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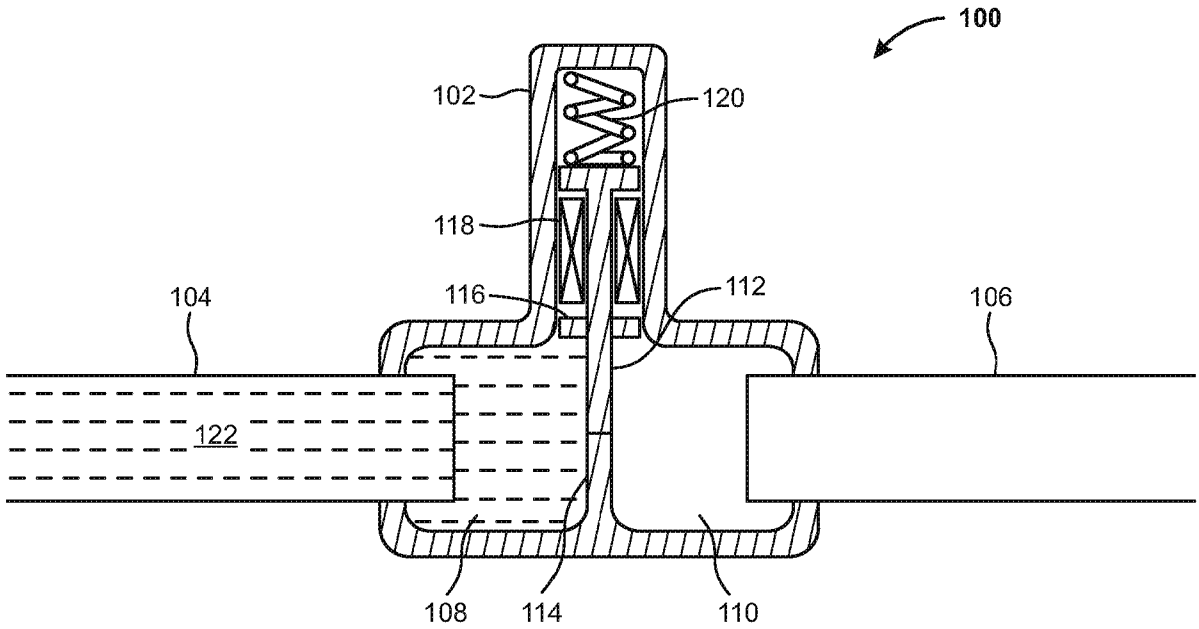


Figure 1a

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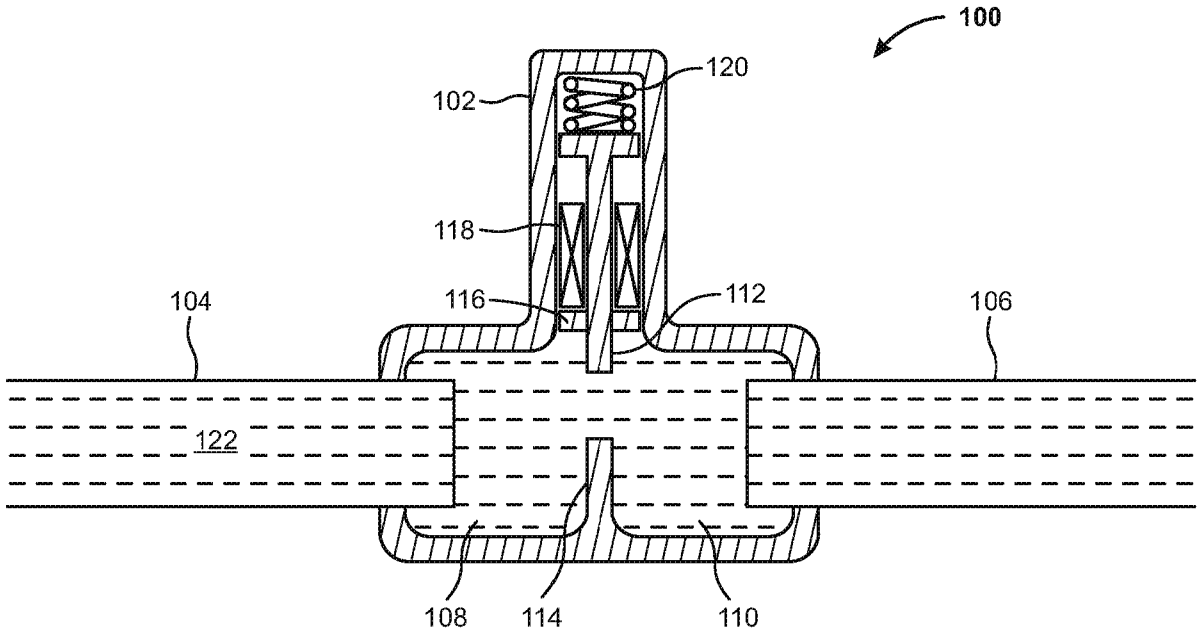


Figure 1b

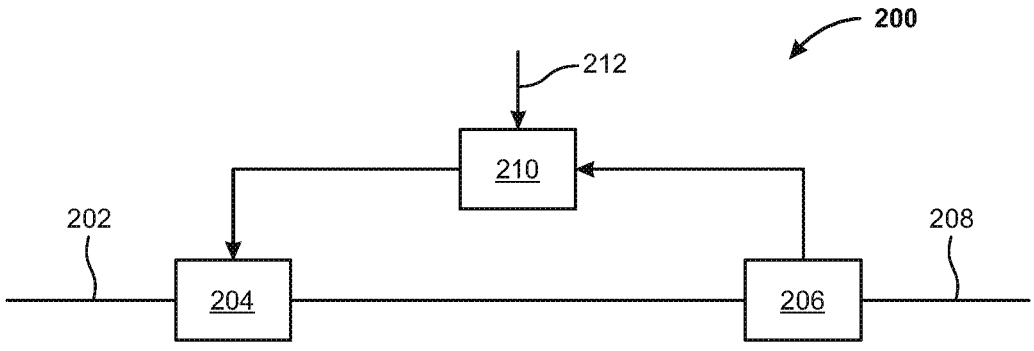


Figure 2

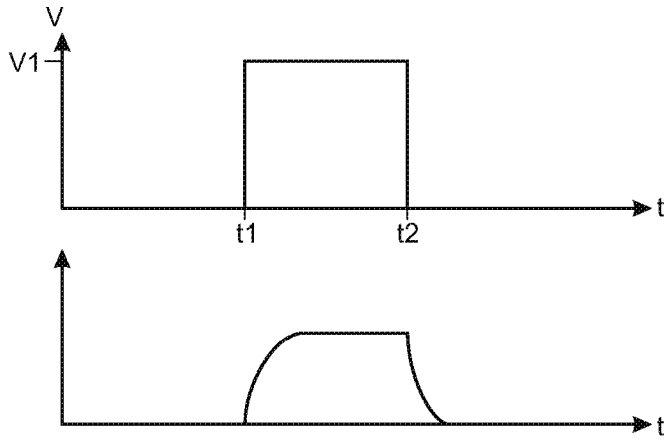


Figure 3

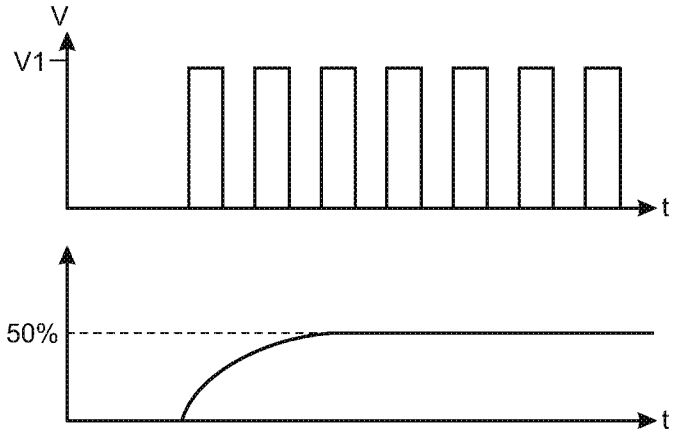


Figure 4

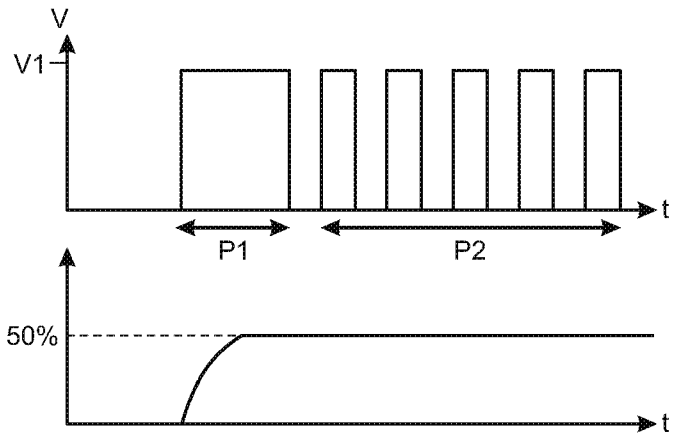


Figure 5

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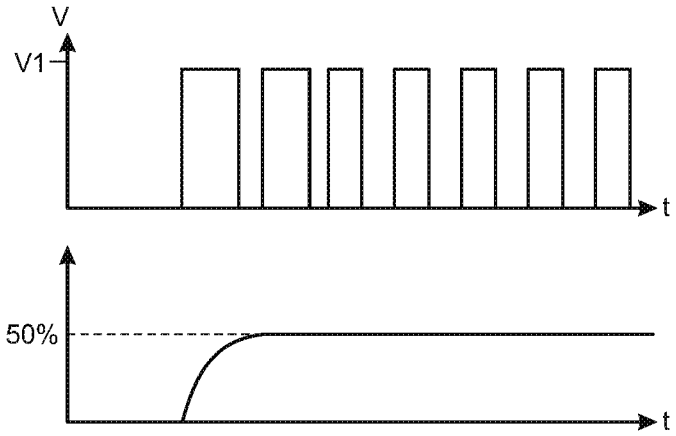


Figure 6

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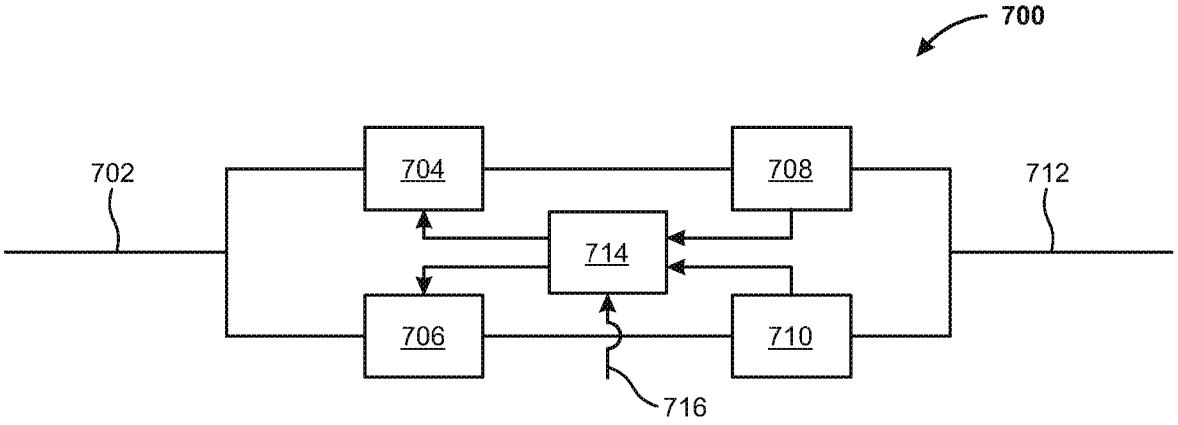


Figure 7

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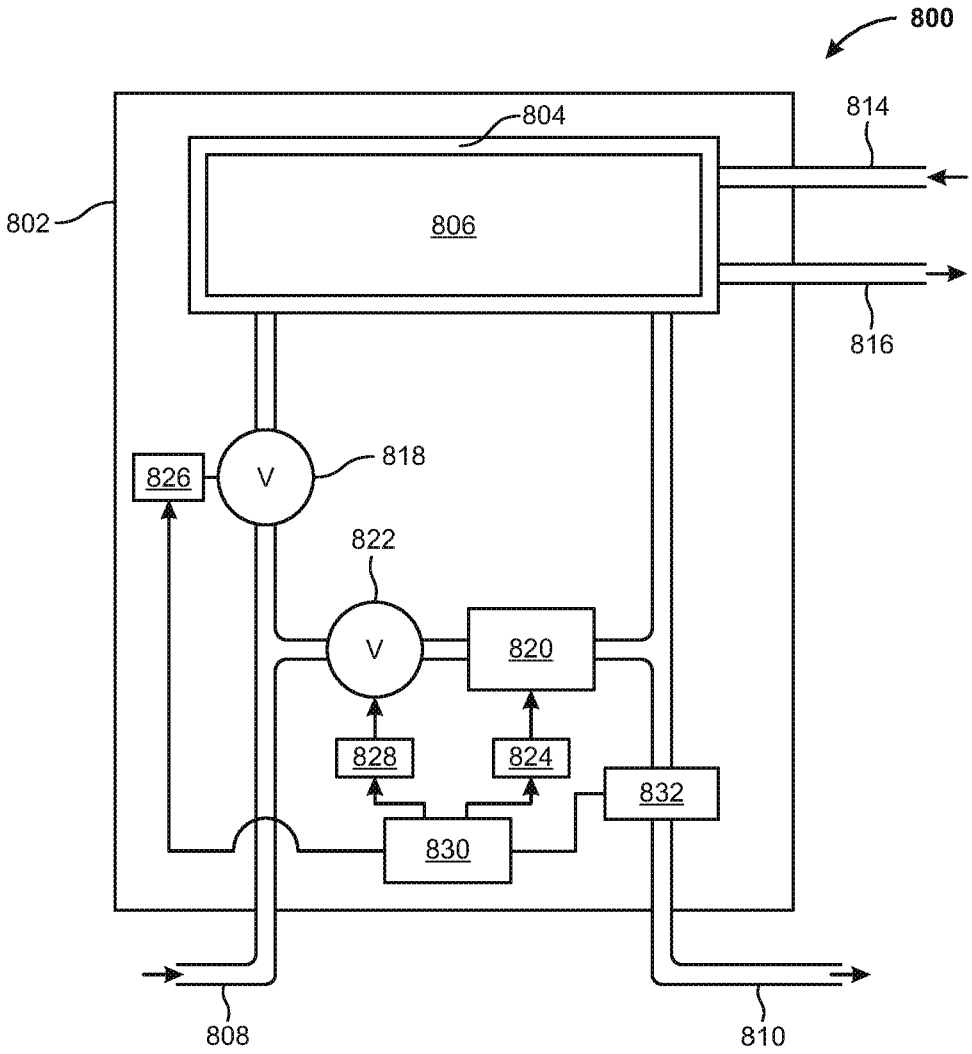


Figure 8

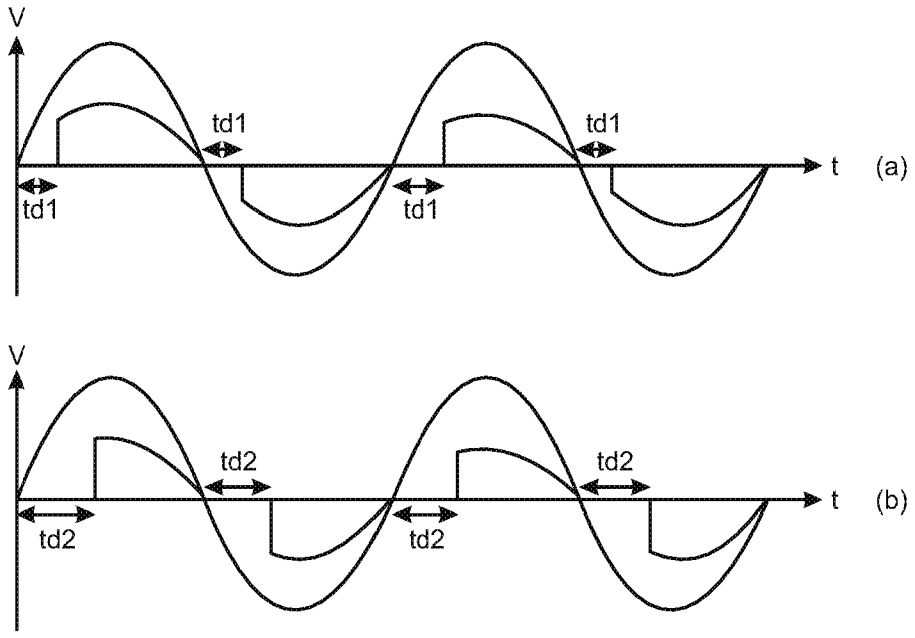


Figure 9

Hot Water Supply System

The present invention relates to a hot water supply system (HWSS), in particular a hot water supply system for use with a heat pump that uses an energy storage arrangement.

Domestic and small commercial premises often meet requirements for hot water by a gas-fired boiler or furnace. Either the water is heated and stored in a tank of some kind or is heated on-demand when a hot tap (faucet) is opened on the premises. With increasing concern over the environmental damage caused by burning fossil fuels, attention has turned to alternative techniques to provide hot water, such as heat pumps.

Heat pumps use refrigeration technology to extract heat from a lower-temperature resource and transfer that heat to a higher-temperature resource. A heat pump can, for example, extract heat from air at, say 15 degrees centigrade, and heat water to a temperature of, say 50 degrees centigrade. Such a heat pump is called an air-source heat pump although water-source and ground-source heat pumps are also available and work on the same principle. Despite the (usually electrical) energy required to operate them, heat pumps can be up to four or more times as efficient as, for example, an electrical heater.

However, heat pumps are not suitable for providing instant hot water, such as when a user turns on a tap. Specifically, heat pumps have limits on how quickly they are able to start up and how often they are activated. It can take well over a minute for a heat-pump to switch on, perform self-checks and actually provide any hot water. This is not acceptable for a user who wants hot water for 20 seconds to wash their hands. In addition, heat-pumps typically cannot be activated more than six times per hour and can be unavailable for periods of time such as during a defrost cycle.

To address these problems, the present applicants have developed a hot water supply system including a thermal storage arrangement. The thermal storage arrangement is preferably as described in GB patent application filed 7th February 2021. This uses phase change materials, such as paraffin wax, to store energy in a highly space-efficient manner by utilising materials that change from a solid to liquid (and vice versa) at the relevant temperature. A heat-pump is used to heat an energy store containing the phase change material to a temperature at which the material changes from a solid to a liquid. This phase change absorbs a great deal of energy which is then available to be recovered without activating the heat-pump when a single tap is turned on. Using phase change material makes the energy store very compact, i.e. it can store a lot of energy for its size. Cold water from the mains supply is fed through the energy store to provide smaller quantities of hot water (enough, say, for a shower). Prolonged demand for hot water is met by activating the heat-pump but even in this case the energy store is used to provide hot water until the heat-pump is fully operational.

Despite the development of the energy store, delays in the provision of hot hater can arise due to the slow response of electrically-operated valves within the system.

These valves usually have only two states: open and closed and which state is adopted is determined in response to an electrical drive signal. Typically, the valves open when the drive signal is applied and close when the drive signal is removed, although “normally-open” valves do exist that operate in the opposite manner. In the most common design, spring-loading ensures that the valve is closed (or open, in the case of a normally-open valve) and a solenoid is arranged to act on a magnetic portion of the valve so that when a current flows through the solenoid, the valve opens (or closes).

However, in the hot water supply system one or more electrically-controlled valves are required to provide modulation of the water flow, i.e. that the valve or valves control the amount of flow when open. To do this, the valves must be capable of adopting one or more intermediate positions between fully-open and fully-closed. Control arrangements to achieve this are known but are prone to poor response times. Also, cheaper variable valves tend to have high tolerances, i.e. the degree to which the valve will open in response to a drive signal is not known accurately.

In addition, water pressure can vary significantly over the course of a day, so even if the degree to which a valve is open can be controlled precisely, the actual flow rate of water will still vary.

It is an object of the present invention to ameliorate these problems.

According to a first aspect of the present invention, there is provided a hot water supply system comprising:

a thermal energy store for storing energy received from a heat-pump, the energy store including a layer of insulation,

a heat-pump send connection and a heat-pump return connection connected to the thermal energy store,

a cold-water inlet coupled to the thermal energy store and a hot water outlet coupled to the energy store,

a controller,

a supplementary heater to supply the hot-water outlet, and

a valve for controlling a flow of water to at least one of the energy store and the supplementary heater,

the valve having at least a first liquid-flow path between a first port and a second port, the valve arranged to occupy either a first state in which the first liquid-flow path is closed or a second state in which the at least one liquid-flow path is open, the valve further comprising an electrical element such that the valve occupies one of the first and second states in response to a first drive signal applied to the electrical element and occupies the other of the first and second states in response to a second drive signal applied to the electrical element, wherein

the controller comprises a control input and a drive signal output, the control input specifying a desired liquid flow rate and the drive signal output arranged to drive the electrical element of the valve, the controller being adapted to determine a normal drive signal output in response to the control input, which drive signal is determined to control the valve to meet the desired flow rate, the controller further being adapted to apply an initial drive signal output followed by the normal drive signal output to the electrical element of the valve, the initial drive signal output having a greater magnitude than the normal drive output signal and being applied for an initial duration.

The thermal energy store preferably comprises phase change material.

By driving the valve harder during the initial duration, the controller is arranged to cause the valve to achieve the desired flow rate almost instantaneously. The reason is that the valve takes a finite time to respond to the output drive signal and that it will respond more quickly to an output drive signal having a greater magnitude. The initial drive signal output may be applied for a predetermined initial duration or the initial duration may be determined in response to feedback on flow rate as discussed further below.

The controller preferably further comprises a flow measurement input that provides an indication of the flow rate to the controller. If the measured flow rate is too low then the output drive signal is arranged to increase the opening of the valve and vice versa. This provides precise control of the flow rate without requiring an expensive, high-tolerance valve. This also addresses the problem of varying water pressures.

The valve arrangement preferably further includes a flow sensor arranged to detect the flow through the liquid-flow path and provide the flow rate information to the controller. The flow sensor is preferably incorporated into the valve for ease of fitting and replacement of the valve.

When the controller is provided with a flow measurement input, the initial drive signal output may be applied until the flow rate information indicates that the desired flow rate has been achieved.

Preferably the drive signal output is a pulse-width-modulated (PWM) drive signal. PWM has the benefit of generating minimal power dissipation in the drive electronics of the controller. The frequency of the PWM signal is selected such that the valve adopts a substantially constant degree of opening in response to the PWM drive signal. The mechanical inertia of the valve prevents the valve from fully closing and opening in response to each pulse of the drive signal. As the frequency is increased, the valve will open to a more consistent degree but there is a trade-off in the complexity and cost of the drive electronics. In many applications, some minor variation in flow rate can be tolerated in which case a PWM signal having a lower frequency may be used.

When the valve is an AC valve, an alternative control strategy is applied, known as gate phase control. A 50Hz AC waveform crosses zero 100 times per second. Gate phase control delays the application of a gate signal to a thyristor, triac or other semiconductor switching device for a time period (or phase delay) after the zero-crossing. This means that current flows only during part of the sinusoidal cycle – a small delay corresponds with a strong drive signal while a longer delay corresponds with a weaker drive signal.

The valve may be a three-way valve such as a diverter valve which further comprises a third port. Such a valve can direct a proportion of liquid from the first port to the second port and the remaining proportion of liquid to the third port.

The valve is preferably a solenoid valve as such valves are usually cheap and compact. The teaching of the present invention thus provides the greatest benefit in terms of cost and performance using this type of valve.

The invention will now be described by way of example, with reference to the accompanying drawings, in which:

Figures 1a and 1b show a cutaway view of a solenoid valve which is applicable to embodiments of the present invention,

Figure 2 shows a closed loop control arrangement for managing flows of liquid which is applicable to embodiments of the present invention,

Figure 3 shows a graph of a drive signal and consequent valve opening,

Figure 4 shows another graph of a drive signal and consequent valve opening,

Figure 5 shows another graph of a drive signal and consequent valve opening in accordance with an embodiment of the present invention,

Figure 6 shows a graph of a drive signal and consequent valve opening in accordance with an embodiment of the present invention, and

Figure 7 shows another embodiment of a closed loop control arrangement for managing flows of liquid,

Figure 8 shows a block schematic diagram of a hot water supply system in accordance with an embodiment of the invention, and

Figure 9 shows a graph of a drive signal and consequent valve opening for an AC drive signal.

The following description will use terms like top, bottom, left, right, up, down, upwards, downwards, horizontal and vertical. These terms are to be understood in the sense of the figures to permit description thereof and place no limit on the absolute or relative orientation of any components in use.

Figure 8 shows a block diagram of a hot water supply system 800 according to an embodiment of the present invention. The HWSS is arranged in a cabinet 802 and includes send 814 and return 816 paths for a heat-pump (not shown) as well as a cold-water inlet 808 and a hot water outlet 810. The send and return from the heat-pump are connected to an energy storage arrangement (ESA) 806. The ESA contains phase change material which stores heat energy in a very space-efficient manner. The phase change material is heated by the heat-pump using a heat exchanger within the ESA. The ESA is provided with an insulating layer 804. The ESA also contains another heat exchanger which transfers energy from the ESA to water from the cold-water inlet 808 to provide hot water at the hot-water outlet 810. Energy is thus provided by the heat pump, stored in the ESA and used to heat water from a cold-water inlet when required.

In addition to the ESA, the HWSS is also provided with a supplementary heater 820 which can heat water from the cold-water inlet when necessary. This might occur if the ESA is depleted, if the heat pump is unavailable due to a defrost cycle or if the price of electricity is particularly low. Consequently, there are two possible paths for water through the HWSS.

A first path proceeds from the cold-water inlet to the ESA via a valve 818 and a second path proceeds from the cold-water inlet to a supplementary heater 820 via a valve 822. A controller 830 determines, using temperature information from sensor 832, the extent to which the supplementary heater is to be activated and the relative flow of water through the ESA and the supplementary heater to achieve the desired water temperature at the output. The flow may be completely through one path, in other words one of the valves 818, 822 is open fully and the other one is closed.

Often, however, the two valves are both required to be partially open and the control arrangements to achieve this are described below. Electrical power to the supplementary heater is controlled by a power electronic device 824, activation of the valve 818 is controlled by a power electronic device 826 and activation of the valve 822 is controlled by a power electronic device 828. The power electronic devices are all driven by the controller 830 and may, for example, comprise thryristors or triacs. The power electronic device chosen will depend to some extent on whether the valves are AC or DC valves.

To address, or at least ameliorate, the problem of system responsiveness one or both of the valves 818, 820 in the system are controlled to reach a target value of flow rate more quickly as described below. First, the nature of the valves is described.

Figure 1a shows a sectional view of a valve 100 having a body 102 arranged between a liquid inlet 104 and a liquid outlet 106. The valve comprises an inlet chamber 108 and an outlet chamber 110 largely separated by a protrusion 114 extending upwards from the bottom of the valve body. The top of the protrusion meets the bottom of a piston 112 which is capable of moving up and down under control of an electromagnet or solenoid 118. At least the upper portion of the piston 112 comprises magnetic material. A seal 116 is arranged below the solenoid and above the inlet and outlet chambers to prevent water from coming into contact with electrical elements. The seal may be attached to the body of the valve (as shown here) or to the piston 116. Further seals (not shown) may also be provided.

In Figure 1a no voltage is applied to the solenoid 118 and a spring 120 urges the piston downwards to form a liquid-tight seal with the protrusion 114. The valve is consequently closed. Liquid 122, illustrated as horizontal dashes, is confined to the inlet 104 and inlet chamber 108.

Figure 1b shows the same valve as Figure 1a but with a voltage now applied to the solenoid generating a magnetic field around the piston which has now risen upwards against the force of the spring 120. A path for liquid now exists between the inlet chamber 108 and the outlet chamber 110 and liquid 122 can flow between the inlet 104 and the outlet 106. The valve is consequently closed. Several watts of power are dissipated by the solenoid countering the force of the spring 120.

Figure 2 shows, in diagrammatic form, a closed-loop flow control arrangement 200 for managing flows of liquid using a valve as such as the valve shown in Figure 1.

A liquid inlet 202 is connected to a valve 204 such as the valve shown in Figure 1 and an outlet of the valve is connected to the input to a flow-measurement device 206. The output of the flow-measurement device 206 constitutes a (controlled) liquid output 208. The flow measurement device 206 also provides a signal which indicates flow rate information and this is provided to a controller 210. The controller 210 also receives a command or target signal 212. The command signal represents the desired flow rate provided by the arrangement 200 and is typically provided by higher-order control circuitry. The controller outputs a control signal to the valve 204 which determines how widely the valve is opened.

In operation the controller responds to the command signal to provide a drive signal to the valve 204. The flow measurement device 206 then provides the controller with the actual flow rate and the controller adjusts the output drive signal until the desired flow rate (as indicated by the flow-measurement device) is achieved. The flow measurement device could equally be placed on the inlet side of the valve. The flow measurement device may provide an analogue output signal. When the controller 210 is implemented by digital circuitry (such as a programmed microcontroller), the analogue output of the flow measurement device will be digitized, for example by an analogue-to-digital converter.

The control signal for driving the valve could be a variable DC voltage (for a DC valve). As voltage increases so will current through the solenoid and the valve will open to a greater degree. However, DC voltage drive has the drawback that the drive circuitry in the controller is expensive, and will dissipate a significant amount of power (usually as heat). This not only wastes electrical energy, it may also require cooling of components in the controller (further driving up cost).

A preferred control arrangement uses pulse width modulation (PWM). PWM is a drive arrangement in which the output signal is either zero or fully on which for a solenoid valve is usually 12v or 24v. The width of the pulses is varied to provide different levels of output drive signal. Since semiconductor switch(es) in the controller are either on or off, they dissipate little power. The

frequency of the pulses is selected to provide control of the valve with an acceptable variation in flow rate. If the frequency is too low then there will be noticeable variation in the degree to which the valve is opened. However, raising the frequency usually increases the cost and power dissipation of the drive circuitry. The skilled reader will be able to determine a suitable compromise in drive frequency based on these factors.

Figure 3 is a graph showing valve response to a straightforward on/off signal. The upper trace shows a voltage V1 is applied to the valve at a time t0 and removed at a time t1. The lower trace shows the response of the valve to this drive signal, that is the degree to which the valve is open. The mechanical inertia of the valve causes a delay in both opening and closing of the valve.

Cheaper control valves often exhibit a slower response than their more expensive counterparts and may also be more prone to failure. These issues are addressed in the following embodiments.

Figure 4 shows a graph of a different drive arrangement intended to open the valve to a point between fully open and fully closed. Instead of driving the coil with a fixed DC voltage, a Pulse Width Modulated (PWM) drive signal is applied. The upper trace shows the voltage applied to the coil – effectively a square wave at either full drive voltage or zero voltage. The frequency of the drive signal is high enough to ensure that the valve doesn't open and close in response to the individual voltage pulses, but opens part-way. The mechanical inertia of the valve results in the valve opening to a substantially fixed but partial extent while the square wave drive signal is applied.

The controller may control (modulate) the valve drive signal with longer or shorter pulses to obtain the desired flow rate. The duration of the pulses relative to the zero-voltage periods is known as the duty cycle. If the duration of the pulses and the zero-voltage periods is the same, the duty cycle is said to be 50%. An always-on drive signal is said to have 100% duty cycle. The controller is programmed to increase the duty cycle if the flow rate is too low and to decrease the duty cycle if the flow rate is too high. (This assumes that the valve is a preferred normally-closed valve. The controller is programmed to behave in the opposite manner for a normally-open valve).

Alternatively, the control signal may comprise a variable DC voltage to effect the partial opening of the valve but this requires more complex drive circuitry and also dissipates more power than the PWM arrangement.

This closed-loop control addresses the problems of varying performance among different valves and also of varying liquid supply pressure. It also addresses any variation in performance as the valve ages.

However, this control arrangement has a drawback, especially when cheaper valves are used. The lower trace of Figure 4 shows the degree of valve opening in response to the PWM drive signal shown in the upper graph of the Figure. Imagine that a valve opening of 50% is desired and an appropriate drive signal is applied by the controller. Due to mechanical inertia and friction within the valve, there is a noticeable delay between the application of the drive signal and the valve opening to the desired degree. In most applications this will have undesirable consequences for the equipment incorporating the valve.

Figure 5 shows an improved drive signal in accordance with an embodiment of the present invention to address this problem. The upper trace shows the drive signal applied to the valve by the controller and the lower trace shows the degree of valve opening. Instead of applying the PWM immediately, the controller is programmed to apply the full drive voltage to the valve for an initial time period P1 when the valve is to be opened. After the initial time period the controller provides the PWM drive

signal in a closed loop manner during period P2 as previously described. It can be seen from the lower trace that the valve opens much more quickly to the desired degree in this embodiment when compared to the trace in Figure 4. The initial time period P1 may be predetermined or may be determined by the controller in response to a flow rate signal from the flow-rate sensor. The former has the advantage of simplicity while the latter will generally be more accurate (and avoid most, if not all, of any "overshoot").

Figure 6 shows a drive signal and valve response according to a further embodiment. In this case the initial drive signal applied during the initial time period does not have 100% duty cycle. The initial drive signal does have a greater magnitude (in the sense of driving the valve to a more open position) than the drive signal applied afterwards. This has the advantage that the valve will still attain the desired degree of opening quickly but may be less likely to overshoot that degree of opening.

When the initial drive signal has less than 100% duty cycle, the controller must determine the duty cycle to be used. One way of doing this is to estimate the duty cycle of the drive signal to be applied after the initial period and apply some uplift. The uplift could be a fixed percentage, for example 20% higher duty cycle, or it could be a fixed amount such as extending each pulse by a fixed duration. These techniques are purely exemplary and the skilled reader will understand how to program the controller in different circumstances. The estimation of the required duty cycle can be determined using the following equation:

duty cycle = control input (desired flow rate)/maximum flow rate of valve

This calculation assumes that the behaviour of the valve is linear i.e. that a drive signal having a 50% duty cycle will open the valve to 50%. However, this is often not the case in practice and also fails to take account of water supply pressure and aging of the valve.

To address this, in another preferred embodiment, the controller is arranged to store the behaviour of the valve as observed in operation. In other words, the controller stores the historical flow rate achieved in response to one or more levels of output drive signal. This permits the controller to estimate the duty cycle more accurately for the particular valve. For example:

Duty cycle of PWM output drive signal	Detected flow rate
33%	6.3 litre/minute
50%	8.8 litre/minute
100%	17.8 litre/minute

and so on. A more sophisticated control strategy could also take account of the input water pressure determined by another sensor (not shown).

In this embodiment, to make the estimation of the duty cycle, the controller takes two things into account – the degree of flow required and the previous behaviour of the valve. The degree of flow required is straightforward, typically having been received by the controller from further control circuitry. The controller is arranged to consult the table to select a suitable duty cycle for the degree of flow required. The controller may interpolate between entries in the table if no precise match is available for the desired flow rate.

Alternatively, the previous behaviour of the valve can be programmed during manufacture. This has the benefit that the valve arrangement will perform well "out of the box" but has the drawback of

requiring extra manufacturing steps. It is preferred that the controller is arranged to determine the behaviour of the valve in operation.

In addition, the failure of the control valve can be detected by the controller in the event that a drive signal is provided to the valve but the flow-measurement device indicates that no liquid is flowing. This may also occur in response to a lack of liquid flow (i.e. the source of the liquid has failed or been turned off). Where the controller is also receiving an output from a pressure sensor at the liquid inlet of the valve, it will be able to determine whether the lack of flow is due to failure of the valve or failure of the supply. The controller can provide fault signals locally to a user and/or remotely to a utility supplier as appropriate in response to these conditions. The controller may also determine when the valve is close to failure. This is done in response to the behaviour of the valve changing quickly, i.e. the expected flow rate differs markedly from the measured flow rate.

Figure 9 shows a graph similar to that of Figure 5 for control of an AC valve, such as a 240V valve in the UK.

Figure 9a shows two cycles of sinusoidal waveform representing mains voltage in the thinner lines. After each zero-crossing of the voltage, the controller applies a time delay (or phase delay) td1 before providing a gate signal to the semiconductor switch. The voltage is thus only applied to the valve for the time duration shown in the thicker lines. Current only flows through the valve solenoid for part of the AC cycle, reducing the drive signal to the valve.

Figure 9b shows two more cycles of sinusoidal waveform representing mains voltage in the thinner lines. However, the controller applies a longer time delay td2 meaning that the drive signal is weaker than that shown in Figure 9a. A suitable drive signal, therefore, may comprise the signal of Figure 9a followed by that of Figure 9b.

The initial drive signal may alternatively be a full drive signal in which there is no switching delay. This is equivalent to the 100% duty cycle of a PWM signal driving a DC valve.

Determining the time delays requires slightly more complex processing than the determination of duty cycles in the PWM arrangement because the AC voltage is varying. A delay of one quarter cycle will result in a 50% drive signal but shorter and longer delays have a non-linear relationship to the magnitude of the resulting drive signal. The controller can determine the relevant delay using a simple trigonometric algorithm.

Figure 7 shows a similar arrangement to that of Figure 2 with the addition of second valve in parallel to the first valve. This provides redundancy in the event of valve failure. The arrangement 700 comprises a liquid inlet 702 which is connected both to the inlet of a first valve 704 and to the inlet of a second valve 706. The outlets of the two valves are connected to respective flow sensors 708, 710 and the outlets of the flow sensors are combined to provide a single liquid outlet 712. A controller 714 is connected to receive flow-rate information from each of the flow-measurement devices 708, 710 and to output a respective drive signal to each of the control valves. The controller also receives a command signal 716 as before. In an alternative arrangement, only one flow-sensing device is provided at the outlet 712.

In operation, the controller operates in a similar manner to that described previously. Typically, the controller will select, for example, the first valve 704 to activate in response to a command signal 712. If the flow measurement device 708 fails to indicate any flow of liquid then the controller will cease to drive the first valve and will provide a drive signal to the second valve 706. If the flow sensor 710 now indicates that liquid is flowing, the controller will conclude that the first valve is

faulty. If there is still no liquid flowing then the controller will conclude that the liquid supply has failed. The controller can then notify the user and/or supplier as before.

Alternatively, the controller may drive both of the control valves to provide a combined flow in response to the command signal. However, this mode of operation is not favoured due to additional complexity in the control algorithm and unnecessary wear of both valves.

The controller may additionally be arranged, in normal operation, to distribute the wear between the two valves using alternate operation. This has the advantage over using a single valve until failure, which is that the hitherto unused valve is unlikely to seize closed due to non-use and liquid does not stagnate in the pipes. The controller may be programmed to achieve this end in a number of different ways. For example, the controller could be programmed to alternate between use of the valves which will require the controller to maintain only a simple toggle bit. Another technique could be to alternate use of the valves on different days or different weeks.

CLAIMS

1. A hot water supply system comprising:

a thermal energy store for storing energy received from a heat-pump, the energy store including a layer of insulation,

a heat-pump send connection and a heat-pump return connection connected to the thermal energy store,

a cold-water inlet coupled to the thermal energy store and a hot water outlet coupled to the energy store,

a controller,

a supplementary heater to supply the hot-water outlet, and

a valve for controlling a flow of water to at least one of the energy store and the supplementary heater,

the valve having at least a first liquid-flow path between a first port and a second port, the valve arranged to occupy either a first state in which the first liquid-flow path is closed or a second state in which the at least one liquid-flow path is open, the valve further comprising an electrical element such that the valve occupies one of the first and second states in response to a first drive signal applied to the electrical element and occupies the other of the first and second states in response to a second drive signal applied to the electrical element, wherein

the controller comprises a control input and a drive signal output, the control input specifying a desired liquid flow rate and the drive signal output arranged to drive the electrical element of the valve, the controller being adapted to determine a normal drive signal output in response to the control input, which drive signal is determined to control the valve to meet the desired flow rate, the controller further being adapted to apply an initial drive signal output followed by the normal drive signal output to the electrical element of the valve, the initial drive signal output having a greater magnitude than the normal drive output signal and being applied for an initial duration.

2. A hot water supply system as claimed in claim 1, wherein the controller further comprises a flow rate input responsive to flow rate information through the valve.

3. A hot water supply system as claimed in claim 2, further comprising a flow rate sensor arranged to provide the flow rate information to the flow rate input.

4. A hot water supply system as claimed in claim 3, wherein the flow rate sensor is incorporated into the valve.

5. A hot water supply system as claimed in any one of the claims 1 to 4, wherein the controller is further arranged to terminate the initial duration in response to the flow rate information.

6. A hot water supply system as claimed in any one of the claims 1 to 5, wherein the controller comprises at least one temperature input and is further arranged to determine the normal drive signal in response to a temperature in the hot water supply system.

7. A hot water supply system as claimed in any preceding claim, wherein the controller is further arranged to store data defining a relationship between the normal drive signal and an

indication of flow rate and to determine the normal drive signal in response both to the stored data and to the control input to provide a desired flow rate.

8. A hot water supply system as claimed in any one of the claims 1 to 7, wherein the initial duration is predetermined.

9. A hot water supply system as claimed in any one of the claims 1 to 8, wherein the greater magnitude drive signal is a maximum magnitude drive signal.

10. A hot water supply system as claimed in any one of the claims 1 to 8, wherein the valve is a DC valve, the output drive signal is a pulse-width-modulated (PWM) drive signal and the normal drive signal output has a duty cycle of less than 100%.

11. A hot water supply system as claimed in claim 10, wherein the initial drive signal output comprises a PWM signal having 100% duty cycle.

12. A hot water supply system as claimed in claim 10, wherein the initial drive signal output comprises a PWM signal having a duty cycle less than 100% and greater than the normal drive signal output.

13. A hot water supply system as claimed in claim 12, wherein the initial drive signal output comprises PWM signal having a duty cycle derived from the duty cycle of the normal drive output signal.

14. A hot water supply system as claimed in any one of the claims 1 to 9, wherein the valve is an AC valve, the output drive signal is a phase-controlled AC voltage and the normal drive signal has a finite phase delay.

15. A hot water supply system as claimed in claim 14, wherein the initial drive signal output comprises a phase-controlled AC voltage with a minimum phase delay.

16. A hot water supply system as claimed in claim 14, wherein the initial drive signal output comprises a phase-controlled AC voltage having a finite phase delay that is less than the phase delay applied to derive the normal drive signal output.

17. A hot water supply system as claimed in claim 16, wherein the initial drive signal output has a phase delay derived from the phase-delay of the normal drive output signal.

18. A hot water supply system as claimed in any one of the preceding claims, wherein the valve comprises a solenoid valve.

19. A hot water supply system as claimed in any one of the preceding claims, wherein the valve comprises a normally-closed valve.

20. A hot water supply system as claimed in any one of the claims 1 to 18, wherein the valve comprises a three-way valve.

21. A hot water supply system as claimed in any one of the preceding claims, further comprising another valve connected in parallel with the valve, the controller being arranged to further control the another valve in response to the control input.

22. A hot water supply system as claimed in claim 21, wherein the controller is arranged to use either the valve or the another valve according to a predetermined algorithm.

23. A hot water supply system as claimed in claim 22, wherein the algorithm defines alternate use of the first and second electrically-operated valves.

24. A hot water supply system as claimed in claim 22, wherein the algorithm defines use of either the first electrically-operated valve or the second electrically-operated valve according to different time periods.

25. A hot water supply system as claimed in any one of the preceding claims, wherein the thermal energy store comprises phase change materials.