure source and said fluid motor comprising electro-responsive means for actuating said valve to cause the operation of said fluid motor in one direction; relay means for controlling the flow of electric energy from a source to said electro-responsive means; switch means for initially energizing said relay means to start the flow of electric energy to said electro-responsive means and the operation of said fluid motor in said one direction; and means responsive to the movement of the movable element of said fluid motor when operating in said one direction to keep said relay means energized during such operation of the motor irrespective of the condition of said switch means.

4. Control mechanism for hydraulic apparatus of the type having a reversible fluid motor with a movable element, a source of fluid pressure and a reversing valve between said pressure source and said fluid motor comprising electro-responsive means for actuating said valve to cause the operation of said fluid motor in one direction; relay means for controlling the flow of electric energy from a source to said electro-responsive means; switch means for initially energizing said relay means to start the flow of electric energy to said electro-responsive means and the operation of said fluid motor in said one direction; means responsive to the movement of the movable element of said fluid motor when operating in said one direction to keep said relay means energized during such operation of the motor irrespective of the condition of said switch means; and additional switch means for rendering the first-mentioned switch means effective only at a predetermined stage of operation of said fluid motor.

5. Control mechanism for hydraulic apparatus of the type having a reversible fluid motor having a movable element, a source of fluid pressure and a reversing valve between said pressure source and said fluid motor comprising electro-responsive means for actuating said valve to cause the operation of said fluid motor in one direction; relay means for controlling the flow of electric energy from a source to said electro-responsive means; switch means for initially energizing said relay means to start the flow of electric energy to said electro-responsive means and the operation of said fluid motor in said one direction; means responsive to the movement of the movable element of said fluid motor when operating in said one direction to keep said relay means energized during such operation of the motor irrespective of the condition of said switch means; and additional switch means arranged in series with said first-mentioned switch means, said additional switch means being operated in part by said fluid motor to render said first-mentioned switch means effective only at a predetermined stage of operation of said fluid motor.

6. Control mechanism for hydraulic apparatus of the type having a reversible fluid motor having a movable element, a source of fluid pressure and a reversing valve between said pressure source and said fluid motor comprising electro-responsive means for actuating said valve to cause the operation of said fluid motor in one direction; relay means for controlling the flow of electric energy from a source to said electro-responsive means; switch means for initially energizing said relay means to start the flow of electric energy to said electro-responsive means and the operation of said fluid motor in said one direction; means responsive to the movement of the movable element of said fluid motor when operating in said one direction to keep said relay means energized during such operation of the motor irrespective of the condition of said switch means; additional switch means arranged in series with said first-mentioned switch means, said additional switch means being operated in part by said fluid motor to render said first-mentioned switch means effective only at a predetermined stage of operation of said fluid motor; and a selectively operable switch means arranged in parallel with said additional switch means.

7. Control mechanism for hydraulic apparatus of the type having a reversible fluid motor with a movable element, a source of fluid pressure and a reversing valve between said pressure source and said fluid motor comprising electro-responsive means for actuating said valve to cause the operation of said fluid motor in one direction; relay means for controlling the flow of electric energy from a source to said electro-responsive means; switch means for initially energizing said relay means to start the flow of electric energy to said electro-responsive means and the operation of said fluid motor in said one direction; means responsive to the movement of the movable element of said fluid motor when operating in said one direction to keep said relay means energized during such operation of the motor irrespective of the condition of said switch means; additional switch means arranged in series with said first-mentioned switch means, said additional switch means being operated in part by said fluid motor to render said first-mentioned switch means effective only at a predetermined stage of operation of said fluid motor; and a third switch means having two effective positions, one of which places said third switch in parallel with said additional switch means and the other position placing said third switch in parallel with said first-mentioned switch means.

8. Control mechanism for hydraulic apparatus of the type having a reversible fluid motor with a movable element, a source of fluid pressure and a reversing valve between said pressure source and said fluid motor comprising electro-responsive means for actuating said valve

to cause the operation of said fluid motor in one direction; relay means for controlling the flow of electric energy from a source to said electro-responsive means; switch means connected with said relay means and operative to initially energize said relay to start the flow of electric energy to said electro-responsive means and the operation of said fluid motor in said one direction; and a second electronic switch means responsive to the movement of the movable element of said fluid motor when operating in said one direction to keep said relay means energized during such operation of the motor.

9. Control mechanism for hydraulic apparatus of the type having a reversible fluid motor with a movable element, a source of fluid pressure and a reversing valve between said pressure source and said fluid motor comprising electro-responsive means for actuating said valve to cause the operation of said fluid motor in one direction; relay means for controlling the flow of electric energy from a source to said electro-responsive means; switch means connected with said relay means and operative to initially energize said relay to start the flow of electric energy to said electro-responsive means and the operation of said fluid motor in said one direction; an electronic switch means for controlling the current supply for said relay means; and means electrically connected with said electronic switch means and responsive to the movement of the movable element of said fluid motor when operating in said one direction to place said electronic switch in condition to direct current from the source to said relay means.

10. Control mechanism for hydraulic apparatus of the type having a reversible fluid motor, a source of fluid pressure and a reversing valve between said pressure source and said fluid motor comprising electro-responsive means for actuating said valve to cause the operation of said fluid motor in one direction; relay means for controlling the flow of electric energy from a source to said electro-responsive means; switch means for initially energizing said relay means to start the flow of electric energy to said electro-responsive means and the operation of said fluid motor in said one direction; an electronic switch means for controlling the current supply for said relay means; and current generating means actuated by said fluid motor to energize said electronic switch means and place the same in condition to direct current from the source to said relay means.

11. Control mechanism for hydraulic apparatus of the type having a reversible fluid motor, a source of fluid

pressure and a reversing valve between said pressure source and said fluid motor comprising electro-responsive means for actuating said valve to cause the operation of said fluid motor in one direction; relay means for controlling the flow of electric energy from a source to said electro-responsive means; switch means for initially energizing said relay means to start the flow of electric energy to said electro-responsive means and the operation of said fluid motor in said one direction; an electronic switch means for controlling the current supply for said relay means; a coil supported adjacent said fluid motor and connected in the circuit for said electronic switch means; and a magnetized element moved by said fluid motor relative to said coil to generate current therein and cause the excitation of said electronic switch means to place the same in condition to direct current from the source to said relay means.

12. In a hydraulic apparatus, a reversible fluid motor having a movable element; a source of fluid pressure; a control valve mechanism between said pressure source and said motor; solenoid means for actuating said control valve mechanism to cause said motor to operate in a certain direction; a second means for actuating said control valve mechanism when said solenoid is deenergized to cause said motor to operate in a reverse direction; relay means for controlling the flow of electric energy from a source to said solenoid means; and current generating means operated by the movable element of said motor during operation in said certain direction to maintain said relay in condition to direct current to said solenoid and retain said valve mechanism in position to cause said motor to continue to operate in said certain direction, said relay interrupting current flow to said solenoid when the current generating means becomes inoperative due to the cessation of motion of the movable element of said fluid motor, said second means then operating said valve mechanism to reverse the operation of said fluid motor.

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