

PRESSURE REDUCING DEVICE, HOT AND COLD WATER SUPPLY SYSTEM
USING SAID PRESSURE REDUCING DEVICE, AND METHOD OF SELECTING
THE PRESSURE REDUCING DEVICE USED IN SAID SYSTEM

BACKGROUND OF THE INVENTION

Field of the Invention

This invention concerns a pressure reducing device, a hot and cold water supply system using this pressure reducing device, and a method of selecting a pressure reducing device to be used in this system.

Description of the Prior Art

With a conventional, pressure-fed type hot and cold water supply system, a cold water supply pipe and a hot water supply pipe are connected at a combination faucet and hot/cold water of a preset temperature is supplied from a water tap, such as a faucet or shower or bath tap, etc., at the service terminal in each household (room).

However, with the abovementioned system, a variation of the cold water supply load or hot water supply load in the cold water supply pipe or hot water supply pipe accompanies a pressure variation and thus gives rise to a variation of water temperature at the water tap of each household, etc.

A cause of this lies in the direct-acting type pressure reducing valve that is connected to the piping at the discharge side of a pump that is installed at each of the cold water supply pipe and hot water supply pipe.

Since the discharge pressure of a pump is high, the pressure reducing valves are installed as mentioned above in the cold water supply pipe and hot water supply pipe to reduce the pressure to a level that enables use at a cold water supply pipe terminal or hot water supply pipe terminal of each household, etc.

Thus with an abovementioned pressure reducing valve, the variation of the valve-outlet pressure with respect to the consumption amount of hot/cold water is large and when the consumption amount of hot/cold water changes due to use of the respective water taps, since the variations of the respective valve-outlet pressures of the cold water supply pipe and hot water supply pipe are large, the flow rates of the cold water from the cold water supply pipe and the hot water from the hot water supply pipe, which are in accordance to the preset temperatures, vary, causing the pressure at the cold water supply side or hot water supply side to drop or rise suddenly during use and thereby causing hot/cold water that is lower or higher in temperature than the preset temperature to be

supplied.

Though in order to secure the respective flow rates of hot water and cold water with such a pressure reducing valve, the ratio of the effective diameter of the diaphragm with respect to the valve port diameter of the pressure reducing valve must be made large, this cannot be put into practice as it will make the pressure reducing valve itself become too large.

SUMMARY OF THE INVENTION

An object of this invention is to provide a pressure reducing device, a hot water supply system using this pressure reducing device, and a method of selecting a pressure reducing device to be used in this system, with which pressured water can be supplied in a stable manner even when the consumption amount varies.

In view of the above theme, with this invention, by providing a main valve, wherein a master valve, which opens and closes a valve port that puts into communication a valve-inlet pressure chamber and a valve-outlet pressure chamber that are provided in the interior of the main body of the main valve, is urged in the closing direction by means of a spring and a diaphragm that is coupled to the master valve

partitions a diaphragm chamber, which is provided at the rear side of the diaphragm, and the valve-inlet pressure chamber, disposing a pilot pipeline, having a pressure reducing valve interposed therein, between the abovementioned valve-inlet pressure chamber and valve-outlet pressure chamber, and in this pipeline, connecting a branch pipeline, provided at the valve-inlet side (upstream side) of the pressure reducing valve, to the abovementioned diaphragm chamber and disposing a restriction means upstream the branching point to restrict, by means of the restriction means, the amount of water that is passed from the valve-inlet pressure chamber of the main body to the valve-inlet pressure chamber of the pressure reducing valve and the diaphragm chamber, the pressure in the diaphragm chamber is made to drop to thereby cause the main body to open when the pressure reducing valve is opened by the use of water.

That is, when by the use of water, the valve-outlet pressure falls below the preset value, the same amount of water as the amount of water used passes through the main body so that the valve-outlet pressure will not be decreased greatly. Supplying of water at a stable pressure is thus enabled even when the consumption amount changes.

And by equipping a hot and cold water supply system with

a pressure reducing device that has been selected based on a fixed set of conditions, hot water of the desired temperature can be supplied in a stable manner, thereby solving the above-described problems.

Thus with the first aspect of the invention, since pilot pipeline 3, in which pressure reducing valve 4 is interposed, is installed between the valve-inlet pressure chamber 8 and valve-outlet pressure chamber 9 of main valve 2 of the above-described arrangement and since in pilot pipeline 3, branch pipeline 3a, which is installed at the valve-inlet side of pressure reducing valve 4, is connected to diaphragm chamber 14 and restriction means 20 is installed upstream the branching point M, the pressure reducing valve 4 opens when, due to the consumption of water at the valve-outlet side of main body 2, the valve-outlet pressure P_4 falls below the preset pressure P_s , and at this time, since the flow volume Q_2 from valve-inlet pressure chamber 8 of main body 2 to valve-inlet pressure chamber 25 of pressure reducing valve 4 and diaphragm chamber 14 is restricted by restriction means 20, that is, since an arrangement is made so that the flow rate Q_1 at pressure reducing valve 4 when the valve-outlet pressure P_4 falls from its preset pressure P_s to the lower limit P_L of the allowable range will exceed the flow rate Q_2 restricted by restriction means 20,

the pilot valve-inlet pressure P_2 and the pressure P_3 of diaphragm chamber 14 drop drastically at once, enabling main valve 17 to be displaced in the opening direction and be opened along with diaphragm 13.

The same amount of water as the consumption amount can thereby be made to pass through valve port 11 and since the consumption amount and the amount of water passing through the valve port is substantially matched, the valve-outlet pressure P_4 will not drop greatly. That is, by satisfying the above-described condition of flow rate $Q_1 > \text{flow rate } Q_2$, pressure control of pressure reducing device 1 by pressure reducing valve 4 is enabled from the preset valve-outlet pressure P_s to the lower limit P_L of the allowable range of the valve-outlet pressure P_4 when the consumption amount is less than or equal to the maximum consumption amount F_m , and thus the width of pressure variation in this control process can be narrowed significantly in comparison to the prior art, with which the valve-outlet pressure drops greatly as the consumption amount increases.

Thus by the present invention, pressured water can be supplied in a stable manner even when the consumption amount varies.

Moreover, since pressure reducing device 1 is arranged

from a pressure reducing valve 4, which controls the opening and closing of main body 2 upon detection of the valve-outlet pressure P_4 , and main body 2, which regulates the flow rate in accordance to the instruction of pressure reducing valve 4, the ratio of the valve port diameter to the effective diameter of diaphragm 13 of main body 2 can be made small in comparison to that of the prior art and main body 2 can thus be made more compact.

With the second aspect of the invention, since the separate restriction means 21 is installed in branch pipeline 3a of the above-described pressure reducing device 1, the flow volume that enters and exits between valve-inlet pressure chamber 25 of pressure reducing valve 4 and diaphragm chamber 14 via restriction means 21 can be restricted so that the pressure P_3 inside diaphragm chamber 14 will not change suddenly even when the pilot valve-inlet pressure P_2 of pressure reducing valve 4 changes due to consumption of water or stoppage of consumption at the valve-outlet side of main body 2. The operation of main valve 17 of main body 2, which is opened and closed by this change of pressure P_3 , can thus be made gradual and the water hammer and other problems that occur at the upstream side of main body 2 when main valve 17 is opened or closed suddenly can be prevented.

The third aspect of the invention provides hot and cold water supply system Z, with which cold water supply pipe X1 and hot water supply pipe Y1, which branch downstream the pressure reducing devices 1 of cold water supply pipeline X and hot water supply pipeline Y of the above-described arrangement, are joined at a combination faucet C and connected to water tap W, and since each pressure reducing device 1 is selected so that the valve-outlet pressure P_4 will be within the allowable range at consumption amounts less than or equal to the maximum consumption amount F_m , even when the consumption amount of hot water or cold water changes due to consumption at the respective faucets C, the valve-outlet pressure P_4 varies only within the allowable range and the flow rates in accordance to the preset temperature of the cold water from cold water supply pipe X and hot water from hot water supply pipe Y do not vary. Hot/cold water of the preset temperature is thus supplied in a stable manner from water tap W.

The fourth aspect of the invention provides hot and cold water supply system Z1, with which cold water supply pipe X1 and hot water supply pipe Y1, which branch between the respective pressure reducing devices 1 and flow regulation means X3 and Y3 of cold water circulation line Xa and hot water circulation line Ya of the above-described arrangement, are

joined at a combination faucet C and connected to water tap W, and since each pressure reducing device 1 is selected so that the valve-outlet pressure P_4 will be within the allowable range even when the consumption amount exceeds the preset maximum consumption F_m of hot water or cold water and the respective circulation flows of cold water circulation line X_a and hot water circulation line Y_a are set within a flow rate range derived from the difference between the consumption limit F_s , based on the above-described allowable range, and the maximum consumption amount F_m , the variation width of the valve-outlet pressure P_4 with respect to the consumption amount can be maintained within the allowable range up to the consumption limit F_s , which exceeds the maximum consumption amount F_m of hot/cold water, even when the circulation flow rate is set to less than or equal to the difference between the consumption limit F_s and the maximum consumption amount F_m .

Since the initial value of the valve-outlet pressure P_4 is thereby lessened by the pressure corresponding to the preset circulation flow rate, the variation width of the valve-outlet pressure P_4 can be narrowed correspondingly to further stabilize the flow rates according to preset temperature of the cold water from cold water supply pipe X and hot water from

hot water supply pipe Y and thus further stabilize the supply of hot/cold water of the preset temperature.

Also, with cold water supply pipe X and hot water supply pipe Y of hot and cold water supply system Z, even in the case where use of the respective water taps W is stopped at once and the pilot valve-inlet pressure P_2 rises due to the resulting closure of pressure reducing valve 4, the pressure P_3 at diaphragm chamber 14 is prevented from rising immediately and main valve 17 is made to open slowly by restriction means 21, and there is thus a possibility for the valve-outlet side of main body 2 to tend to rise in pressure to the preset valve-inlet pressure P_f due to the passage of water from the valve-inlet side to the valve-outlet side of main body 2 in the interval until the closure of the valve. However, with hot and cold water supply system Z1, since water is constantly circulated at preset (circulation) flow rates in each of the cold water circulation line Xa and hot water circulation line Ya, the pressure at the valve-outlet side of main body 2 will not rise to the preset valve-inlet pressure P_f even in the above case.

Since a fixed amount of water is thus constantly passed through main body 2, the chattering that occurs when the consumption amount at a water tap W is low can be prevented, and since cold water and hot water are circulated through cold

water circulation line Xa and hot water circulation line Ya, respectively, hot/cold water of the preset temperature can be used immediately at water tap W. This makes the supply system extremely easy to use and convenient for hospitals, hotels, etc., where hot/cold water are used throughout the day on the average.

With the fifth aspect of the invention, since the flow characteristics curves a to c of various main valve candidates, indicated in flow characteristics graph II, are converted and indicated in flow characteristics graph I, in which, based on determined items (the maximum consumption amount F_m of hot water or cold water, preset valve-inlet pressure P_f , preset valve-outlet pressure P_s , and variation width of the valve-outlet pressure P_v with respect to the consumption of hot/cold water) of a hot and cold water supply system Z or Z1, the flow characteristics curve A of a pressure reducing valve 4 is indicated, having a restriction means 20 connected to the upstream side, and since a main valve 2, which corresponds to the flow characteristics curve a with which the intersection coordinates, among the coordinates Ra to Rc of intersection of the flow characteristics curve A of the abovementioned pressure reducing valve 4 with the flow characteristics curves a to c of the main valve candidates, exceed the abovementioned

maximum consumption amount F_m and is lowest in the difference with respect to the preset valve-outlet pressure P_s , is selected, a main valve 2 of a capacity that meets the various setting conditions can be selected simply and the capacity of pressure reducing device 1 can be ascertained by means of flow characteristics graph I.

Especially in the selection of the respective pressure reducing devices 1 to be used in hot and cold water supply system Z1, when a main valve of a capacity such that the valve-outlet pressure P_4 will lie within the allowable range even when the maximum consumption amount F_m of hot water or cold water is exceeded is selected, that the difference between the consumption limit F_s , based on the allowable range, and the preset maximum consumption amount F_m is within the range of the respective circulation flows of cold water circulation line Xa and hot water circulation line Ya can be read from graph I and the circulation flows can thus be determined within this range.

Also, though the flow characteristics curve A of pressure reducing valve 4, which is illustrated in flow characteristics graph I, is drawn by making measurements upon connecting a restriction means 20 at the upstream side of pressure reducing valve 4, which has been selected under the condition that the

preset valve-outlet pressure P_s lies within the pressure adjustment range, and arranging so that (the flow rate of pressure reducing valve 4) $Q_1 >$ (supply flow rate restricted by restriction means 20) Q_2 when the valve-outlet pressure P_4 reaches the lower limit P_L of the allowable range, since under the condition, $Q_1 > Q_2$, the flow characteristics curve A will be a straight line, which has a slightly rightward-declining slope and is substantially parallel to the x-axis of graph I, and since this slope will be fixed for any pressure reducing valve 4, it is sufficient to simply indicate a flow characteristics curve A having the preset value P_s of the valve-outlet pressure P_4 corresponding to a flow rate of 0 as the starting point and having the abovementioned slope.

With the sixth aspect of the invention, since the flow characteristics curve A of pressure reducing valve 4 that is indicated in flow characteristics graph I is substantially the same as the horizontal straight line (parallel to the x-axis, which expresses the flow rate in graph I) that passes through the lower limit P_L of the allowable range of the valve-outlet pressure P_4 as has been described above, there will be no problems in the selection of main valve 2 even when flow rate characteristics curve A is replaced by the straight line indicated by the alternate long and short dash line in Fig.

9. Significant practical effects, such as the enabling of graph I for this selection to be prepared readily, etc., are thus provided.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

An embodiment of this invention shall now be described based on the drawings.

Fig. 1 shows a sectional view of a pilot-actuated type pressure reducing device. This pressure reducing device 1 is mainly comprised of the main valve main body 2, which is installed in each of a cold water supply pipe and a hot water supply pipe, and a pressure reducing valve 4, which is connected to main body 2 by a pilot pipeline 3.

The valve box 5, provided in main body 2, has an inlet 6 and an outlet 7 opened at its right and left sides, respectively, and a valve-inlet pressure chamber 8 and a valve-outlet pressure chamber 9, which are in communication with inlet 6 and outlet 7, respectively, are provided in the interior of valve box 5. Valve-inlet pressure chamber 8 and valve-outlet pressure chamber 9 are partitioned and formed at the outer side and inner side, respectively, in the interior of valve box 5 by a partition wall 10. A valve port 11, which is directed upwards in the direction orthogonal to inlet 6 is

formed in partition wall 10, and valve-inlet pressure chamber 8 and valve-outlet pressure chamber 9 are put in communication with each other via this valve port 11.

Also, an opening 5a, which is in communication with valve-inlet pressure chamber 8 and valve port 11, is provided at the upper part of valve box 5, and this opening 5a is closed by a diaphragm 13, which is interposed between valve box 5 and a bonnet 12, capped onto valve box 5.

Bonnet 12 is provided at its inner side with a recessed space, which is partitioned from the interior of valve box 5 by diaphragm 13, and this space corresponding to the rear side of diaphragm 13 is used as a diaphragm chamber 14. A port 15, which is connected to pilot pipeline 3 is provided at the center of the upper part (corresponding to bonnet 12) of this diaphragm chamber 14.

At the lower surface of diaphragm 13, a master valve 17 is arranged by protruding the lower surface of diaphragm 13 in a substantially annular manner so as to correspond to a valve seat 16 provided along the circumference of valve port 11, and by thus forming master valve 17 to be integral with diaphragm 13, master valve 17 and diaphragm 13 are coupled.

Diaphragm pressers 18 and 18a of substantially disk-like shape are joined respectively to the upper surface of

diaphragm 13 corresponding to master valve 17 and the lower surface of diaphragm 13 at the inner side of master valve 17.

A spring 19 is interposed in the compressed condition between the upper part of diaphragm chamber 14 and diaphragm presser 18, and master valve 17 is urged in the closing direction by this spring 19.

Pilot pipeline 3 connects the ports 15a and 15b, provided in valve-inlet pressure chamber 8 and valve-outlet pressure chamber 9, respectively, of main body 2, to the exterior, and in pilot pipeline 3, a branch pipeline 3a is provided at the valve-inlet side (upstream side) of the pressure reducing valve 4 interposed in the pipeline 3. This branch pipeline 3a is connected to port 15 provided on diaphragm chamber 14, and in pilot pipeline 3, restriction means 20 and 21, each comprised of a needle valve, are provided respectively at a part at the upstream side of branching point M and a part in branch pipeline 3a.

The flow capacity (flow rate Q_1) of pressure reducing valve 4 is set to exceed the supply capacity (flow rate Q_2) restricted by restriction means 20 when the valve-outlet pressure P_4 drops from its preset pressure P_s to a lower limit value P_L of an allowable range (range in which hot/cold water can be supplied at a stable pressure).

That is, pressure reducing valve 4 is set to satisfy the condition $Q_1 > Q_2$.

Pressure reducing device 1 thus enables the valve-outlet pressure P_4 to be controlled within the allowable range at or below a preset maximum consumption amount F_m in a hot and cold water supply system in which pressure reducing device 1 is incorporated.

Pressure reducing valve 4 has an inlet 23 and an outlet 24, connected to pilot pipeline 3, opened at the right and left sides, respectively, of its valve box 22, and a valve-inlet pressure chamber 25 and a valve-outlet pressure chamber 26, which are in communication with inlet 23 and outlet 24, respectively, are provided in the interior of valve box 22. Valve-inlet pressure chamber 25 and valve-outlet pressure chamber 26 are respectively partitioned and formed at the right side and left side, respectively, in the interior of valve box 22 by a partition wall 27. A valve port 28, which is directed downwards in the direction orthogonal to inlet 23 is formed in partition wall 27, and the pressure chambers 25 and 26 are put in communication with each other via this valve port 28.

At the upper part of valve box 22 is provided a recessed part 29 of substantially plate-like shape that is opened in the upward direction. A part of the bottom of this recessed

part 29 is opened and communicated with valve-outlet pressure chamber 26, and recessed part 29 is closed by a diaphragm 31, which is interposed between recessed part 29 and a spring cover 30, which is capped onto recessed part 29.

An adjustment spring 35 is interposed in the compressed condition between a diaphragm presser 32, which is bonded to the upper surface of diaphragm 31, and an adjustment screw 34, which is screwed onto a cylindrical female thread part 33 that is formed in the interior of spring cover 30 so as to descend from the upper end of spring cover 30. The resilient force of adjustment spring 35 is adjusted by moving adjustment screw 34 up or down.

At the center of the lower part of recessed part 29 that corresponds to valve port 28 is provided an opening 36 for communication with valve-inlet pressure chamber 25, and a cylindrical part 37 of a predetermined length is provided so as to extend downwards in continuation from opening 36.

Meanwhile, a valve rod 38, which is inserted through cylindrical part 37 and valve port 28, is formed in a descending manner at the center of diaphragm 31, and a valve plug 39, which opens and closes valve port 28, is provided at the lower end of valve rod 38.

Valve plug 39 is provided in a manner enabling attachment

to and detachment from a valve seat 40, which is provided at the circumference of valve port 28 so as to receive the valve-inlet pressure in the valve-opening direction, and the opening of valve plug 39 is arranged to be controlled by the displacement of diaphragm 31.

Also, a piston 41, which slides along the inner wall of cylindrical part 37 is provided in an outwardly protruding manner on an intermediate portion of valve rod 38, and an O-ring 42 is provided on the circumference of piston 41 so as to partition valve-inlet pressure chamber 25 and recessed part 29 (valve-outlet pressure chamber 26) in a watertight manner.

A diaphragm presser 32a, which is joined to the lower surface of diaphragm 31, is formed to be larger in diameter than opening 36, and in the condition where diaphragm 31 is displaced to the lowermost limit, this diaphragm presser 32a becomes seated along the peripheral edge of opening 36 so as to close opening 36 and restrict the lifting of valve plug 39 in this condition.

Pressure reducing valve 4 is not limited to that of the above-described arrangement as long as it has a pressure reducing function and it is sufficient that it functions as a pilot valve of main body 2.

The actions of pressure reducing device 1 shall now be

described based on Fig. 1.

In the following, a description shall be given with:

the valve-inlet pressure P_1 being the pressure at the upstream side connected to valve-inlet pressure chamber 8 of main body 2,

the valve-inlet pressure P_4 being the pressure at the downstream side connected to valve-outlet pressure chamber 9 of main body 2,

the pilot valve-inlet pressure P_2 being the pressure at the upstream side connected to valve-inlet pressure chamber 25 of pressure reducing valve 4 in pilot pipeline 3,

the diaphragm pressure P_3 being the pressure inside diaphragm chamber 14 of main body 2,

P_f (referred to hereinafter as preset valve-inlet pressure P_f) being the preset pressure at the valve-inlet side of main body 2, and

P_s (may also referred to hereinafter as preset valve-outlet pressure P_s) being the (pressure) value of valve-outlet pressure P_4 that is set by pressure reducing valve 4, as shown in Fig. 1.

When the valve-outlet side of main body 2 is closed, main body 2 and pressure reducing valve 4 are respectively closed and the following conditions are maintained for the respective

pressures of Fig. 1:

$$P_1 = P_2 = P_3 = P_f \text{ and } P_4 = P_s$$

When the valve-outlet side is opened from the above-described closed condition, since the valve-outlet pressure P_4 drops from its preset pressure P_s , pressure reducing valve 4 opens, causing pilot valve-inlet pressure P_2 to fall from the preset valve-inlet pressure P_f and a flow to form in pressure reducing valve 4.

In this condition, since the flow volume from the upstream side (valve-inlet pressure chamber 8 of main body 2) to valve-inlet pressure chamber 25 of pressure reducing valve 4 and diaphragm chamber 14 is restricted by restriction means 20, when the valve-outlet pressure P_4 falls below the preset value P_s , the (pilot) valve-inlet pressure P_2 of pressure reducing valve 4, which is in the opened condition, will decrease drastically at once, and in accompaniment, the diaphragm chamber pressure P_3 of main body 2 will likewise drop and main valve 17 will be displaced in the opening direction and be opened, causing valve-inlet pressure chamber 8 and valve-outlet pressure chamber 9 to be in communication and water to be passed from the valve-inlet side to the valve-outlet side via main body 2.

Since the flow volume from diaphragm chamber 14 to the

valve-inlet pressure chamber 25 of pressure reducing valve 4 is restricted by restriction means 21, the pressure drop of the abovementioned diaphragm chamber pressure P_3 will progress more gradually than that at valve-inlet pressure chamber 25.

The opening of main valve 17 is thus made to occur gradually and the occurrence of water hammer and other problems at the upstream side of main body 2 due to the opening of main valve 17 is thus prevented.

Here, the abovementioned condition of $Q_1 > Q_2$ was made to be satisfied when the valve-outlet pressure P_4 drops to the lower limit P_L of the allowable range since, with pressure reducing device 1, it may be necessary for the maximum consumption amount F_m to be supplied when the valve-outlet pressure P_4 has dropped to the lower limit P_L of the allowable range, and in this case, in order to open main body 2 to supply the maximum consumption amount F_m from pressure reducing device 1, a drop of the pilot valve-inlet pressure P_2 that is adequate for the opening of main valve 17 cannot be expected unless the flow capacity (flow rate Q_1) of pressure reducing valve 4 when valve-outlet pressure P_4 has dropped to the lower limit P_L of the allowable range exceeds the supply capacity (flow rate Q_2) that flows from restriction means 20. Thus by setting the above condition, pressure reducing device 1 can perform stable

control by means of pressure reducing valve 4 in the range from the preset valve-outlet pressure P_s to the lower limit P_L of the allowable range of the valve-outlet pressure P_4 at a consumption amount less than or equal to the maximum consumption amount F_m .

Fig. 6 is a flow characteristics graph (with the x-axis being the consumption amount (flow rate) and y-axis being the valve-outlet pressure) of a solitary pressure reducing valve (without restriction means 20 connected) selected with a preset valve-outlet pressure P_s of 0.30MPa. In the case where the maximum consumption amount F_m must be supplied when the lower limit P_L of the allowable range of the valve-outlet pressure P_4 is 0.27MPa, since from Fig. 6, the flow rate Q_1 of pressure reducing valve 4 when the valve-outlet pressure P_4 is 0.27MPa is 8l/min, control in the above manner can be performed by setting the flow rate Q_2 restricted by restriction means 20 to less than 8l/min.

Thus when the valve-outlet pressure P_4 falls below the preset pressure P_s due to use of water at the valve-outlet side, the valve port 11 of main body 2 opens to enable the same amount of water as the consumption amount to pass through valve port 11, and since the consumption amount substantially matches the amount of water passing through the valve port, the valve-

outlet pressure P_4 does not drop much and the variation width of this pressure is therefore significantly narrow in comparison to that of a pressure reducing valve of the prior art.

This can also be understood clearly from the flow characteristics graph (Fig. 7), which shows the relationship between the consumption amount (x-axis) and the valve-outlet pressure (y-axis) of pressure reducing device 1, and the flow characteristics graph (Fig. 13), which shows the relationship between the consumption amount (x-axis) and the valve-outlet pressure (y-axis) of a prior-art direct-acting type pressure reducing valve (referred to hereinafter as the "prior art").

The graphs of Figs. 7 and 13 are the results of measurements made with the maximum consumption amount being set to 300l/min, the preset valve-inlet pressure P_1 being set to 0.50MPa, and preset valve-outlet pressure P_2 of pressure reducing valve 4 of pressure reducing device 1 and of the prior art being set to 0.30MPa.

With pressure reducing device 1 (Fig. 7), the variation width of the valve-outlet pressure P_4 between a consumption amount of 0 to 300l/min is the difference between the valve-outlet pressure P_4 (= 0.30MPa) at 0l/min and the valve-outlet pressure P_4 (= 0.27MPa) at 300l/min, that is,

approximately 0.03MPa.

In contrast, with the prior art (Fig. 13), the difference between the valve-outlet pressure P_4 ($= 0.30\text{MPa}$) at 0l/min and the valve-outlet pressure P_4 ($= 0.10\text{MPa}$) at 300l/min is approximately 0.20MPa and it is quite apparent that the variation width of the valve-outlet pressure P_4 is narrower with pressure reducing device than with the prior art.

When the opening of the valve-outlet side is stopped from the above-described water passing condition, the valve-outlet pressure P_4 , which was lower than the preset valve-outlet pressure P_s , when water was being passed through, rises due to the supply of water from main body 2, and at the same time that this pressure reaches the preset value P_s , the valve plug 39 of pressure reducing valve 4 closes, and due to this closure, the pilot valve-inlet pressure P_2 rises to the preset valve-inlet pressure P_f .

Here, since the amount of water passed through diaphragm 14 is restricted by restriction means 21 in branch line 3a, the diaphragm chamber pressure P_3 rises gradually, main valve 17 becomes slowly displaced in the closing direction along with diaphragm 13 in accompaniment with this pressure rise, and when the diaphragm chamber pressure P_3 becomes equal to the preset valve-inlet pressure P_f , main valve 17 closes to stop the

passage of water.

The piping schematics of a hot and cold water supply system Z, which makes use of pressure reducing device 1, is shown in Fig. 4.

With this hot and cold water supply system Z, each of a cold water supply pipeline X and a hot water supply pipeline Y is equipped with pressure reducing device 1, and at the downstream side of pressure reducing device 1, a plurality of cold water supply pipes X1 and hot water supply pipes Y1 are branched respectively from cold water pipeline X and hot water supply pipeline Y. A cold water supply pipe X1 from cold water supply pipeline X and a hot water supply pipe Y1 from hot water supply pipeline Y are joined at a combination faucet C and connected to a water tap W.

With cold water supply pipeline X, fixed rate and variable rate pumps XP1 and XP2 are connected in parallel or one of either pump XP1 or XP2 is connected to the feeding side of a water receiving tank X2, the inlet 6 of main body 2 of pressure reducing device 1 is connected to the discharge side of the pumps XP1 and XP2 and the outlet 7 is connected to the downstream side of cold water supply pipeline X.

Hot water supply pipeline Y has a pipe path arranged with substantially the same equipment as those mentioned above.

That is, parallel-connected fixed rate and variable rate pumps YP1 and YP2 or one of either pump YP1 or YP2 and pressure reducing device 1 are installed in that order starting from the feeding side of a water receiving tank Y2, which is equipped with a heating device H, such as an electric water heater, boiler, etc.

With cold water supply pipeline X and hot water supply pipeline Y, devices (not shown) that detect changes in pressure or flow rate are installed at parts located at the discharge sides of pumps XP1, XP2, YP1, and YP2 and upstream side of main bodies 2, and by means of these devices, the number of pumps XP1, XP2, YP1, and YP2 that are in operation is increased or decreased or the number of times of operation of pumps XP1, XP2, YP1, and YP2 is changed to change the flow rate and pressure.

The actions of pressure reducing devices 1 in hot and cold water supply system Z shall now be described based on Figs. 1 and 4.

Each of the pressure reducing devices 1 used in this hot and cold water supply system has been selected based on the selection method to be described below so that the valve-outlet pressure P_1 will be within an allowable range (range in which hot/cold water can be supplied at a stable pressure) when the

hot/cold water consumption amount is less than or equal to the maximum hot/cold water consumption amount F_m that has been set.

Here, pressure reducing devices 1 of the flow capacity shown in Fig. 7 are used with the maximum hot/cold water consumption amount F_m being set to 300l/min, the preset valve-inlet pressure being set to 0.50MPa, and preset valve-outlet pressure being set to 0.30MPa.

It can be understood (see Fig. 7) that with pressure reducing devices 1 of the above capacity, the variation width of the valve-outlet pressure P_4 with respect to the consumption of hot/cold water can be maintained adequately within the allowable range (approximately 0.03MPa) as long as the maximum hot/cold water consumption amount F_m is 300l/min or less.

Thus when a water tap W of this hot and cold water supply system Z is opened, cold water and hot water, which are supplied, by the same actions as has been described above, from cold water supply pipe X and hot water supply pipe Y at appropriate flow rates that are in accordance to a preset temperature, become mixed at combination faucet C.

At this time, even when the hot/cold water consumption amount (within the range of the maximum consumption amount F_m of 300l/min) changes due to consumption at another faucet C, since a flow rate that is substantially matched to the

consumption amount is made to pass through main body 2 so as to maintain the variation width (approximately 0.03MPa) of the valve-outlet pressure P_4 , the flow rates of cold water from cold water supply pipe X and hot water from hot water supply pipe Y that are in accordance to the preset temperature do not change and hot/cold water of the preset temperature is thus supplied from water tap W.

When each of the water taps W is stopped from the water passing condition described above, main valve 17 is closed in the same manner as described above to stop the passage of water and the operations of pumps XP1, XP2, YP1, and YP2 are stopped by the unillustrated pressure or flow rate detection devices.

Next, a hot and cold water supply system Z1, which is a modification example of hot and cold water supply system Z, shall be described based on Fig. 5.

With hot and cold water supply system Z1, the respective downstream end parts of the cold water supply piping X and hot water supply piping Y in the above-described hot and cold water supply system Z is connected to the return side of water receiving tanks X2 and Y2 to form cold water circulation line Xa and hot water circulation line Ya. The parts that are the same as or that correspond to parts of the hot and cold water supply system Z shall be provided with the same symbols and

descriptions thereof shall be omitted.

Cold water circulation line Xa and hot water circulation line Ya have flow regulation means X3 and Y3 connected near the return side of water receiving tanks X2 and Y2.

The flow regulation means X3 and Y3 shown in Fig. 5(a) are needle valves N that are arranged to constantly return fixed, preset flow rates to water receiving tanks X2 and Y2.

Each of the flow regulation means X3 and Y3 shown in Fig. 5(b) is comprised of a needle valve N, which is installed in the same manner as described above, and a relief valve R, which is installed in a bypass pipeline that branches from circulation line Xa or Ya at a point downstream needle valve N and is connected to the return side of water receiving tank X2 or Y2. With this arrangement, when the flow rate to be returned to water receiving tank X2 or Y2 cannot be supplemented by needle valve N and the pressure at the terminal side of circulation line Xa or Ya becomes equal to a preset value, the relief valve R opens so that a fixed, preset flow rate of water will constantly be returned to water receiving tank X2 or Y2.

With a hot and cold water supply systems Z1 shown in each of Figs. 5(a) and 5(b), the flow regulation means X3 and Y3 are not limited to those described above, and it is sufficient for the flow regulation means to be such that will constantly

return a preset flow rate of water to water receiving tanks X2 and Y2 from cold water circulation line Xa and hot water circulation line Ya.

The pressure or flow rate detection device that was equipped in hot and cold water supply system Z does not have to be installed.

The actions of pressure reducing device 1 in a hot and cold water supply system Z1 shall now be described based on Figs. 1 and 5.

With hot and cold water supply system Z1, since the flow rates (referred to hereinafter as the circulation flow) of water to be returned to water receiving tanks X2 and Y2 via flow regulation means X3 and Y3 are set, preset amounts of hot water and cold water constantly circulate through cold water circulation line Xa and hot water circulation line Ya (regardless of the opening or closing of water tap W).

Each of the pressure reducing devices 1 that are used in this hot and cold water supply system Z1 has been selected based on the selection method to be described below so that the valve-outlet pressure P_v will be within an allowable range (range in which hot water or cold water can be supplied at a stable pressure) even when the maximum consumption amount F_m of hot water or cold water is exceeded, and the respective

circulation flows of cold water circulation line Xa and hot water circulation line Ya are set within a flow rate range that has been derived from the difference between the consumption limit F_s , which is based on the allowable range, and the preset maximum consumption amount F_m .

Here, pressure reducing devices 1 of the flow capacity shown in Fig. 7 are used with the maximum consumption amount F_m being set to 300l/min, the preset valve-inlet pressure being set to 0.50MPa, and preset valve-outlet pressure being set to 0.30MPa.

It can be understood (see Fig. 7) that with pressure reducing devices 1 of the above capacity, the variation width of the valve-outlet pressure P_4 with respect to the consumption amount can be maintained within the allowable range (approximately 0.03MPa) up to a consumption amount of approximately 420l/min (consumption limit F_s) that exceeds the maximum consumption F_m even when the circulation flow rate is set to approximately 120l/min or less, which is the difference between the consumption limit F_s and maximum consumption F_m .

Here, when the circulation flow rate of each of cold water circulation line Xa and hot water circulation line Ya is set to 50l/min, since the valve-outlet pressure P_4 at this flow rate is approximately 0.29MPa as shown by the graph of Fig.

7, the variation width of the valve-outlet pressure P_4 of hot and cold water supply system Z1 at hot/cold water consumption amounts between 0 to 300l/min will be the difference between the valve-outlet pressure P_4 of pressure reducing device 1 for 0l/min (= approximately 0.29MPa) and the valve-outlet pressure P_4 for 300l/min (= approximately 0.27MPa), in other words, approximately 0.02MPa. The variation width of the valve-outlet pressure P_4 can thus be narrowed further from that of the above-described hot and cold water supply system Z.

The method of selecting the pressure reducing device 1 shall now be described.

With this selection method, the maximum consumption amount F_m , the preset valve-inlet and valve-outlet pressures P_f and P_s , and the variation width of the valve-outlet pressure P_4 with respect to the consumption amount of hot/cold water (the allowable lower limit P_L) of the hot and cold water supply system Z or Z1 that uses the pressure reducing device 1 are determined, and thereafter the following selection procedure is carried out based on these determined items.

Here, for the sake of description, a selection shall be made for a maximum hot/cold water consumption amount F_m of 300l/min, a preset valve-inlet pressure P_f of 0.50MPa, a preset valve-outlet pressure P_s of 0.30MPa, and a lower limit P_L of

the allowable range of the valve-outlet pressure P_4 with respect to the preset pressure P_s of 0.27MPa.

1. Selection of pressure reducing valve

(1) A pressure reducing valve 4, with which the determined preset valve-outlet pressure P_s lies within the pressure adjustment range (a specification of the pressure reducing valve that indicates the range of valve-outlet pressure that can be set), is selected.

(2) Next, a flow characteristics graph I, which illustrates the relationship between flow rate and valve-outlet pressure of this pressure reducing valve 4 in the condition where a restriction means 20 is connected to the upstream side of pressure reducing valve 4 and the flow rate capacity (flow rate Q_1) of pressure reducing valve 4 when the valve-outlet pressure P_4 has dropped from its preset pressure P_s to the lower limit P_L of the allowable range is set to exceed the supply capacity (flow rate Q_2) restricted by restriction means 20, is prepared.

Flow characteristics graph I illustrates, in the form of a graph, the results of measuring the valve-outlet pressure upon setting the valve-outlet pressure at a flow rate of 0 and then gradually increasing the flow rate, and the flow rate and valve-outlet pressure are expressed by the x-axis and y-axis,

respectively, of graph I.

It has been confirmed through actual measurements that with the flow characteristics curve A of a graph I, with which the flow characteristics of pressure reducing valve 4 have been measured under the abovementioned condition ($Q_1 > Q_2$) due to restriction means 20, though the dead end shut-off differs for each individual pressure reducing valve 4 due to the characteristics of pressure reducing valve 4 itself, the valve-outlet pressure P_4 at a consumption amount less than or equal to the preset maximum consumption amount F_m exhibits a slightly rightward-declining slope that declines from the preset pressure P_s to the lower limit P_L of the allowable range (a substantially horizontal line that passes through the allowable pressure value P_L) and that this slope is practically fixed for any pressure reducing valve 4.

Thus, even without making measurements, the flow rate characteristics curve A of a pressure reducing valve 4 under the abovementioned condition can be determined as having a fixed, rightward-declining slope that is substantially close to being horizontal (parallel to the x-axis), regardless of the preset valve-outlet pressure P_s (see Fig. 8), and in the below-described selection of the main valve, a straight line that is substantially parallel to the x-axis and passes through

the allowable range's lower limit value (allowable pressure value) P_L may be used as flow characteristics curve A (the alternate long and short dash line in Fig. 9).

With Fig. 8's graph of flow characteristics curves A of the above-described slopes, a plurality of settings P_s [0.40, 0.30, 0.20, 0.10 (MPa)] of the valve-outlet pressure P_4 corresponding to a flow rate of 0 are shown and flow characteristics curves A, which are based on the respective settings P_s and have the same slopes, are shown. Here, since the preset valve-outlet pressure P_s that has been determined for the hot and cold water supply system Z or Z1 is 0.30MPa, a flow characteristics graph I, with which the flow characteristics curve A for a preset valve-outlet pressure P_s of 0.30MPa has been transferred to Fig. 9, is used.

2. Selection of the main valve

(1) A plurality of main valve candidates, having the same basic arrangement as described above and which mainly differ in the diameter of valve port 11, are made available as suited.

(2) A flow characteristics graph II (Fig. 10), which illustrates the relationship between the valve-inlet pressure P_1 (the differential pressure between valve-inlet pressure P_1 and valve-outlet pressure P_4) and the flow rate for each candidate, is then prepared.

Flow characteristics graph II illustrates, in the form of a graph, the results of measurement of the flow rate upon setting valve port 11 to the open condition, in other words, upon setting the valve-outlet pressure to 0 and then gradually increasing the valve-inlet pressure, and the valve-inlet pressure (which corresponds to the differential pressure between the valve-inlet pressure and the valve-outlet pressure since the valve-outlet pressure is 0) and the flow rate are expressed by the x-axis and y-axis, respectively, of graph II.

The flow characteristics graph II of Fig. 10 shows the flow characteristics curves a to c corresponding to the respective main valve candidates.

(3) The flow characteristics curves a to c of flow characteristics graph II are converted and indicated in the flow characteristics graph I in which the flow characteristics curve A is indicated.

In graph II, the flow rate that is indicated for a valve-inlet pressure for example of 0.20MPa is the flow rate when the valve-inlet pressure P_1 is 0.20MPa and the valve-outlet pressure P_2 is 0. In other words, this flow rate can be said to be the flow rate when the differential pressure between the valve-inlet pressure P_1 and the valve-outlet pressure P_2 is 0.20MPa.

Thus with the flow characteristics curve a, the flow rate when the differential pressure is 0.20MPa, that is, when the valve-inlet pressure P_1 is 0.50MPa and the valve-outlet pressure P_4 is 0.30MPa, is 440l/min.

The results of conversion of the valve-outlet pressure P_4 and the flow rate when the preset valve-inlet pressure P_f is 0.50MPa by the above procedure are shown in the table of Fig. 11.

In the conversion table of Fig. 11,

$\hat{a}$ indicates the pressure indicated in graph II (the differential pressure between the valve-inlet pressure P_1 and the valve-outlet pressure P_4),

$\hat{a}$ indicates the valve-outlet pressure P_4 when the preset valve-inlet pressure P_f is 0.50MPa,

in other words, $\hat{a} = P_f - \hat{a}$, and

$\tilde{a}$ indicates the flow rate (capacity) corresponding to $\hat{a}$ in graph II.

The $\hat{a}$ and $\tilde{a}$ indicated in the above conversion table are plotted onto graph I to convert and indicate the flow capacity curve a.

Likewise for flow characteristics curves b and c in graph II, conversion tables (not shown) are prepared and conversion and indication in graph I is carried out.

The results of indicating the flow characteristics curves a to c, which have been converted in the above manner, in graph I in which the flow characteristics curve A is displayed is shown in Fig. 9.

(6) In the flow characteristics graph I, the coordinates of the intersections Ra to Rc of the flow characteristics curve A and the respective flow characteristics curves a to c that have been converted and indicated are Ra(0.27, 420), Rb(0.26, 605), and Rc(0.26, 680), and these intersection coordinates Ra to Rc are the limit points at which supply at a stable pressure (valve-outlet pressure) can be carried out even when the consumption flow rate changes for the respective cases where the selected pressure reducing valve 4 is combined with the main valve candidates and used based on the determined items described above.

In graph I shown in Fig. 9, the curves formed by making flow characteristics curve A continuous with the respective flow characteristics curves a to c correspond to being the flow characteristics curve of pressure reducing device 1, with which pressure reducing valve 4 and main body 2 are combined.

Of the limit points Ra to Rc of the respective main valve candidates, that for which the difference with respect to the preset valve-outlet pressure $P_s = 0.30\text{MPa}$, when the

abovementioned maximum consumption $F_m = 300\text{l/min}$ is exceeded, is the smallest is the intersection coordinate $R_a(0.27, 420)$ of flow characteristics curve a. The main valve 2 that corresponds to this curve a is thus selected.

By using a pressure reducing device 1, with which a pressure reducing valve 4 and a main valve 2 that have been selected in the above manner are combined, in a hot and cold water supply system Z or Z1, hot/cold water can be supplied at a stable pressure even when the consumption amount varies.

Fig. 12 shows a flow characteristics graph of actually measured values of the flow rate and valve-outlet pressure P_v for the cases where the pressure reducing valve 4 selected in the manner described above is combined with the respective main valve candidates, with the maximum consumption F_m of hot/cold water being set to 300l/min , the preset valve-inlet pressure P_i being set to 0.50MPa , and the preset valve-outlet pressure P_s being set to 0.30MPa .

The flow characteristics curve J1, J2, and J3 of the respective pressure reducing devices shown in Fig. 12 are practically the same as the flow characteristics curves (A~a), (A~b), and (A~c) of the respective pressure reducing device shown in Fig. 9. It is thus confirmed that with the above-described method 1, measurements of the respective

pressure reducing devices, with which pressure reducing valve 4 is combined with the main valve candidates, do not have to be made.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a sectional view of a pressure reducing device.

Fig. 2 is an enlarged sectional view of the main valve.

Fig. 3 is an enlarged sectional view of the pressure reducing valve.

Fig. 4 is piping schematics of a hot and cold water supply system that uses the pressure reducing device.

Fig. 5 is piping schematics of a circulating type hot and cold water supply system that uses the pressure reducing device, with (a) being a piping schematics of a system using a needle valve as the flow regulation means and (b) being a piping schematics of a system using a combination of a needle valve and a relief valve as the flow regulation means.

Fig. 6 is a flow characteristics graph of just the pressure reducing valve to be used in a pressure reducing device.

Fig. 7 is a flow characteristics graph of a pressure reducing device.

Fig. 8 is a flow characteristics graph I, which shows

the respective flow characteristics curves of pressure reducing valves, which have a restriction means connected and differ in the preset valve-outlet pressure.

Fig. 9 is a flow characteristics graph I, in which one of the flow characteristics curves shown in Fig. 8 has been transferred and the respective flow characteristics curves shown in Fig. 10 have been converted and indicated.

Fig. 10 is a flow characteristics graph II, which shows the flow characteristics curves of the respective main valve candidates.

Fig. 11 is a conversion table.

Fig. 12 is a flow characteristics graph, which is based on actually measured values of pressure reducing devices that make use of the respective main valve candidates.

Fig. 13 is a flow characteristics graph of the prior art.



WHAT IS CLAIMED IS:

1. A pressure reducing device characterized in that a main valve is provided wherein a valve-inlet pressure chamber and a valve-outlet pressure chamber, respectively in communication with an inlet and an outlet opened at the side parts of the main body of the main valve, are formed in a partitioned manner in the interior of the main body, the valve-inlet pressure chamber and valve-outlet pressure chamber are put in communication via a valve port, a master valve, disposed so as to open and close said valve port, is urged in the closing direction by means of a spring, and a diaphragm that is coupled to the master valve partitions a diaphragm chamber, provided at the rear side of the diaphragm, and the valve-inlet pressure chamber, a pilot pipeline, having a pressure reducing valve interposed therein, is disposed between said valve-inlet pressure chamber and valve-outlet pressure chamber, and in said pilot pipeline, a branch pipeline, installed at the valve-inlet side of the pressure reducing valve, is connected to said diaphragm chamber, a restriction means is installed upstream the branching point, and the flow rate at the pressure reducing valve, in the condition where the valve-outlet pressure has dropped from its preset pressure to the lower limit of an allowable range, is set to exceed the flow rate restricted by



the restriction means.

2. A pressure reducing device as set forth in Claim 1, wherein a separate restriction means is disposed in the branch pipeline.

3. A hot and cold water supply system characterized in that a cold water supply pipeline is arranged with a pump and a pressure reducing device of Claim 1 or Claim 2 being installed in that order from the feeding side of a water receiving tank, a hot water supply pipeline is arranged with a pump and a pressure reducing device of Claim 1 or Claim 2 being installed in that order from the feeding side of a water receiving tank equipped with a heating device, a cold water supply pipe and a hot water supply pipe, which are branched from the downstream sides of the respective pressure reducing devices of the cold water supply pipeline and hot water supply pipeline, are joined at a combination faucet and then connected to a water tap, and each pressure reducing device is selected so that the valve-outlet pressure will be within an allowable range when the consumption amount of hot water or cold water is less than or equal to a preset maximum consumption amount of hot water or cold water.

4. A hot and cold water supply system characterized in that a cold water circulation line is arranged with a pump, a pressure



reducing device of Claim 1 or Claim 2, and a flow regulation means being installed in that order from the feeding side of a water receiving tank and is connected to the return side of the water receiving tank, a hot water circulation line is arranged with a pump, a pressure reducing device of Claim 1 or Claim 2, and a flow regulation means being installed in that order from the feeding side of a water receiving tank equipped with a heating device and is connected to the return side of the water receiving tank, a cold water supply pipe and a hot water supply pipe, which are branched from between the respective pressure reducing devices 1 and flow regulation means of the cold water circulation line and hot water circulation line, are joined at a combination faucet and connected to a water tap, and each pressure reducing device is selected so that the valve-outlet pressure will be within an allowable range even when a preset maximum consumption amount of hot water or cold water is exceeded, and the respective circulation flows of the cold water circulation line and the hot water circulation line are set within a flow rate range derived from a consumption limit that is based on said allowable range and the preset maximum consumption amount.

5. A method of selecting a pressure reducing device in a hot and cold water supply system using a pressure reducing



device of Claim 1 or Claim 2, said method being characterized in that a maximum consumption amount of hot/cold water, preset valve-inlet and valve-outlet pressures, and width of variation of the valve-outlet pressure with respect to the consumption amount of hot/cold water are determined, a pressure reducing valve is selected for which the determined preset valve-outlet pressure falls within the pressure adjustment range of the valve, flow characteristic curves of various main valve candidates, indicated in a flow characteristics graph indicating the relationship between the differential pressure between the valve-inlet side and the valve-outlet side and the flow rate, are converted and indicated in a flow characteristics graph, which indicates the relationship between the flow rate and the valve-outlet pressure of said pressure reducing valve in the condition where a restriction means is connected to the upstream side of the pressure reducing valve and the flow rate of the pressure reducing valve when the valve-outlet pressure has dropped from its preset pressure to the lower limit of an allowable range is set to exceed the flow rate restricted by the restriction means, and the main valve, for which the coordinates of intersection of the flow characteristics curve of the pressure reducing valve and the flow characteristics curve of the main valve candidate exceeds

said maximum consumption amount and for which the flow characteristics curve is smallest in the difference with respect to the preset valve-outlet pressure, is selected.

6. A pressure reducing valve selection method as set forth in Claim 5, wherein the flow characteristics curve of the pressure reducing valve to be indicated in the flow characteristics graph that indicates relationship between the flow rate and the valve-outlet pressure of the pressure reducing valve is made a straight line that is parallel to said flow characteristics graph's x-axis, which expresses the flow rate, and passes through lower limit of the allowable range of valve-outlet pressure.

