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IMPROVEMENTS IN OR RELATING TO THE ACTUATION
OF FLUID FLOW CONTROL VALVES

5 This invention concerns improvements in or relating to the electrical actuation of fluid flow control valves.

10 It is well known to utilise solenoid actuated valves to control fluid flows, but such valves require a mains or other substantial supply of electricity, and are thus not suitable for use in situations and applications where such a supply is not available, and other valves, such as manually actuated valves, have to be used. However, solenoid actuated valves have the advantage of affording both remote control and automatic control.

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It is further well known to provide manually actuatable valves with a mechanical linkage, e.g. a "Bowden" cable for remote actuation, but such linkages are of restricted utility and application; and it is further known to incorporate into such valves a device which is responsive, after the valve has been manually actuated, to the existence of a particular condition, e.g. a minimum operating burner temperature, to hold the valve in the actuated state, and which is responsive to the termination of said condition, e.g. a drop in the temperature to below said minimum, to restore the valve to or allow the valve to return to a non-actuated state. Valves incorporating such devices are useful for supplying fuel gas to the burners of, for example, caravan heaters, because they provide a degree of protection in the event of a burner flame failure; however, they have the disadvantages that the initial manual actuation must be maintained until the said particular condition is established, that the manual actuation must be repeated in the event of the valve being returned to the non-actuated state, and that they are not suitable for automatic control.

35 The present invention provides a fluid flow control valve, for automatic remote actuation where a mains or other substantial supply



of electricity is lacking, the valve, in accordance with the present invention, comprising a movable closure member, movable between a valve closing position in which the valve is closed and a further position in which the valve is opened; a first solenoid assembly and
5 a second solenoid assembly; and a closure bias which urges the closure member away from the second solenoid assembly towards the valve closing position; characterised in that the first solenoid assembly has an armature movable against said bias and a further force from a first position to a second position so as to bring the closure
10 member and the second solenoid assembly into contact when the first solenoid assembly is energised by an electrical input of predetermined power; and in that the second solenoid assembly is arranged to be energised by a lower power input to hold said closure member against the urge of said bias whilst the armature is returned to its first
15 position, by said force upon de-energisation of the first solenoid assembly, whereby to open the valve or to allow the valve to be held open.

According to the present invention there is also provided a
20 method of actuating the fluid flow control valve comprising the steps of:-

- (a) providing a first electrical input of high power and a predetermined short duration to the first solenoid assembly to move the armature of the first solenoid assembly against the
25 force from its first position to its second position so as to bring into contact the movable closure member of the valve and the second solenoid assembly against the bias which urges the closure member towards a valve closing position;
- (b) providing a second electrical input of low power and a predetermined longer duration to the second solenoid assembly
30 prior to the termination of the first input to keep the second solenoid assembly and closure member in contact, and terminating said first input to allow said force to restore the armature to its first position; and
- (c) holding said valve open against said ^{bias} ~~spring~~ by providing a
35 third electrical input of low power to said second solenoid

assembly, prior to termination of said second electrical input.

The first solenoid assembly may be arranged so that energisation
 5 of the first solenoid assembly opens the valve, but to give an
 improved fail safe capability, the arrangement is preferably such that
 energisation of the first solenoid assembly takes the second solenoid
 assembly into contact with the closure member whilst the valve remains
 closed, and de-energisation of the first solenoid assembly allows the
 10 armature to move the closure member and second solenoid assembly in
 unison to open the valve.

The predetermined duration of the second input is preferably
 selected to allow a condition to be established as a result of the
 15 valve being opened, and preferably the third electrical input of low
 power is derived from the establishment of said condition. For
 example, the present invention further provides a method of
 controlling a supply of fuel to a heater comprising a fluid flow
 control valve, a burner and an ignitor, the method comprising the
 20 steps of:-

- (a) opening the valve to supply fuel to the burner by providing
 a first electrical input of high power and a predetermined short
 duration to a first solenoid assembly to move an armature of the
 first solenoid assembly against a force from a first position to
 25 a second position so as to bring in contact a movable closure
 member of the valve and a second solenoid assembly against a
 spring thrust which urges the closure member to a valve closing
 position; and by, prior to the termination of the first input,
 providing a second electrical input of low power and a
 30 predetermined longer duration to keep the second solenoid
 assembly and closure member in contact whilst terminating the
 first electrical input to de-energise the first solenoid assembly
 to allow said force to restore the armature to the first
 position;
- 35 (b) during step (a) supplying power to the ignitor to ignite the
 fuel at the burner to establish a flame; and



(c) prior to termination of step (a), in the event of a flame being established, utilising heat from said flame to generate a third electrical input of low power and supplying the third input to the second solenoid assembly

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The power required to energise the second solenoid assembly is preferably at least one order of magnitude, e.g. about two orders of magnitude, smaller than the power required to energise the first solenoid assembly, for opening of the valve.

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The valve is preferably employed in heater apparatus which further comprises a burner, an ignitor, electrical control means and generator means,

wherein the electrical control means is automatically responsive to an "on" electrical signal to perform an ignition sequence in which the electrical control means provides a first electrical input of high power and short duration to the first solenoid assembly, provides, prior to termination of the first electrical input, a second electrical input of low power and longer duration to the second solenoid assembly, and supplies power to the ignitor prior to termination of the second electrical input; and wherein said generator means is responsive to heat produced by the burner to generate and supply to the second solenoid assembly a third electrical input of the low power.

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The first solenoid assembly is preferably of bobbin form in which the armature is axially movable to produce a large movement; whereas the second solenoid assembly preferably has a "horse shoe" or other reflex form of non-moving core, e.g. of soft iron, arranged to provide a plurality of poles which serve as abutments for the closure member, so that the latter may serve as a keeper to provide with the core a closed flux loop.

The electrical control means is preferably arranged to interrupt said third electrical input in response to an "off" electrical signal.

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The heating apparatus preferably includes a thermostat to give the or further "on" or "off" signals to which the control means is responsive to control the supply of fuel to, and to control the ignition of the burner.

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The invention will be described further, by way of example, with reference to the accompanying diagrammatic drawings, wherein:-

FIGURES 1 and 2 show a first embodiment of a valve in accordance with the invention, in partial longitudinal cross section;

10 FIGURE 3 is a view similar to FIGURE 1 showing a second embodiment of valve in accordance with the invention; and

FIGURE 4 is a schematic diagram of control means of heater apparatus in accordance with the invention.

15 Referring to FIGURE 1 and, the first embodiment of the valve comprises an inlet 10, an outlet 11, a seating 12 around a passage 13 between the inlet and outlet, a movable closure member 14, a first solenoid assembly 15 and a second solenoid assembly 16 mounted in a body 22 of the valve.

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In the closed condition of the valve, a resilient seal 17, mounted on the movable closure member 14, abuts the seating 12 to close the passage, as shown in FIGURE 1. The member 14 is located on a guide 18 which is slidably located in a socket in the second
25 solenoid assembly 16. A compression spring 19 extends between the second solenoid assembly and the member 14 to exert a closure bias on the latter to urge the seal 17 against the seating 12. The solenoid assembly 16 is mounted in the inlet 10, and has a solenoid wound on a static core of reflex form which provides a plurality of exposed poles
30 20 at the bottom of the assembly, and the movable closure member 14 and guide 18 are movable by the first solenoid assembly 15 against said closure bias to bring the member 14 into contact with said poles 20 as shown in FIGURE 2, so that the member 14 serves as a keeper to provide a closed flux path between said poles when the solenoid
35 assembly 16 is energised to hold the member 14 against said closure bias.

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The first solenoid assembly 15 comprises a cylindrical solenoid and an axial armature 21 movable upwards along the axis, against the force of gravity, by the solenoid to raise the movable valve member 14 to open the passage, and is located in the outlet 11. A seal 22 is provided around the outlet to enable the valve to be mounted on a manifold.

The valve can be actuated by electrical control means shown in FIGURE 4, which is arranged to provide a first electrical input of high power and a predetermined short duration to first solenoid assembly to move the armature 21 upwards from a first position to a second position so as to take the movable closure member 14 into contact with the second solenoid assembly to open the valve; and, prior to the termination of the first input, provides a second electrical input of low power and a predetermined longer duration to keep the second solenoid assembly and closure member in contact to hold the valve open whilst first solenoid assembly is de-energised to allow said force of gravity to restore the armature to the first position.

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Referring to FIGURE 3, the second embodiment of valve is similar to the first embodiment in that it also comprises an inlet 30, an outlet 31, a seating 32 around a passage 33 between the inlet and outlet, a movable closure member 34, a first solenoid assembly 35 and a second solenoid assembly 36.

In the closed condition of the valve, a resilient seal 37, mounted on the member 34, abuts the seating 32 to close the passage. The member 34 is located on a guide 38 slidably located in a socket in the second solenoid assembly 36. A compression spring 39 extends between the second solenoid assembly 36 and the member 34 to exert a closure bias on the latter to urge the seal 37 against the seating 12. The second solenoid assembly 36 has a solenoid wound on a static core of reflex form which provides a plurality of exposed poles 40 which confront the member 34. The first solenoid assembly 35 comprises a cylindrical solenoid and an axial armature 41 movable by the solenoid

along the axis.

However, the second embodiment of the valve differs considerably from the first embodiment in construction, operation and utilisation, whereby to offer major advantages over the first embodiment, as hereinafter described.

In the second embodiment, the second solenoid assembly 36 is clamped to a diaphragm 50 which is peripherally clamped between a valve body 51 and a valve cap 52. The first solenoid assembly 35 is mounted on the valve cap and the armature 41 is mechanically connected to the diaphragm and second solenoid assembly for movement in unison therewith. An extension 42 of the armature 41 carries and adjustable or preset stop 43 and a return spring 44 is located between stop 43 and an end face 45 of the assembly 35 to exert a return bias on the armature 41. A flexible electrical input lead or leads 53 extend from the second solenoid assembly through an insulated port 54 in the cap 52.

The arrangement of the valve is such that energisation of the first solenoid assembly 35 causes the armature 41 to move the second solenoid assembly 36 towards the seating 32 against a total bias which includes:-

- (a) the return bias
- (b) the closure bias
- (c) the deflection resistance of the diaphragm, and possibly also
- (d) the thrust applied to the diaphragm by the presence of fluid under pressure in the inlet.

The stroke of the armature 41 is sufficient to bring the poles 40 into contact with the movable closure member 34, whilst the passage remains closed. Thereafter the valve can be opened only by energising the second solenoid assembly to retain the member 34 in contact with the poles, and de-energising the first solenoid assembly to allow the return bias to raise the armature, diaphragm and second solenoid



assembly together with the movable closure member 34 to lift the latter from the seating.

An advantage of the second embodiment is that the portion of the total bias derived from (a), (b) and (c), above may be determined in relation to the predetermined level of power applied to energise the first solenoid, to render the first solenoid non-effective if said inlet pressure exceeds a predetermined value U, which value can be determined accurately and reliably, by only a relatively small amount due to the relatively large effective area of the diaphragm. A further and major advantage is that sticking or failure of the first solenoid assembly, cannot result in the valve being unwantedly held open.

The apparatus shown in FIGURE 4 comprises the second embodiment of the valve (but may instead utilise the first embodiment), and electrical control means to control the supply of fuel gas to a burner 60 of a heater, for use in a situation wherein a mains or other substantial supply of electricity is not available, e.g. for use in a caravan. The burner 60 is arranged to heat a heat exchanger 61 or other body, e.g. a water tank, to be heated.

The electrical control means comprises electronic circuitry which is arranged to provide the functions of a cycle controller 62, a first solenoid controller 63, a second solenoid controller 64, a generator controller 65, a safety controller 66, an ignitor controller 67 and a resettable counter 68. The electronic circuit forms a unit 69 which may be mounted on the valve for remote actuation.

The control means further includes a manually operable on/off electrical switch 74, a control thermostat 75 (which may be preset or manually adjustable), an overheat thermostat 76, a flame detector 70, an ignitor 71 and a generator 72 such as a thermocouple device. The thermostat 75 may be arranged to respond to the temperature of or in the heat exchanger 61, or, for example, to ambient or a temperature.



In use, when the switch 74 is closed it connects a dry cell battery 73 to the control thermostat 75. If the temperature to which the thermostat responds is below the temperature setting of the thermostat, the thermostat 75 connects the battery to the electronic
5 circuitry and actuates the cycle controller 62 and the safety controller 66. The cycle controller 62 initiates an ignition sequence by actuating the solenoid controllers 63 and 64.

The controller 63 applies a first controlled electrical input to
10 the first solenoid assembly 35 (or 15), which input is in the form of an electrical pulse of high power and short duration, for example 10 to 20 watts for a period of 1 to 2 seconds; whereas the controller 64 applies a second controlled electrical input to the second solenoid
15 assembly 36 (or 16), which input is in the form of an electrical signal of low power and longer duration, for example 0.1 to 0.2 watts for a period of 15 to 30 seconds, which signal is applied during the application of said pulse, whereby to open the valve to supply gas to the burner 60.

20 Upon termination of the pulse, the ignitor controller 67 actuates the ignitor 71, e.g. to produce a high voltage low wattage spark or sequence of sparks during at least part of the period during which the signal is applied to the second solenoid assembly, to ignite the burner.

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Upon ignition, the safety controller 66 receives a flame recognition input from the flame detector 70 and the generator 72 is heated by heat from the burner flame to generate an electrical output which is applied via the generator controller 65 as a third controlled
30 electrical input of low power to the second solenoid assembly, which third input serves to hold the valve open when the second electrical input signal ^{subsequently} ceases; and actuation of the ignitor is halted preferably after the detection of the flame, but optionally after a predetermined period, e.g. to terminate when the second input signal
35 ceases.



The thermostat senses heater temperature to give "on" and "off" signals, so that heating continues until the temperature setting of the thermostat 75 is reached, whereupon the thermostat de-activates the cycle controller 62 which automatically causes the generator
5 controller 65 to block the third electrical input to the second solenoid assembly whereby to allow the valve to close rapidly; and when the temperature sensed by the thermostat falls below the temperature setting of the thermostat, the thermostat reactivates the cycle controller to initiate the ignition sequence.

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In the event of the burner failing to ignite or otherwise failing, becoming extinguished, whilst the cycle controller 62 is activated, the absence of a flame will be sensed by the detector 70, and the safety controller 66 is arranged to actuate the counter 68
15 which records the failure and actuates the controller 62 to initiate a second ignition sequence. Should the burner fail again, the second and further failures, up to a predetermined maximum number, will similarly be recorded and will cause the ignition sequence to be repeated. Thereafter a further failure will cause the counter 68 to
20 block the cycle controller 62, and, optionally, the counter will cause a fault indication to be displayed. The cycle controller 62 and the counter 68 can be unblocked, reset and re-actuated by manually opening and re-closing the switch 74.

25 The safety controller 66 also reacts to an overheat signal from the overheat thermostat 76 to cause the cycle controller to be blocked and the or another fault indication to be displayed.

The valve of the invention, and the heater apparatus having
30 control means arranged to actuate the valve in accordance with the invention, gives the major advantage that the electrical power requirements are easily capable of being met, over periods of at least several weeks, by a simple and relatively inexpensive dry cell battery or a small plurality thereof. Furthermore, because the first solenoid
35 is energised at a given wattage for only a very short period, a light inexpensive first solenoid assembly having a lower continuous wattage

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operating rating may be employed without detriment thereby enabling considerable cost and weight savings to be made which savings offset or exceed the cost and weight of the second solenoid assembly, which assembly may be of very simple construction as it is only needed to
5 perform a holding function and is not required to produce a movement.

The invention is not confined to the precise details of the foregoing examples and many variations are possible within the scope of the invention, particularly in respect of the arrangement,
10 construction and internal organisation of the control means to perform the functions described or equivalent functions. For example, the valve may be adapted to control a supply of liquid.

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CLAIMS

1. A fluid flow control valve, comprising a movable closure member, movable between a valve closing position in which the valve is closed
5 and a further position in which the valve is opened; a first solenoid assembly and a second solenoid assembly; and a closure bias which urges the closure member away from the second solenoid assembly towards the valve closing position; characterised in that the first solenoid ^{assembly} has an armature movable against said bias and a further force
10 from a first position to a second position so as to bring the closure member and the second solenoid assembly into contact when the first solenoid assembly is energised by an electrical input of predetermined power; and in that the second solenoid assembly is arranged to be energised by a lower power input to hold said closure member against
15 the urge of said bias whilst the armature is returned to its first position, by said force upon de-energisation of the first solenoid assembly, whereby to open the valve or to allow the valve to remain open.
- 20 2. A valve as claimed in Claim 1 wherein movement of the armature from said first to said second position takes the closure member from the valve closing position to said further position to open the valve; and wherein said armature is movable from said second position to said first position, whilst the second solenoid assembly is energised,
25 without moving the closure member from said further position.
3. A valve as claimed in Claim 2 wherein the first solenoid assembly is arranged to lift the armature against the force of gravity.
- 30 4. A valve as claimed in Claim 1 wherein the second solenoid assembly is supported by the armature so as to be movable by the armature.
- 35 5. A valve as claimed in Claim 4 wherein said further force is provided by a spring acting on the armature.

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6. A method of actuating a fluid flow control valve as claimed in Claim 1 comprising the steps of:-

- 5 (a) providing a first electrical input of high power and a predetermined short duration to the first solenoid assembly to move the armature of the first solenoid assembly against the force from its first position to its second position so as to bring into contact the movable closure member of the valve and the second solenoid assembly against the bias which urges the closure member towards a valve closing position;
- 10 (b) providing a second electrical input of low power and a predetermined longer duration to the second solenoid assembly prior to the termination of the first input to keep the second solenoid assembly and closure member in contact, and terminating said first input to allow said force to restore the armature to its first position; and
- 15 (c) holding said valve open against said bias by providing a third electrical input of low power to said second solenoid assembly, prior to termination of said second electrical input.

20 7. A method as claimed in Claim 6, wherein in step (a) energisation of the first solenoid assembly moves the armature to move the closure member to open the valve, and wherein in step (b) energisation of the second solenoid assembly holds the valve open whilst the armature returns to the first position.

25 8. A method as claimed in Claim 6, wherein in step (a) energisation of the first solenoid assembly moves the armature to take the second solenoid assembly into contact with the closure member whilst the valve remains closed, and wherein in step (b) the armature, upon de-energisation of the first solenoid assembly, moves the movable member and second solenoid assembly in unison to open the valve.

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9. A valve substantially as hereinbefore described, or arranged to be operated by the method substantially as hereinbefore described, with reference to FIGURES 1 and 2 or FIGURE 3 of the accompanying drawings.

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10. A method of controlling a supply of fuel to a heater comprising a fluid flow control valve, a burner and an ignitor, the method comprising the steps of:-

- 5 (a) opening the valve to supply fuel to the burner by providing a first electrical input of high power and a predetermined short duration to a first solenoid assembly to move an armature of the first solenoid assembly against a force from a first position to a second position so as to bring into contact a movable closure member of the valve and a second solenoid assembly against a
- 10 spring thrust which urges the closure member to a valve closing position; and by, prior to the termination of the first input, providing a second electrical input of low power and a predetermined longer duration to keep the second solenoid assembly and closure member in contact whilst terminating the
- 15 electrical input to de-energise the first solenoid assembly to allow said force to restore the armature to the first position;
- (b) during step (a) supplying power to the ignitor to ignite the fuel at the burner to establish a flame; and
- (c) prior to termination of step (a), in the event of a flame
- 20 being established, utilising heat from said flame to generate a third electrical input of low power and supplying the third input to the second solenoid assembly.

11. A method as claimed in Claim 10 wherein in the event of a flame

25 not being established, repeating steps (a) and (b), counting the number of times steps (a) and (b) are repeated, and providing a signal when a predetermined number is reached.

12. A method as claimed in Claim 10 wherein in step (a) energisation

30 of the first solenoid assembly moves the armature to move the closure member to open the valve, and energisation of the second solenoid assembly holds the valve open whilst the armature returns to the first position.

35 13. A method as claimed in Claim 10, wherein in step (a) energisation of the first solenoid assembly moves the armature to take the second

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solenoid assembly into contact with the closure member whilst the valve remains closed; and wherein the armature, upon de-energisation of the first solenoid assembly, moves the closure member and second solenoid assembly in unison to open the valve.

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14. A method as claimed in Claims 10, 12 or 13 including the further step of sensing a temperature within the heater and interrupting said third electrical input to allow the spring thrust to return the closure member to the valve closing position in the event of a
10 predetermined upper temperature being reached.

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15. A method as claimed in Claim 14 including the further step of sensing the temperature within the heater and repeating steps (a), (b) and (c), when the temperature falls below a predetermined temperature.

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16. A method as claimed in Claim 10, 12 or 13 including the step of sensing the presence of a flame, and, in the event of flame failure, repeating steps (a) and (b).

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17. A method as claimed in Claim 10 and substantially as hereinbefore described with reference to FIGURE 4 of the accompanying drawings.

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18. Heater apparatus comprising a valve as claimed in any one of Claims 1 to 5 or 9, a burner, an ignitor, electrical control means and
25 generator means,

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wherein the electrical control means is automatically responsive to an "on" electrical signal to perform an ignition sequence in which the electrical control means provides a first electrical input of high power and short duration to the first solenoid assembly, provides, prior to termination of the first electrical input, a second electrical input of low power and longer duration to the second solenoid^{assembly}, and supplies power to the ignitor prior to termination of the second electrical input;

and wherein said generator means is responsive to heat produced by the burner to generate and supply to the second solenoid assembly a third electrical input of the low power.



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19. Apparatus as claimed in Claim 18 wherein the electrical control means is arranged to interrupt said third electrical input in response to an "off" electrical signal from a thermostat.
- 5 20. Apparatus as claimed in Claim 18 or 19 wherein the electrical control means comprises a flame detector, and is arranged to repeat said ignition sequence in the event of flame failure.
- 10 21. Apparatus as claimed in Claim 20 wherein the electrical control means comprises a counter to count the number of times said ignition sequence is repeated, and is arranged to cease repeating said ignition sequence when the counter has counted to a predetermined number.
- 15 22. Apparatus as claimed in Claim 20, wherein the electrical control means is arranged to provide a warning signal when the counter has counted to said predetermined number.
- 20 23. A valve as claimed in any one of Claims 1 to 5; or apparatus as claimed in any one of claims 18 to 22 wherein the first solenoid assembly is of bobbin form in which the armature is axially movable; and wherein the second solenoid assembly has a "horse shoe" or other reflex form of non-moving core arranged to provide a plurality of poles which serve as abutments for the closure member so that the latter may serve as a keeper to provide, with the non-moving core, a
25 closed flux loop.
24. A valve as claimed in any one of Claims 1, 4 or 5 or apparatus as claimed in any one of Claims 18 to 23 wherein the valve is as claimed in Claim 1, 4 or 5, wherein the armature is connected to a diaphragm
30 in the valve, which diaphragm is subjected to the fluid pressure in a fluid inlet of the valve to exert a force, proportional to said fluid pressure, upon the armature.
25. A valve as claimed in any one of Claims 1 to 5, or apparatus as
35 claimed in any one of Claims 18 to 24 wherein the power required to energise the first solenoid assembly to move the armature from said



first to said second position is at least one order of magnitude greater than the power required to energise the second solenoid assembly to hold the closure member and second solenoid assembly in contact.

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26. Apparatus as claimed in any one of Claims 18 to 25 wherein the electrical control means is substantially as hereinbefore described with reference to FIGURE 4 of the accompanying drawings.

10 27. Heating apparatus substantially as hereinbefore described with reference to FIGURES 1, 2 and 4 or FIGURES 3 and 4 of the accompanying drawings.

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