

IMPROVEMENTS IN BALANCING AND CONTROL VALVES

The present invention relates to control valves and balancing valves commonly used in hydronic systems to monitor and adjust fluid flow rate and ensure a relatively steady flow of fluid through the system. The invention provides a control valve incorporating a novel design of balancing mechanism which results in better performance of a hydronic system when the improved valve is incorporated.

In fluid networks, it is common to distribute fluid from a source to one or more points of consumption (loads). In order to provide the correct amount of fluid under varying demands, one or more control valves are commonly provided. These control valves respond to a control signal to create variable restrictions in the system providing an appropriate amount of fluid to each load. For example, the control signal might be supplied by a thermostat, and the valve would respond by changing the flow of heating or cooling fluid through a heat exchanger. If these control valves are chosen with a maximum opening that is larger than the maximum needed for the application, then they must be controlled to close excessively at all times. This excessive closure results in unstable control as the control valve changes from an open to a closed condition repeatedly rather than settling at the proper location. Conversely, if the valve is chosen with too small a maximum opening, excessive pumping energy is required to address unnecessary pressure drops arising in the system. This problem is compounded by the fact that control valves are ordinarily available only in fixed steps, forcing the user to select one or another type of error.

These systems also normally have differing amounts of surplus pressure at different terminals. An ordinary control valve provides no means for reading the flow rate of the fluid, nor of manually adjusting its maximum opening which will cause an ordinary control valve to flow incorrectly. While the amount of surplus pressure might be calculated in theory, in practice the calculations are often not done due to their complexity, or are inaccurate due to construction variations. This problem is frequently addressed by installing balancing valves, which provide a calibrated

adjustable restriction and a means of measuring the flow rate. A balancing contractor is then employed to adjust these balancing valves throughout the system so that at maximum flow conditions all terminals receive the correct flow of fluid without excess.

A limitation of current techniques is that the restriction created by the balancing valve is not taken into account by the control valve, so that a portion of the control valve's stroke is wasted.

Some prior devices combine the function of a control valve and a balancing valve in a single unit, providing improved performance of the combined unit. With the control function and balancing accomplished by a single device, it is possible to provide improved control performance tailored to the exact conditions experienced at a given terminal.

The present invention seeks to provide a control valve with an integrated balancing component which overcomes the problems presented by prior art arrangements.

In accordance with the present invention, there is provided a combined balancing and control valve suitable for use in a hydronic system, the valve comprising a chamber enclosing a plug, a seat and an adjustment means for adjusting the separation of the plug and the seat, monitoring means for monitoring the rate of fluid flow across the separation and characterized in that the adjustment means comprises a motion transformation means operable by an actuator to restrict the motion of the valve plug whereby to provide a favourable change in conductance of the valve for a given change in the actuator position and in that the actuator is calibrated in increments which correspond to incremental changes in the conductance.

The adjustment needed for the balancing of circuits is accomplished by limiting the maximum opening of the control valve by use of a calibrated scale which provided a known restriction at any particular setting. The flow rate reading needed for the

balancing of circuits is accomplished by reading the differential pressure across the valve restriction. In one practical embodiment of the invention, the adjustment means includes a calibration means having a scale visible outside of the chamber and is operable to adjust a maximum possible separation of the plug and seat in increments corresponding to units provided on the scale. After the balancing procedure, the actuator can change the conductance of the valve to any appropriate value between closed and the set maximum value in response to an external control signal.

In preferred embodiments, the calibration means conveniently emerges from the chamber in the form of a rod having a linear scale presented along its length and linear movement of the rod is translated to one or both of the valve seat and plug whereby to adjust the separation of the seat and plug by an amount which corresponds to the distance travelled by the rod according to the linear scale.

In an option, the rod is surrounded by a threaded sleeve operable to limit its travel, which engages with a complementary thread fixed relative to the chamber and linear movement is effected by rotating the sleeve. Optionally, the sleeve could be prevented from rotating, and it could engage against a nut which is translationally fixed with respect to the housing. In either option, a scale may be provided about the circumference of the rotating element whether in addition to the aforementioned linear scale (for example to allow fine adjustment) or as the only scale.

Desirably the valve and seat are arranged in axial alignment with the intended direction of flow of fluid in the system. In an axial geometry, fluid flows into and out of the valve along a single axis, and the valve has a plug which moves along that same axis. This geometry provides reduced turbulence and consequently less noise than geometries which require the fluid to change direction excessively. This geometry also allows the valve to be more compact than other geometries.

In one preferred embodiment, the calibrated rod extends into the chamber to include a toothed rack portion, this engages with a pinion which in turn is fixed to a cam

plate of a cam mechanism which cam plate rotates with the pinion to effect movement of a cam follower, the cam mechanism being operable to adjust the separation of the plug and seat. The cam follower is conveniently fixed to a shaft to which in turn is fixedly mounted the seat or plug. As the cam follower follows the guide provided in the cam plate, axial movement of the shaft occurs thereby adjusting the separation of the plug and seat.

The geometry of the cam is selected to translate constant motion from an actuator into a favourable motion of the plug, thereby providing a favourable change in the fluid conductance of the valve in response to a control signal. For example, the cam might be so designed that the valve opening compensates for the output characteristic of a heat transfer device, thereby creating a more nearly linear relation between the control signal and the heat transfer. Such a linear relationship between the control signal and the desired controlled variable is sometimes referred to as a constant gain and is advantageous to control systems. The cam motion may also provide a mechanical advantage to an actuator in moving the plug as it nears its closed position, thereby reducing power needed to drive the actuator.

Preferably the plug and seat are configured to provide a fluid conductance which is approximately proportional to the movement of the plug. Optionally, the plug may be provided with partial differential pressure compensation, further reducing the needed power of the actuator.

Optionally, axial movement of the shaft is resisted by a biasing spring which might be arranged either to bias the valve in an open position or a closed position. Desirably, the biasing spring urges the valve to open, this assists in preventing oscillations.

It is common in control valves involving linear motion of the plug for the pressure of the system to urge the valve to an open position as a result of the pressure differential between the interior of the valve and the exterior location where the actuator is placed. Therefore in an optional improvement on the already described

invention, this problem is addressed by providing two shafts of equal diameters arranged for simultaneous axial movement in opposing directions between the two areas of different pressure.

As already stated, in some embodiments, one or more springs may be provided to create a biasing force, such that the valve is either always urged toward an open position or always urged towards a closed position. In such cases the balancing of the differential pressure may additionally be configured to provide a "biasing force" in the same direction.

By way of example an embodiment of the invention will now be further described with reference to the accompanying drawings in which:

Figure 1 shows a side view of a valve in accordance with the invention in partial cut away view;

Figure 2 shows a top view of the valve of Figure 1 in partial cut away view;

Figure 3 shows the valve in cross section partially through its travel;

Figure 4 shows an external side view of the valve with an electromechanical actuator attached.

The valve of Figure 1 generally comprises a housing (14, 17) which defines a chamber in which is provided a plug assembly (6, 10, 15, 16) and a seat (13) in axial alignment along the direction of flow of fluid in hydronic system. The plug (6, 10, 15, 16) is carried on a shaft (24) whose axis passes through the centre of the plug (6, 10, 15, 16). The shaft (24) also carries a cam follower assembly (23, 25). A calibration means is provided in the form of assembly (1, 2, 29, 30 and 31) which interacts with a rod (28) which passes through a sealed inlet chamber which is free to slide axially by means of a bearing mounted in the inlet. The rod is adapted to connect to an electromechanical or other controlled drive means. The calibrated stroke limiting mechanism (1, 2, 28, 29, 30, 31) is provided to adjust the maximum opening of the valve during a balancing procedure.

The rod (28) extends into the chamber in a direction perpendicular to the motion of the plug and parallel with the face of the plug (6, 10, 15, 16) in the form of a toothed portion. The toothed portion engages with a pinion gear (21) which is fixedly mounted by means of pin (26) to a cam plate which incorporates a guide (20) for a cam follower (23). The cam follower (23) is fixedly mounted on the shaft (24) and the pinion gear (21) passes through a slot in the shaft (24) so as not to obstruct its axial movement. As the rod moves axially, the pinion gear (21), through its engagement with the teeth of rod (28) is forced to rotate and the cam plate rotates with it. As the cam plate rotates, the cam follower (23) is forced to travel in the cam guide (20) carrying with it the shaft (24). Movement of the shaft (24) in any direction other than axially is prevented by the housing (14, 17), engagement of the pinion gear (21) in the slot of the shaft (24) and other components. The plug (6, 10, 15, 16), carried on the shaft (24) is also forced to move axially thereby adjusting the separation of the plug (6, 10, 15, 16) and seat (13). The distance over which the plug is caused to travel is measured by a scale provided on the area of the rod which emerges from the chamber. A distance travelled by the rod along the scale corresponds to a pre calculated travel distance for the plug (6, 10, 15, 16). The shaft (24) is assisted to move smoothly by rack bearings (12, 18, 19) which hold the rack portion against the pinion without impeding its linear motion.

Just behind the plug (6, 10, 15, 16) encircling the shaft (24) is a spring (4). The spring (4) is compressed so as to urge the plug (6, 10, 15, 16) and seat (13) to separate.

A chamber is formed between the plug (16) and cover plate (11) which is connected by a series of passages to strategically located points upstream of the plug (16). The pressure in this chamber partially compensates the pressure difference across the valve to reduce the actuation force required to move the plug.

Front and rear bearing plates (5, 22) seal around the shaft (24) at opposite ends separate fluid from air in the chamber. The circumference of the shaft (24) where it passes through each of the bearing plates (5, 22) is equal.

With reference to Figure 2 it can be seen that the pinion gear (21) is mounted in a rod bearing (34) and follower bearings (36, 37) assist in the smooth travel of the cam follower (23). By means of pin (39) and biasing spring (33), the positioning of the cam plate with respect to the cam follower (23) is biased so as to urge a return of the cam follower (23) to its position as shown in Figure 1, and consequently resists downward strokes of the rod.

The pressure differential across the valve is monitored using ports (42, 43) positioned on opposing sides of the chamber. The scale used on the calibration means (1, 2, 29, 30 and 31) is chosen to correlate with a scale used to monitor the differential pressure such that flow rate can be determined from these two readings.

In Figure 3, two regions of interest are shown with hatching patterns: a pressure compensation chamber (40) and its associated passages which connect to the upstream region of the chamber. Positioning of the passages is selected to give as little force against the actuator as possible while maintaining stability. The mechanism chamber (41) is separated from the fluid and is connected to the air outside of the chamber.

In use, a maximum operational flow is first applied to the valve and by using the combination of the calibration scale and the measured pressure differential at that flow rate, the optimal maximum separation of the plug and seat is identified and the valve adjusted to restrict the maximum separation to that optimum. After which a controlled drive means can operate an actuator to move the valve between a closed position and the optimum maximum opening position in the normal operation of the valve in response to the external control signal.

The following table summarises the referenced components in Figures 1, 2 and 3.

Ref:	Label	Notes
1, 2	Stroke Limit Setting	Used to set the maximum flow

4	Biasing Spring	Urges the mechanism toward an open position, helping prevent oscillation
5	Front bearing plate	Includes a seal around shaft 24, separating water from air
6	plug screw	Attaches two halves of the plug together, capturing the seal
7, 8, 9	Plug Position Calibration Setting	These parts are used during factory calibration to ensure that the plug presses against the seat with the correct force at the end of its stroke
6, 10,16, 15	Plug	Two metal pieces are held together with screws, and a resilient seal is held between them
15	Plug Seal	Resilient face of plug, which helps with sealing
11	mechanism sealing plate	Keeps water out of mechanism, removable for assembly and possible repair
12, 18, 19	Rack Bearing	
13	Seat	Cooperates with plug to create control restriction
14, 17	Housing	
20	Cam	
21	Pinion	Connected by a shaft to cam plate 20
22	Rear Bearing Plate	Includes seal around shaft 24 separating air from water again, but in the opposite direction: shaft 24 is compensated with respect to the pressure difference between water and air.
23	Follower Rod	The cam 20 has a groove which defines the motion of the plug. A follower moves within this groove, and includes a small shaft and a bearing. There are actually two bearings and two cams, but they function as a single cam/follower pair
24	Shaft	Transmits motion from the characterizing mechanism to the plug
25	Follower Shaft Pin	Connects the follower rod 23 to shaft 24
26	Cam Pin	Connects the cam to pinion
27	Mechanism support plate	Supports bearings for rack and pinion
28	Stem	Connects actuator to characterizing mechanism
29, 30, 31	Stroke Limit Setting	See 1,2 above
32	Housing Screw	Connects parts of the housing
33	Spiral Bias Spring	This component may be deleted in future versions
34	Pinion Rod Bearing	
35	Mechanism Support Plate	
36, 37	Follower Bearing	

38	Mechanism Support Screw	
39	Spiral Spring Pin	
40	Pressure compensation chamber	
41	Mechanism chamber	
42, 43	Pressure ports	Monitor differential pressure across the valve chamber

CLAIMS

1. A combined balancing and control valve suitable for use in a hydronic system, the valve comprising a chamber enclosing a plug (6, 10, 16, 15), a seat (13) and an adjustment means (20-28) for adjusting the separation of the plug (6, 10, 16, 15) and the seat (13), monitoring means for monitoring the rate of fluid flow across the separation and characterized in that the adjustment means comprises a motion transformation means (20-27) operable by an actuator (28) to control the motion of the valve plug (6, 10, 16, 15) whereby to provide a favourable change in conductance of the valve for a given change in the actuator position and in that the actuator (28) is calibrated in increments which correspond to incremental changes in the conductance.
2. A valve as claimed in claim 1 characterized in that the actuator comprises a rod (28) operable on linear motion to actuate the motion transformation means (20-27) to adjust separation of the plug (6, 10, 16, 15) and seat (13) and an associated calibration means (1, 2, 29, 30, 31) emerging from the chamber having a scale visible outside of the chamber and is operable to limit the maximum separation between the plug and seat which can be created by the actuator.
3. A valve as claimed in claim 1 or 2 characterized in that calibration means (1, 2, 29, 30, 31) consists of one or more threaded members (1, 31) arranged to block the linear travel of the actuator (28) by a predetermined increment based on the rotation of the one or more threaded members (1, 31).
4. A valve as claimed in any of claims 3 characterized in that a scale is provided about the circumference of the rotating threaded member (1, 31) whether in addition to the aforementioned linear scale or as the only scale.
5. A valve as claimed in any preceding claim characterized in that the valve plug (6, 10, 16, 15) and seat (13) are arranged in axial alignment with the intended direction of flow of fluid in the system.

6. A valve as claimed in any of claims 2 to 5 characterized in that the motion transformation means (20-27) engages with a toothed rack portion of the rod (28), which engages with a pinion (21) which in turn is fixed to a cam plate defining a cam guide (20) of a cam mechanism which cam plate rotates with the pinion (21) to effect movement of a cam follower (23), the cam mechanism being operable to adjust the separation of the plug and seat.
7. A valve as claimed in claim 6 characterized in that the cam follower (23) is fixed to a shaft (24) to which in turn is fixedly mounted the seat (13) or plug (6, 10, 16, 15) configured such that, as the cam follower (23) follows the guide (20) provided in the cam plate axial movement of the shaft (24) occurs thereby adjusting the separation of the plug and seat.
8. A valve as claimed in claim 6 or claim 7 including a biasing mechanism (32, 39) urging the rod (28) to emerge from the housing (14, 17).
9. A valve as claimed in claim 7 or 8 characterized in that the shaft (24) is received at opposing ends into front and rear bearing plates (5, 22) and has the same diameter where it passes through each of the two bearing plates (5, 22).
10. A valve as claimed in any of claims 1 to 9 characterized in that the actuator (28) is driven by a drive means which is responsive to an external control signal to drive the actuator (28) and wherein the motion transformation means (20-27) is configured to translate constant motion of the drive means and actuator into a favourable motion of the plug (6, 10, 16, 15), thereby providing a favourable change in the fluid conductance of the valve in response to the control signal.

11. A valve as claimed in any preceding claim characterized in that the plug (6,10, 16, 15) and seat (13) are configured to provide a fluid conductance which is approximately proportional to the movement of the plug (6,10, 16, 15).
12. A valve as claimed in any preceding claim characterised in that the plug (6, 10, 16, 15) is provided with a partial differential pressure compensation.
13. A valve as claimed in any preceding claim characterised in that axial movement of the plug (6, 10, 16, 15) relative to the seat (13) is resisted by a biasing spring (4).
14. A valve as claimed in claim 13 characterised in that the biasing spring (4) is arranged to urge the valve to open.
15. A valve as claimed in any preceding claim characterised in that fluid pressure is transferred through internal chambers to minimise the force required from the driven actuator (28) to overcome a given pressure difference between the inlet and outlet.
16. A valve as claimed in any preceding claim characterised in that the adjustment means (20-28) is operable in response to constant actuation to cause the valve to provide a change in the separation that approximately follows the equation:

$$K_v = \frac{K_{vs} \cdot \phi}{\frac{1}{h} - 1 + \phi}$$

where K_v is the conductance of the valve at a given position of the actuator, K_{vs} is a maximum conductance of the valve, h is the position of the actuator ranging from 0 for a fully closed valve to 1 for fully open valve separation, and ϕ is an "EQM coefficient".

17. A valve as claimed in any preceding claim 1 configured to adjust the separation between the plug (6, 10, 16, 15) and seat (13) in a smooth and continuous fashion from a fully open position to the fully closed position.
18. A valve as claimed in claim 17 wherein the plug (6, 10, 16, 15) includes a resilient sealing means (15), said sealing means (15) being configured to cooperate with the seat (13) through most of the travel of the plug.
19. A valve according to any preceding claim wherein the motion transformation means (20-27) is located within the path of the fluid flow.
20. A valve of any preceding claim characterised in that it is configured such that the plug (6, 10, 16, 15) can be adjusted to reach its fully closed position at a predefined travel of the actuator (28).
21. A valve of any preceding claim further characterised in that monitoring means and calibration means are together configured to enable a user to calculate the flow rate of fluid through the valve from a reading on the scale of the calibration means (1, 2, 29, 30, 31) and a determination of the differential pressure across the valve.
22. A valve of any preceding claim further characterised in that monitoring means incorporates a processor configured to calculate the flow rate of fluid through the valve from a reading on the scale of the calibration means (1, 2, 29, 30, 31) and a determination of the differential pressure across the valve.
23. A valve as claimed in claim 22 wherein the processor comprises a reference chart from which the flow rate for a given differential pressure and scale increment on the calibration means (1, 2, 29, 30, 31) can be identified.
24. A valve of claim 21 or 22 wherein the processing means is automated.