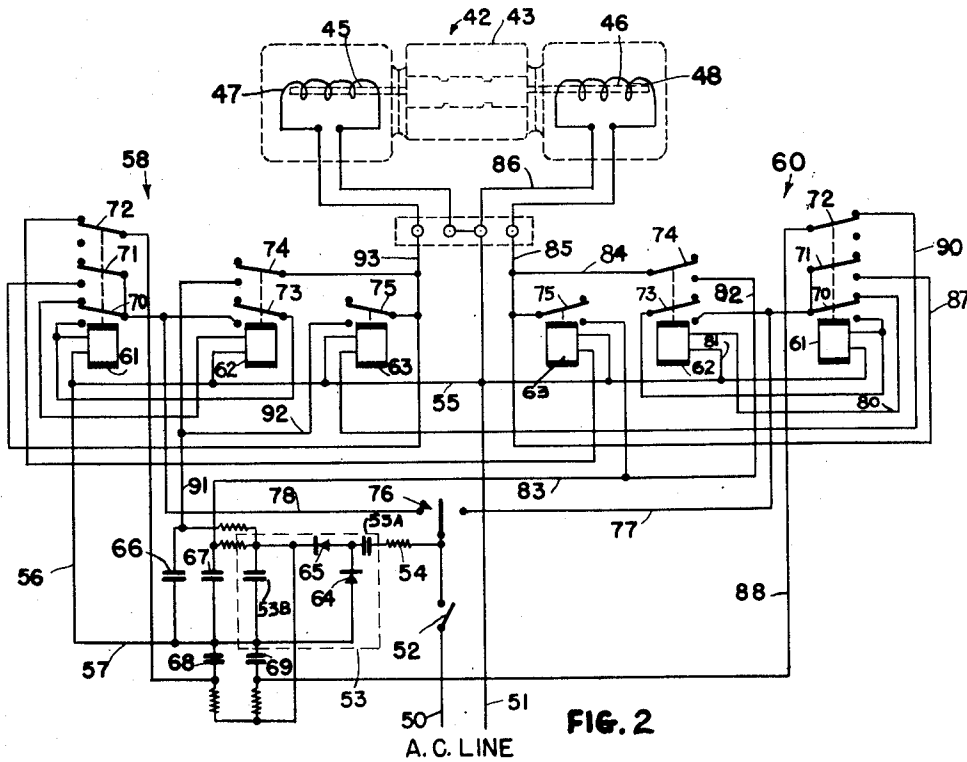
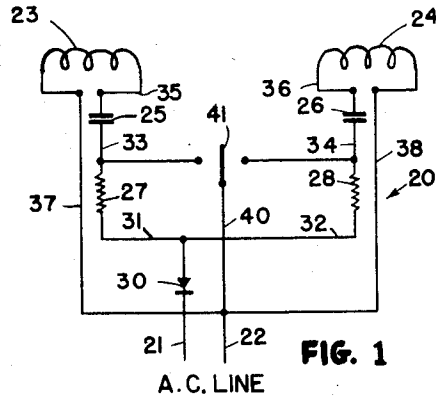


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SOLENOID OPERATED VALVES

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SOLENOID OPERATED VALVES

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This invention relates generally to hydraulics and more particularly to valves of the electrically actuated type sometimes designated in the trade as solenoid operated valves.

Solenoid operated valves generally have a spool element which slides back and forth in a bore to control communication between ports in the valve casing. When these valves are employed to govern fluid under high pressures, there is a tendency, particularly noticeable when the valves have remained in a specific flow directing condition for prolonged periods, for the spool element to stick and fail to move when the solenoid is energized. If the condition is not remedied in due time the solenoid may overheat or burn out and require replacement. The reasons for the sticking of the spool are not fully known but it has been found that a sticking spool may be jarred loose through the application of an impulse of greater magnitude than the force required to move it under normal operating condition. It has been found also that a solenoid of a size sufficient to exert the additional force necessary to move a spool when it sticks is generally excessive in size and impractical to supply since the additional force is only needed occasionally and then only for a short time. The present invention is partially based on the theory that a solenoid designed to operate at a given A. C. voltage to produce a predetermined force has a coil which will produce approximately the same force when a D. C. voltage equal to one-fourth the given A. C. voltage is applied or a force greater than such predetermined force when a D. C. voltage equal to the given A. C. voltage is applied. It is, of course, obvious that the coil would burn out if such D. C. voltage were sustained, therefore, it is an object of this invention to provide means for momentarily applying a large D. C. voltage to the coil to cause it to exert a surge of force of increased intensity without the use of a large power source.

An object of this invention is to provide solenoid means for operating a hydraulic valve and to provide means for energizing such solenoid means to cause it to initially apply an impulse of considerable force to the spool element of the valve to jar it loose from a sticking condition and then apply a sustained force of normal magnitude to the freed spool to move it to and retain it in the desired position.

Another object of the invention is to provide electrical means for causing a solenoid of predetermined capacity to momentarily exert a force of multiplied intensity to free the sticking spool then exert its normal force to move the freed spool.

A further object of the invention is to provide a hydraulic control valve having one or more solenoids for operating the valve, each solenoid being designed to operate at a predetermined alternating current voltage to produce a desired force and providing an electric control circuit having a capacitor discharge means for momentarily applying a direct current voltage of predetermined magnitude to the solenoid coil, the direct current voltage

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serving to multiply the force exerted by the solenoid, the circuit being designed to apply the direct current voltage only momentarily to prevent injury to the solenoid and then apply the alternating current voltage to cause normal operation after the direct current charge has restored the valve to normal operating condition.

A still further object of the invention is to provide a hydraulic control valve having alternating current solenoids for effecting its operation and electrical means for operating the solenoids, the electrical means having a control circuit for each solenoid and means for converting alternating current to direct current and storing the same, the control circuits having relay means for momentarily applying a charge of direct current to a selected solenoid to cause it to exert a predetermined force on a movable element of the valve then continuously apply alternating current to the solenoid to cause normal operation, the relay means also serving, when the application of the alternating current is interrupted, to momentarily apply another charge of direct current to another solenoid to free the movable element of the valve so that it may assume another position under normal operation.

Another object of the invention is to provide a hydraulic control valve and solenoid operating mechanism of the type mentioned in the foregoing paragraph with a rectifier and condenser combination known in the trade as a "cascade voltage doubler" by means of which alternating current is converted to direct current of substantially double magnitude and stored in the condenser means to be applied at the proper instant to the solenoid and relay coils to effect desired results, it having been found that, by converting the alternating current and increasing the magnitude, a multiplied force may be developed in the solenoid coil to which it is applied, resistor means being provided to limit the application of the converted current to the solenoid coils to prevent premature deterioration thereof.

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:

Fig. 1 is a diagrammatic view illustrating one example of a capacitor discharge portion of an electrical system which capacitor discharge portion may be used to convert alternating current to direct current and momentarily apply direct current impulses to solenoids employed in operating a hydraulic valve; and

Fig. 2 is a diagrammatic view of an electrical circuit embodying a modified capacitor discharge system for operating a double solenoid control valve.

In the drawings, the numeral 20 designates generally the simple form of capacitor discharge system shown in Fig. 1 which may be used in an electrical circuit. In the system shown in Fig. 1 leads 21 and 22 are provided to connect the illustration to an alternating current power source. In this system, the coils of the solenoids are indicated by the numerals 23 and 24. The system also includes a condenser 25 and 26 and a resistance element 27, 28 for each coil. The system further includes a rectifier, indicated by the numeral 30, one terminal of the rectifier being connected with one of the alternating current leads 21. The other terminal of the rectifier is connected by leads 31 and 32 with the resistance elements, these also being connected by lines 33 and 34 with one terminal of the condensers 25 and 26. The other terminals of these condensers are connected by lines 35 and 36 with one terminal of the coils 23 and 24, the other terminals being connected by the lines 37 and 38 with the other alternating current conductor 22. This con-

ductor is also connected by a line 40 with a selector switch 41, the switch being shown in Fig. 1 in an "off" position. This switch may be moved in either of two directions to momentarily connect line 33 or 34 with line 40. When the system is connected with the alternating current power source, the rectifier will convert the alternating current to direct current and the condensers 25 and 26 will be charged with this direct current, the rate of the charging current being determined by the resistance elements 27 and 28. When the selector switch is moved to connect either line 33 or line 34 with lines 40 and 37 or 38, respectively, the respective condenser 25 or 26 will be connected with its associated coil 23 or 24. The direct current stored in the condenser will then be discharged into the coil to momentarily energize it and cause it to exert an operating force on the core, not shown, of the solenoid. The switch 41 is only closed momentarily since the current stored in the condenser connected with the respective coil will be quickly dissipated.

It will be obvious that the size of the valve to be operated will determine the power requirements of the solenoids used to effect its operation. It will also be obvious to one skilled in the art that the solenoids and power source utilized will determine the ratings of the rectifier 30, the condensers or capacitors 25 and 26 and the current limiting or isolation resistors 27 and 28. An example of a group of parts found suitable for use with one valve designed for operation by 110 volt A. C. solenoids and 110 volt A. C. power is as follows: The rectifier 30 may be of any suitable type, such as a selenium rectifier, and have a rating of one ampere at 110 volts. The condensers 25 and 26 have a capacitance of 200 microfarads with a rating of approximately 450 volts D. C. And the isolation resistors 27 and 28 have a rating of one thousand ohms resistance with a power of 50 watts. With the system connected to a 110 volt A. C. source, as shown, the rectifier converts the applied alternating voltage to D. C. voltage in the usual manner and this D. C. voltage is stored in the capacitors 25 and 26. The energy stored is determined by the amount of capacitance 25 and 26, which in the above example is approximately 150 volts D. C., at 22½ watt-seconds. It will be seen that the instant the switch 41 is connected with the line 34 the energy stored in capacitor 26 will be discharged into the coil 24. The voltage stored in the capacitor 26 will be quickly exhausted, but, since the charge is D. C. voltage, the power developed will be substantially four times that normally developed by the solenoid and will be sufficient to jar the spool loose from a sticking position. After the spool is loosened, it may easily be moved with the normal 110 volt A. C. supply.

In the circuit shown diagrammatically in Fig. 2 a modified form of capacitor discharge system is used to apply an impulse of increased intensity to the solenoids of the hydraulic valve indicated at 42. The valve 42 is of substantially conventional construction and includes a casing 43 having a plurality of ports, not shown. The casing also includes a bore for slidably receiving a spool valve element which serves in various positions to connect certain sets of the ports in the casing. The spool also has projections 45 and 46 which extend into solenoid coils 47 and 48, these extensions functioning as cores for the solenoids and being attracted by the forces exerted by the coils when they are energized. When these forces are applied to the extensions, the valve spool is moved from a centered position to one end or the other of the valve casing. The control valve and solenoids are substantially conventional in construction and further description thereof is unnecessary.

The invention resides in the adaptation of a capacitor discharge system to the electrical control circuit for the solenoids. The invention also comprises the provision of electrical means for converting the alternating current supplied from a suitable source into direct current of greater magnitude and momentarily applying this current

to the solenoids at the proper time to cause them to exert a force equal to the normal designed force multiplied a predetermined number of times, to impart a jarring impulse to the valve spool to loosen it from a sticking condition so that it may then be moved by the normal force of the solenoid. The means chosen to illustrate the conversion of the alternating current to direct current of higher voltage comprises an electrical device known in the trade as a "cascade voltage doubler" of the half wave type. It is an electrical device commonly used in electronic work to obtain a D. C. voltage which is higher than a given A. C. input.

This device includes a plurality of rectifiers and condensers connected in a certain manner shown diagrammatically in Fig. 2. This "cascade voltage doubler" is connected with an alternating current line indicated generally by the numeral 50, the other alternating current line being designated by the numeral 51. A main switch 52 is disposed in line 50 to control the connection of the "cascade voltage doubler," indicated generally by the numeral 53, with the alternating current source. A resistance 54 is also arranged between the voltage doubler and line 50. Line 51 is connected by lines 55, 56 and 57 with the second terminal of the voltage doubler. Voltage doubler 53 includes a condenser 53A, with which A. C. supply line 50 is connected through resistor 54, and a pair of rectifiers 64 and 65 which are oppositely arranged, rectifier 64 being connected between condenser 53A and line 57 while rectifier 65 is connected between condenser 53A and a second condenser 53B which is in turn connected with line 57. The line 57 is connected through lines 56 and 55, with A. C. supply line 51. When switch 52 is closed, the condenser 53A is charged through one rectifier with the peak voltage on one-half of the cycle and this voltage is then added in series on the next half cycle to the voltage charge to condenser 53B through the other rectifier. Condenser 53B is thus charged with twice the peak voltage of the A. C. input. Condensers 66, 67, 68 and 69 are connected in parallel through current limiting resistors with condenser 53B and are charged therefrom with the capacitance required to do the particular job for which they have been provided.

The electrical system shown in Fig. 2 has a control section for each solenoid, the section controlling solenoid 47 being indicated generally by the numeral 58 while numeral 60 designates the section controlling the solenoid 48. These control sections are substantially duplicates, each having first, second and third relays indicated by the numerals 61, 62 and 63, respectively.

The first relay No. 61 in each control circuit includes three switches designated, respectively, by the numerals 70, 71 and 72. The second relay in each control circuit includes two switches 73 and 74 while the third relay has a single switch 75. A selector switch 76 is provided to connect either of the control circuits 58 or 60 with the alternating current power supply. A lead 77 extends from the switch 76 to the control system 60 while a lead 78 extends from the switch to the other control system 58. Since the control circuits for each solenoid are identical, a description of section 60 only will be made at this time to simplify the description and facilitate an understanding of the invention.

It will be noted that switch 70 of the first relay 61 is a two-position switch and, when the relay 61 is de-energized, will be in a position to establish a connection between line 77 and a line 80 which leads to the coil of the second relay 62, this coil being connected by lines 81 and 55 with the second alternating current lead 51. It will be obvious that, when the main switch 52 is closed and the selector switch 76 moved to a position to connect lead 77 with alternating current lead 50, the coil of the second relay 62 will be energized. When this coil is energized, switches 73 and 74, which are normally open switches, will be moved to closed positions. Switch 74 will then complete a circuit from condenser 67, in which a direct current charge has been stored, to the coil 48,

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this circuit including lines 82, 83, 84, 85 and 86. The instant switch 74 is moved to a closed position, the current stored in condenser 67 will be applied to the solenoid coil 48. Since this current is a direct current and of twice the capacity of the alternating current source, the force exerted by the coil 48 will be a number of times the normal force and will, therefore, impart a severe jolt or jar to the core associated with the coil, this core transmitting the jar to the valve spool. If the spool is in a sticking condition before the jar is applied thereto, it will be forced loose by the power applied by the direct current charge to the coil. This charge will be momentarily applied, however, and will have no deleterious effect on the coil.

When switch 73 of the second relay moves to a closed position, it will connect the coil of the relay 61 with the alternating current source causing this coil to actuate the three switches 70, 71 and 72 forming a part of relay 61. When switch 70 is moved, relay coil 62 will be disconnected from the alternating current source and switches 73 and 74 will move to an open position. Although switch 73 moves to an open position, current will continue to flow to relay 61 through switch 70 of this relay. The relay will remain energized as long as the selector switch 76 is held in position to connect line 77 with alternating current line 50. Switch 70 completes the holding circuit for relay 61. The switch 71, when in a closed position, completes the circuit from the alternating current power source to the solenoid coil 48, this circuit being completed through line 77, switch 71 and lines 87, 85 and 86. The flow of normal operating current to the solenoid 48 will continue as long as relay 61 is energized. As usual in solenoid operated valves, the energization of solenoid 48 will cause the spool element to move to a predetermined position to establish communication between certain sets of the ports in the valve casing. This communication will be maintained as long as the solenoid 48 is energized.

In some instances, solenoid controlled valves are spring biased toward a predetermined position, one example being a four-way valve in which the spool occupies a centered position when the solenoids are de-energized. It has been found that, in some instances, particularly when the valves are operated at high pressures, the spool may stick after having been retained in a predetermined position for a sustained period. It is, therefore, another object of this invention to impart to the spool a force impulse of high intensity applied to urge the spool in the opposite direction from the force previously applied. To carry out this object, the third relay 63 has been provided in each control circuit. However, the operation of the relay 63 in each control section is governed by the switch 72 of the relay 61 in the other control section. Switch 72 is a normally closed switch, that is, it is closed when the relay coil is de-energized. When the coil of the relay is energized, the switch 72 is held in an open position. Then, following the movement of the selector switch 76 to an "off" position, the switch 72 will return to its closed position and will complete the connection of a condenser 69 through lines 88 and 90 to the coil of the third relay 63 of the other control circuit, this relay being connected by lines 55, 56 and 57 with the second terminal of the condenser 69.

When the coil of the third relay is so connected, direct current previously stored in the condenser 69 will flow through the coil of the third relay 63 energizing this coil and closing switch 75. When this switch is closed, direct current from another condenser 66 will flow through lines 91 and 92, switch 75 and line 93 to the coil of the solenoid 47, this being the solenoid for moving the spool in the opposite direction to that in which it is moved by the coil 48. The electrical impulse from condenser 66 transmitted by the closing of switch 75 is a direct current impulse of greater magnitude which will cause the coil to impart a sharp thrust to the spool which will dis-

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lodge the spool in the event it has a tendency to stick. After this sharp thrust loosens the spool, it is returned to a normal centered position by the spring force in the conventional manner.

If the selector switch is moved in the opposite direction, that is, to connect lead 78 with the alternating current line 50, the other control circuit will be energized to cause the solenoid valve to move in the opposite direction. This control circuit works in the same manner as the control circuit 60, the switch 70 of the first relay providing for the operation of the second relay 62 which applies a charge of direct current from condenser 66 to the solenoid 47 then interrupts this flow of direct current and actuates relay 61 to effect the flow of normal operating current to the solenoid. Then, when the selector switch is open, the switch 72 completes a circuit for the coil of the third relay in the other control circuit effecting a closing of the switch 75 of this relay which then effects a momentary flow of direct current from condenser 67 to the solenoid 48 controlled by the latter circuit, this solenoid serving to free to spool in the event it is in a sticking condition. The spool may then return to its normal inoperative position.

From the foregoing, it will be obvious that a conventional solenoid operated valve having the customary alternating current source and "on" and "off" selector switch has been provided with an electric circuit having means automatically operative to impart a charge of direct current to the solenoid immediately prior to the connection of the alternating current source with the solenoid, the direct current charge serving to free a movable element of the valve so that it may move normally when the alternating current is supplied thereto. It will also be apparent that the circuit has been so designed that, after one solenoid of a double solenoid valve has been energized to dispose the movable element of the valve in one position and it is desired to return the element to a normal position, a charge of direct current will be imparted to the other solenoid to free the movable element from a possible sticking condition so that it may then return to normal position in the usual manner. These results are secured without requiring the operator to exert any additional effort or pay any further attention to the mechanism.

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. In a solenoid operated valve, a source of alternating current; rectifier means connected with said alternating current source and operating to change alternating current to direct current; condenser means in circuit with said rectifier means to store a charge of direct current converted thereby; a pair of relays arranged in a circuit including the coil of said solenoid, said alternating current source, said rectifier means and said condenser, the first relay of said pair having a normally closed switch in circuit with the field coil of the second relay, the latter relay having a pair of normally open switches, one of which is connected with the field coil of the first relay and the other connected with said condenser and the coil of said solenoid, the first relay having a normally open switch connected with said alternating current source and the coil of said solenoid; and an "on and off" switch in the circuit between said alternating current source and said relays, the closing of said "on and off" switch serving to energize the field coil of the second relay to complete the connection of said condenser with the field coil of said solenoid and the energizing of the field coil of said first relay, the energizing of the latter relay serving to de-energize the second relay and complete the connection of said alternating current source with the field coil of said solenoid.

2. In a solenoid operated valve, a pair of solenoids; a source of alternating current; rectifier means connected

with said alternating current source and operating to change alternating current to direct current; condenser means in circuit with said rectifier means to store charges of direct current converted by said rectifier; a control circuit for each solenoid, each control circuit having a set of relay means with first and second relays, the first relay having a normally closed switch connected with the field coil of the second relay, the second relay having a pair of normally open switches, one of which is connected with the field coil of the first relay and the other of which is connected with said condenser means and the field coil of the solenoid in the respective control circuit; a normally open switch on said first relay connected with said alternating current source and the coil of said solenoid; and an "on and off" switch between said alternating current source and said control circuits, said switch serving to selectively energize the field coils of the second relays in the control circuits to close the open switches of such relays to momentarily complete the connection of said condenser means with the field coil of the respective solenoid then energize the field coil of the first relay to open the normally closed switch thereof to de-energize the field coil of the second relay and close the normally open switch of said first relay to complete the connection of said alternating current source with the field coil of the respective solenoid.

3. In a solenoid operated valve, first and second solenoids; a source of alternating current; rectifier means connected with said alternating current source and operating to change alternating current to direct current; condenser means in circuit with said rectifier means to store charges of direct current converted by said rectifier; a control circuit for each solenoid, each control circuit having a set of relay means with first, second and third relays, the first relay having a normally closed switch connected with the field coil of the second relay, the second relay having a pair of normally open switches, one being connected with the field coil of the first relay and the other being connected with said condenser means and the field coil of the solenoid in the respective control circuit; a selector switch between said alternating current source and said control circuits, said switch serving to selectively connect either control circuit to said alternating current source to energize the field coil of the second relay in the control circuit selected and close the open switches thereof to momentarily complete the connection of said condenser means with the field coil of the respective solenoid then energize the field coil of the first relay to open the normally closed switch thereof to de-energize the field coil of the second relay; a normally open switch on said first relay connected with the coil of the respective solenoid, said switch being closed when the field coil of the first

relay is energized to connect the respective solenoid coil with said alternating current source; a second normally closed switch on said first relay, said switch being connected with said condenser means and the field coil of the third relay in the other control circuit, said second normally closed switch being opened when the field coil of the first relay is energized; and a normally open switch on the third relay in each control circuit, said normally open switches being connected with said condenser means and the field coil of the solenoid in the respective control circuit; the opening of said selector switch serving to de-energize the field coil of said first relay and effect the closing of the second normally closed switch thereof, the closing of this switch momentarily energizing the field coil of the third relay of the other control system to close the normally open switch of such third relay and momentarily energize the field coil of the solenoid in the other control circuit with direct current from said condenser means.

4. In a solenoid operated valve, a pair of solenoids; a source of alternating current; a "cascade voltage doubler" connected with said alternating current source, said "cascade voltage doubler" converting alternating current into direct current of substantially increased magnitude; condenser means for storing charges of direct current converted by said "cascade voltage doubler"; a control circuit for each solenoid, each control circuit having a series of relays; a selector switch between said control circuits and said alternating current source, said selector switch serving to connect either of said control circuits with said alternating current source, said relays having switch elements operative when said selector switch is actuated to connect a predetermined control circuit with said alternating current source to sequentially connect the solenoid of the respective control circuit with said condenser means to receive a charge of direct current then with the source of alternating current to receive current therefrom and, upon opening movement of said selector switch, to connect the solenoid of the other control circuit with said condenser means to apply a charge of direct current to such solenoid.

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