May 12, 1959 T. J. LORD ET AL 2,886,280

REPEATED ACTION INJECTOR APPARATUS

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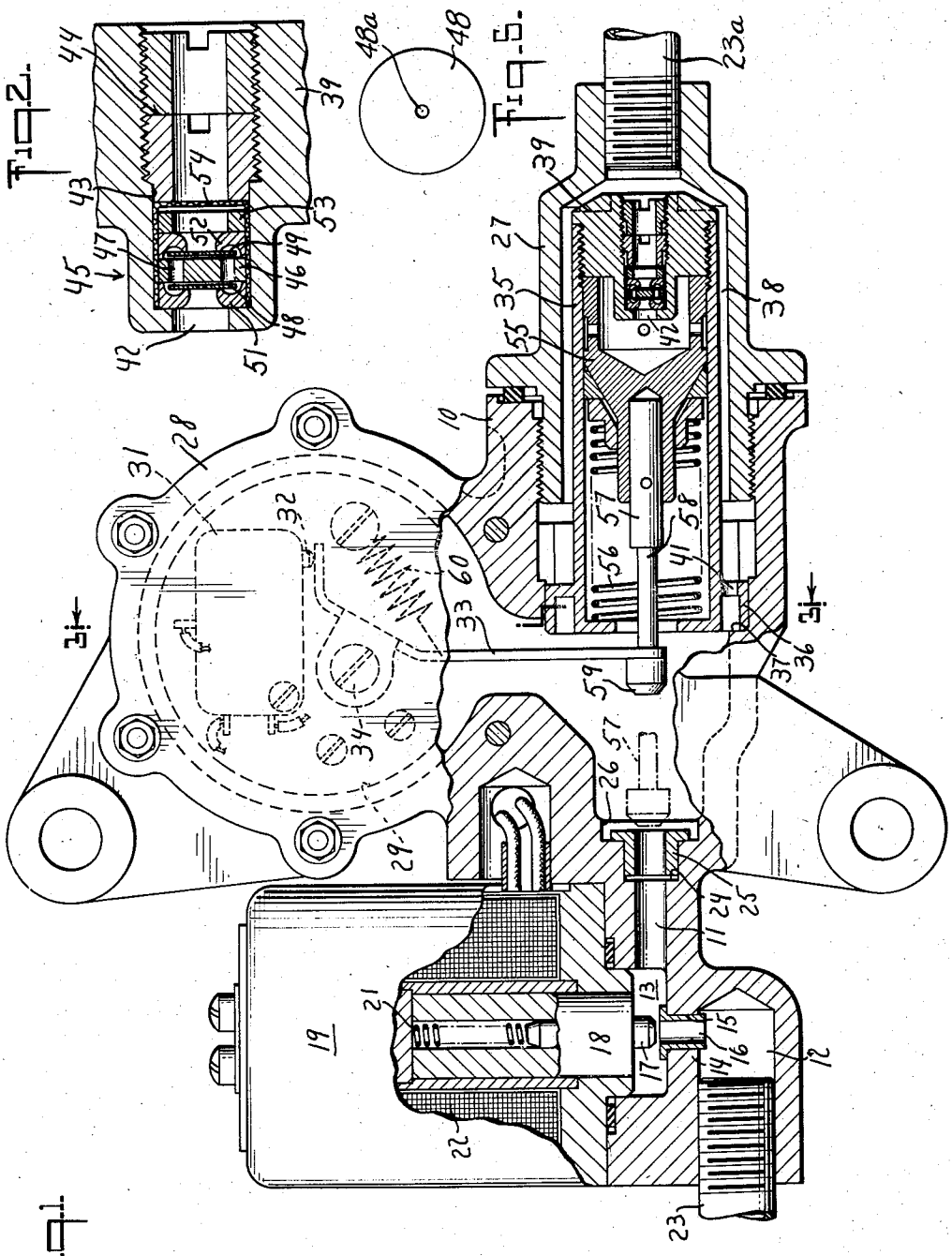


Fig. 1.

Fig. 2.

Fig. 5.

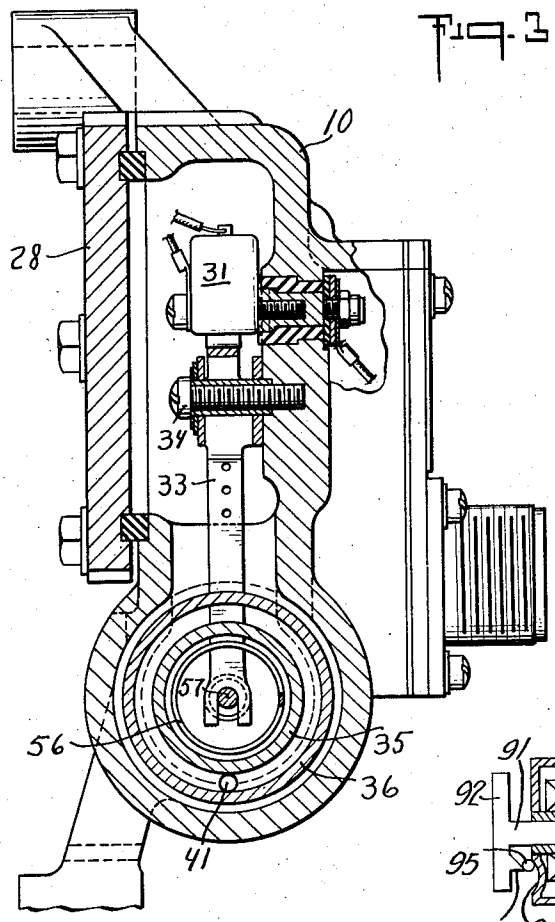
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REPEATED ACTION INJECTOR APPARATUS

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Fig. 3.



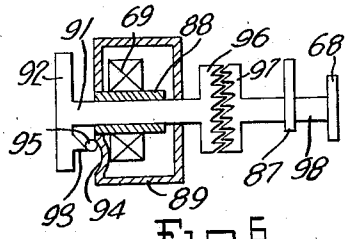


Fig. 5.

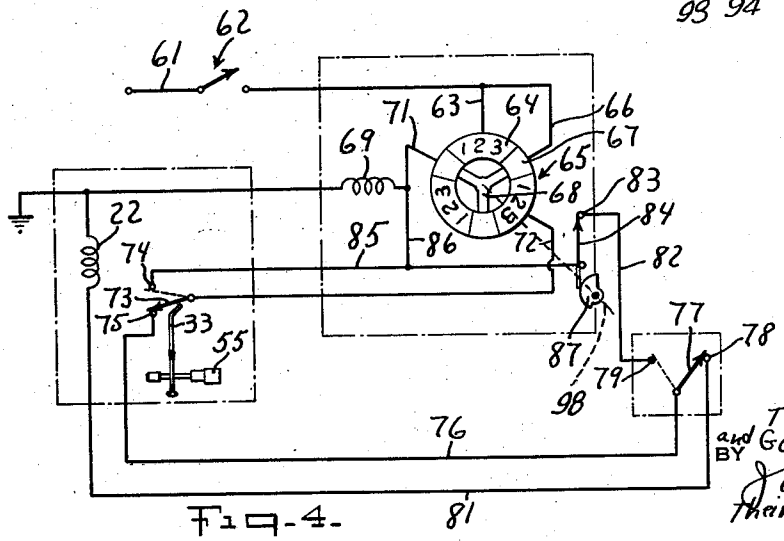


Fig. 4.

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United States Patent Office 2,886,280 Patented May 12, 1959

2,886,280

REPEATED ACTION INJECTOR APPARATUS

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Application October 24, 1956, Serial No. 617,979

7 Claims. (Cl. 251—13)

This invention relates to repeated action injector apparatus, especially as used in fuel systems to inject repeated quantities of fuel into a burner until ignition occurs.

An object of the invention is to produce an electrically controlled device operable to deliver constant pre-determined quantities of fuel during each cycle of operation.

Another object of the invention is to limit the injector device to a pre-determined number of injections or pulses in any one series of operations.

A further object of the invention is to obviate a continuous supply of fuel to the burner as may result from a failure of electro-magnetic valve means constituting the shut off to the burner.

Still another object of the invention is to discontinue the supply of fuel to the burner in the event that ignition takes place therein prior to completion of the pre-determined number of pulses or injections of the injector device.

Other objects and structural details of the invention will appear more clearly from the following description when read in connection with the accompanying drawings, wherein:

Fig. 1 is a view in side elevation, partly broken away, of an injector device in accordance with the illustrated embodiment of the invention;

Fig. 2 is a detail view, enlarged with respect to Fig. 1, of an orifice mechanism in the injector device;

Fig. 3 is a view in cross-section, taken substantially along the line 3—3 of Fig. 1;

Fig. 4 is an electrical diagram showing the control system for the injector device;

Fig. 5 is a detail view, enlarged with respect to Fig. 2, showing in front elevation an orifice disk therein; and

Fig. 6 is a diagrammatic view of a rotary solenoid assembly comprised in the electrical controls for the injector device.

Referring to the drawings, an injector device in accordance with the illustrated embodiment of the invention is adapted to be interposed in a line flowing fluid under pressure, as for example in the fuel inlet line to the after burner in a turbojet engine. In this system, it is desired to inject pre-determined quantities of fuel into the after burner chamber in successive pulses, which are continued until ignition occurs or until a pre-determined number of pulses have been completed.

As shown, the injector device comprises a body **10** having longitudinal bores **11** and **12**. The former opens into a recess **13** over-lying the bore **12** and separated therefrom by a wall **14**. The chamber **13** and bore **12** are connected by a port **15** in which is installed a bushing **16** providing at its upper end a seat for a valve stem **17** on the plunger **18** of an electro-magnetic device **19**. The valve stem **17** tends normally to engage the seat on bushing **16**, by virtue of a compression spring **21**. Upon energizing of the coil **22** of the device **19**, however, the plunger **18** is retracted or moved vertically upward whereby to unseat the valve stem **17**. It will be understood that communication between the bores **11** and **12** is controlled by the electro-magnetic device **19**.

The bore **12** opens to the exterior of the body **10**, at one end thereof. It constitutes the outlet end of the injector device and, as indicated, may receive one end of a pipe **23** for conducting fluid away from the injector device, as to the after burner. Toward the opposite end of the body **10**, the bore **11** opens into a counter-bore **24** in which is installed a bushing **25**, a flange on one end of the bushing seating in a bore **26**. Still further, toward the other end of the body **10**, the bore **26** is expanded and internally threaded to receive a tubular housing member **27**. The latter is open at its outer end to receive a pipe **23***a* by which fuel is supplied to the injector device, the device being in effect installed or interposed in a pipe line **23—23***a*.

Intermediate its ends, the body **10** extends upward to define with a closure plate **28** a compartment **29** in which is a micro-switch **31** controlling the energizing and de-energizing of coil **22** of electro-magnetic device **19**. A switch plunger **32** is arranged to be actuated by a lever **33** pivotally mounted on a stud **34** and having an end portion extending downward into the bore **26** in a path at right angles to the longitudinal axis thereof. With the parts positioned as illustrated the switch **31** may be considered closed with respect to the coil **22** so that the valve plunger **17—18** is at this time lifted, opening flow through the injector device. A rocking of the lever **33** in a clockwise direction releases the plunger **32**, enabling the switch **31** to open the circuit through the coil **22** whereupon the plunger valve **17—18** is permitted to drop to a seat on bushing **16**, so closing the flow path to the outlet pipe **23**.

That end of switch actuating lever **33** which extends into the bore **26** is disposed to the front of or beyond one end of a cylinder **35** longitudinally disposed in the housing **27**. An enlarged end portion **36** on the cylinder **35** is received in a counterbore **37** in the bore **26**. The cylinder is thus fixed in a concentric relation with the bore **26** and with the housing **27**, with the major part of the length of the cylinder spaced from the housing in a manner to define an annular passageway **38** in surrounding relation to the cylinder.

The outer end of the cylinder **35**, or that end facing the inlet end of the housing **27**, is closed by an orifice mounting head **39** stationarily installed therein. The latter is spaced from adjacent portions of the housing **27** so that incoming liquid from the pipe **23***a* may flow freely to the annular passage **38** and then by way of a longitudinal port **41** in the enlarged portion **36** to bore **26**, bores **11** and **12** and outlet pipe **23**.

The closure head **39** is formed with a longitudinal through bore **42** and a counter-bore **43**. The latter is threaded to receive hold down means **44** for retaining in the bottom of the counterbore **43** an orifice plate assembly **45**. The latter comprises a plate **46** having perforations **47** therein, orifice discs **48** and **49** on opposite ends of the plate **46**, respective seats **51** and **52** for the orifice discs, a spacer member **53** and an enclosing screen **54**. The openings **47** in the plate **46** are of a size and are so arranged as not to be closed by a disc **48** or **49** when such disc is pressed against the plate. It will be apparent that the construction and arrangement of parts is such as to provide for a metered flow of fluid through the bore **42** in either direction. Thus, the fluid flow in a leftward direction through the bore presses orifice disc **49** against the plate **46**. The fluid accordingly flows past the seat **52**, around the disc **49** and through the openings **47** where it presses the disc **48** against the seat **51**. Flow past the disc **48** accordingly is prevented except that which may take place through the small diameter orifice **48***a* (see Fig. 5) at the center of the disc.

In the event of fluid flow in a reverse direction, that is

toward the right as viewed in Fig. 2, the orifice disc 49 is effective to control the rate of flow through the bore 42, the disc 48 being at this time off its seat 51 and pressed against the plate 46.

Intermediate the closure head 39 and the opposite end of the cylinder 35 is a piston 55 received in the cylinder for longitudinal sliding motion therein. A spring 56 is interposed in the cylinder between the piston and the partly closed inner end of cylinder 35 in a manner to maintain the piston normally in a retracted position as shown wherein it limits against the closure head 39. Attached to the piston 55 and extending through and beyond the inner end of the cylinder 35 is a rod 57. Intermediate its ends, the rod 57 is formed with a reduced diameter portion 58 which is embraced by the downwardly extending end of the switch actuating lever 33, the latter being forked at such lower end, as indicated in Fig. 3. The reduced diameter portion 58 of the rod 57 defines thereon longitudinally spaced apart shoulders which, it will be understood, are brought alternately into cooperative relationship with the switch actuating lever 33 as the piston 55 reaches relatively extended and retracted positions. Thus, in the illustrated instance, a retracting motion of the piston has caused the end of the rod 57 to engage lever 33 and rock it in a counterclockwise direction depressing plunger 32 with the result previously noted. In a predetermined position of extension of the piston 55, an intermediate shoulder on rod 57, at the opposite end of reduced diameter portion 58, engages the lever 33 and rocks it in an opposite or clockwise direction, releasing the plunger 32. The outer end of the rod 57 is formed as a valve 59 and is adapted to seat on the bushing 25 to close off flow to the bore 11 and outlet 12.

Assuming the fuel pumps or other pressure generating means to be operating, and further assuming the valve plunger 17—18 to be closed, all portions of the device directly communicating with the inlet end thereof are filled with fuel under pressure. The piston 55 accordingly is under control of the spring 56 and occupies a retracted position in the cylinder 35. The lever 33 is in a counterclockwise position of adjustment, with plunger 32 depressed. In this position of the parts, as will hereinafter more clearly appear, the solenoid 22 tends to become energized, and, if electrical energy now is turned on or supplied to the device, the solenoid coil will become energized and will retract the plunger 18, opening the device to fuel flow from the inlet and to the outlet end thereof.

The area of the annular passage 38 is greater than the area of the opening 41. The result is that a pressure difference is established on opposite sides of the opening 41, such difference being thus also applied across the assembly comprising closure head 39 and piston 55. Flow through the orifice plate assembly 45 accordingly results and inward motion of the piston 55 thereby is effected. The pressure difference established across the opening 41 is accordingly utilized as a force to effect motion of the piston 55 inward in the cylinder 35 against the resistance of the spring 56. The pressure difference obtained is related to the rate of flow through the passage 38 and will be of sufficient magnitude to overcome the spring 56.

The piston 55 will move inward in the cylinder at a rate determined by the rate of flow through the orifice disc 48, and this may be considered roughly to be a function of the area of the orifice multiplied by the amount of pressure difference set up by the opening 41. The arrangement is such as to produce a constant ratio between the movement of the piston 55 and the rate of flow through passage 38 whereby for any given travel of the piston a constant pre-determined volume of fuel will have passed through the passage 38 and out of the device.

The piston 55 begins to move immediately that valve plunger 18 is lifted and continues until the intermediate shoulder on rod 57 engages and shifts lever 33 in a clockwise direction to release the plunger 32. When this occurs, the circuit to solenoid coil 22 is open. Plunger 18 descends and shuts off flow through the bushing 16 to the outlet pipe 23. The liquid pressures up stream and down stream of the opening 41 are thus permitted to equalize, and the piston 55 is restored to control of the spring 56 which returns the piston from extended toward retracted position in the cylinder. As the piston reaches fully retracted position the outer end of rod 37 engages and rocks the lever 33 to a counterclockwise position of adjustment, tending to reclose the circuit through coil 22. Another cycle of operation of the injector device is so initiated, and, so long as the electrical control circuit remains unbroken, the device will automatically go through repeated cycles, in effect ejecting each cycle a pre-determined quantity of fuel.

It may be considered that the fuel entering the inlet end of the device is divided into a primary stream which goes by way of passage 38, opening 41 and bores 11 and 12 to the outlet, and a secondary stream which goes through the orifice plate assembly for the operation of piston 55. As noted there is a pre-determined constant ratio flow between these streams which is, of course, variable by substituting other orifice plate assemblies.

The closing of flow through the injector device through the engagement of valve 59 with bushing 25 occurs only upon failure of the electrical system. Thus, the parts are so constructed and arranged that the adjustment of the lever 33 to a clockwise position to de-energize coil 22 is pre-determined to occur when the valve end 59 of the rod 57 reaches an extended position approximately as indicated in broken lines in Fig. 1. There is accordingly normally no shutting off of flow through the device as a function of engagement of the valve end 59 with the bushing 25. Should the electrical system fail to operate, however, and the valve plunger 17—18 fail to shut off flow when the parts reach the indicated position, the continued extending motion of the piston 55 will cause the valve 59 to seat upon the bushing 25 thereby interrupting further flow through the unit. A spring 60 may be attached to the lever 33 to return the lever from such induced overtravel movement.

Further in accordance with the present invention, the injector device is made a part of an electrical control system by which the cycles of operation of the device may be limited to a pre-determined number in any one series, and by which the injections or pulses of the device may be discontinued at any point in the series when ignition occurs and irrespective of whether the pre-determined number of cycles or pulses has been completed.

As shown in Fig. 4, a main power conductor 61 has interposed therein a main control switch 62, normally open. The conductor 61 is connected by a lead 63 to one of a series of electrically conductive segments 64 on a stationary contactor ring 65. Also, the conductor 61 is connected by a lead 66 with one of a series of electrically conductive segments 67 on the ring 65 in alternating relation to the segments 64 and insulated therefrom. A rotor 68 selectively interconnects the segments on the ring 65, the contactor ring, the rotor and the means for rotating the rotor constituting a stepping switch assembly. The rotor is advanced, in a practical embodiment of the invention, by a rotary solenoid, herein represented by the coil 69, the rotary solenoid advancing the rotor 68 through a ratchet mechanism one step for each complete operation of the solenoid. Standing normally in what may be termed a home position, the parts of the rotor 68 interconnect the several segments 67 on the ring. A first increment of rotary movement of the rotor, effected by a first complete actuation of the solenoid 69, moves the rotor until each part thereof is in contact with a respective segment 64 at the number one position thereof. A second increment of movement advances the rotor to the

number two position, a third increment to the number three position and a fourth increment returns the rotor to its starting or neutral position. The instant stepping switch assembly is constructed and arranged to obtain three pulses of the injector device upon closing of the main control switch **62** and then to discontinue operation of the device.

Another of the segments **67** of the stepping switch assembly is connected by a lead **71** through the coil **69** to ground. Another of the segments **64** is connected by a lead **72** to a switch arm **73** forming a part of the previously described switch device **31** in the injector unit. The switch arm **73** is designed alternately to contact a terminal **74** and a terminal **75** under control of the lever **33** and piston **55**. The terminal **75** is connected by a conductor **76** to a switch arm **77** of a second control switch mechanism alternately in contact with a terminal **78** and a terminal **79**. The terminal **78** is connected to ground by way of conductor **81**, passing through the coil **22** and joining lead **71**. The terminal **79** is connected by a lead **82** with a terminal **83**. The latter is connected through a switch arm **84** with a conductor **85** leading to the terminal **74** of switch device **31** and connected also by way of lead **86** with the lead **71** in advance of the solenoid **69**.

The switch arm **84** is adapted to be rocked by a cam **87** out of engagement with terminal **83** once upon each complete actuation of the solenoid **69**, the cam being connected to the solenoid to move to and fro through a sufficient arc to effect the desired disengagement and re-engagement of the switch arm **84** and terminal **83** once for each cycle of operation of the solenoid.

When the switch **62** is closed to initiate after burning, current flows into the one segment **64** by way of lead **63** but there is at present no further connection from this segment into the system. Current flows also by way of lead **66** into the one segment **67** and thence through rotor **68** to the lead **71** and from there to ground. The solenoid **69** is accordingly energized, and advances the rotor **68** out of its neutral position to the number one position on the segments **64**. At the same time, the solenoid **69** is permitted to become de-energized and is restored to a starting position. A circuit now is closed through a pair of the segments **64**, conductor **72** and switch arm **73** to terminal **75** and thence back to ground by way of the solenoid **22** which accordingly becomes energized, opening the injector device for flow therethrough. As the piston **55** reaches its pre-determined extended position under the displacing influence of fuel flow, the switch arm **73** is shifted into contact with the terminal **74**. The coil **22** is thus removed from the circuit and solenoid **69** substituted therein, by way of lead **86**, so that the stepping switch assembly is reactuated while the solenoid coil **22** remains de-energized. The stepping switch is accordingly advanced to its number two position. In the meantime piston **55** is retracting in the injector device and as it reaches fully retracted position effects a return of switch arm **73** back to engagement with terminal **75**. Solenoid **69** is thus de-energized and restores itself to a starting position while coil **22** is re-energized and the passages through the injector device are again opened for flow therethrough. This cycle repeats itself through the number three position of the stepping switch and the parts returned finally to the home position illustrated.

The switch arm **77** and terminals **78** and **79** may be considered to be a part of an automatic switch device responding to a condition changing as a result of ignition in the after burner. This may be temperature since temperature within the after burner chamber mounts rapidly upon ignition. It may also be pressure taken from the turbine since the changed speed of rotation resulting from ignition in the after burner affects the developed pressure at the turbine. The parts are constructed and arranged so that the switch arm **77** normally engages the terminal **78** but in response to the changing condition mentioned will move from terminal **78** to terminal **79**. The result of this is to connect terminal **75** of the switch **31** to the lead **82** and oscillating switch arm **84**. At the same time, the coil **22** is removed from the circuit. The result is that the solenoid **69** is energized and de-energized once for each complete movement of the cam **87**. Thus, after ignition in the after burner the cam **87** will be effective to advance the stepping switch such additional steps as may be required to return it to its home or starting position.

The arrival of the stepping switch in home position finds the coil **69** energized, which energization is continued by reason of the electrical connection effected through lead **66**, segments **67**, rotor **68** and lead **71**. The actuating solenoid of the stepping switch accordingly is in effect stalled and unable to complete its return motion. No further operation of the injector device thus can take place until the switch **62** is opened and then reclosed.

As indicated in Fig. 4, the elements **64** through **69** and cam **87** form a part of an integrated unit. This unit is a commercially known and available solenoid assembly, shown in diagrammatic form in Fig. 6. As there shown, the solenoid is of the rotary type wherein the coil **69** is mounted on a bushing **88** and contained within a stationary housing **89**. A shaft **91** is rotatably mounted in the bushing **88** and extends through and beyond the housing **89** at its opposite ends. On one end of the shaft **91** is a plate **92** having one or a plurality of wedge shaped cam surfaces **93** on the side adjacent to the housing **89**. In the adjacent surface of the housing **89** is a pocket **94** to receive a ball **95** adapted to ride on the cam surface **93** as an inclined plane. On the opposite projecting end of the shaft **91** is a ratchet **96** adapted to engage a complementary ratchet portion **97** on one end of a shaft **98** mounting the rotor **68** and cam **87**. In accordance with the known mode of operation of devices of this kind the energizing of coil **69** serves to retract the shaft **91** in a direction to engage the ratchet portions **96** and **97**. This motion brings the cam surface to bear upon the ball **95** and as retracting motion of the shaft continues the ball in effect rides up the surface of the cam **93**, the forces involved being resolved into a rotary motion of the plate **92** and its shaft **91** in conjunction with the axial movement thereof. Accordingly the energizing of the coil **69** is effective to transmit a rotary impulse to the shaft **98** for a stepping motion of the rotor **68** as has been described. Suitable spring means return the shaft **91** and plate **92** to normal position upon the de-energizing of the coil **69**.

What is claimed is:

1. An injector device of the class described, comprising a housing to be interposed in a line flowing liquid under pressure and presenting an inlet and an outlet, a passage in said housing extending between said inlet and said outlet, said passage providing at an intermediate point therein a valve seat, means for alternatively opening and closing said passage to flow therethrough, including a control device having alternative positions of adjustment, piston means for actuating said control device spring urged to a retracted position, said piston means setting said control device to one position of adjustment only as it reaches a retracted position and to the other position of adjustment only as it reaches an extended position, means for diverting a portion of the liquid from said passage to said piston means, means creating a pressure drop in said passage to extend said piston means from retracted position, and a valve on said piston means seating on said valve seat in response to over travel of said piston means beyond said extended position whereby positively to cut off flow through said passage in the event of failure of said control device.

2. An injector device of the character described, comprising a housing to be interposed in a line flowing liquid under pressure, a valve in said housing adjustable to open and closed positions, in the latter of which flow

through said housing is shut off, a control device for said valve having alternative positions of adjustment in a first one of which said valve is open and in a second one of which said valve is closed, a piston in said housing displaceable under the influence of the liquid flow from a retracted position to an extended position, a spring for returning said piston from extended to retracted position in the absence of liquid flow, a connection between said piston and said control device effective only as said piston reaches said extended position and said retracted position for setting said control device to said alternative positions of adjustment, said connection including resilient means yielding to an over travel of said piston beyond said extended position, and valve means for shutting off flow through said housing in response to over travel of said piston as described.

3. An injector device according to claim 2, characterized in that said valve means comprises a valve seat in the path of flow through said housing and a valve on said piston engageable with said seat in response to over travel of said piston beyond said extended position.

4. Injector apparatus of the class described, including electro-magnetic valve means adapted to be interposed in a line flowing fluid under pressure and operable to permit and to deny flow therethrough, an electrical circuit for controlling the energizing and de-energizing of said means including a power source, a rotary stepping switch, electro magnetic means advancing said switch in step-by-step fashion in response to the energizing and de-energizing thereof, power conducting means including connections from said source through said stepping switch to said electro magnetic valve means and to said electro magnetic means, a control switch settable to a first position in which the power from said stepping switch is used to energize said electro magnetic valve means and to a second position in which said power is used to energize said electro magnetic means, a piston displaceable by flowing fluid in said line to an extended position in which said control switch is moved thereby from its said first position to its said second position, and a spring for returning said piston to a retracted position in which said control switch is moved from its said second position to its said first position.

5. Injector apparatus according to claim 4, characterized in that said stepping switch has a neutral position in which said power source is connected to said electro magnetic means and a series of positions of predetermined number in which said power source is connected to said control switch.

6. Injector apparatus of the kind described, including electro-magnetic valve means adapted to be interposed in a line flowing fluid under pressure and operable to deny flow therethrough when de-energized, and electrical circuit for controlling the energizing and de-energizing of said means including a power source, a rotary stepping switch having a plurality of series of operating positions and intervening neutral positions, electro-magnetic means advancing said switch through successive positions in response to the energizing and de-energizing thereof, a power conductor from said source to said stepping switch, said switch in a said neutral position connecting said source to said electro magnetic means for energizing thereof, power conductor means from the operating positions of said stepping switch to said electro-magnetic means and to said electro-magnetic valve means, a control switch in said conductor means settable to a first position connecting the operating positions of said stepping switch to said electro-magnetic valve means and settable to a second position connecting the operating positions of said stepping switch to said electro-magnetic means, and a device responding to volume flow through said line alternately to shift said control switch between its said first and second positions.

7. Injector apparatus according to claim 6, characterized by another control switch settable to open the circuit to said electro-magnetic valve means for de-energizing thereof and to close a supplemental circuit from the operating positions of said stepping switch to said electro-magnetic means, and means actuated by said electro-magnetic means for intermittently opening and closing said supplemental circuit.

References Cited in the file of this patent

UNITED STATES PATENTS

2,443,648	Austin et al.	June 22, 1948
2,736,166	Mock	Feb. 28, 1956
2,745,625	Booth	May 15, 1956

FOREIGN PATENTS

706,060	Great Britain	Mar. 24, 1954