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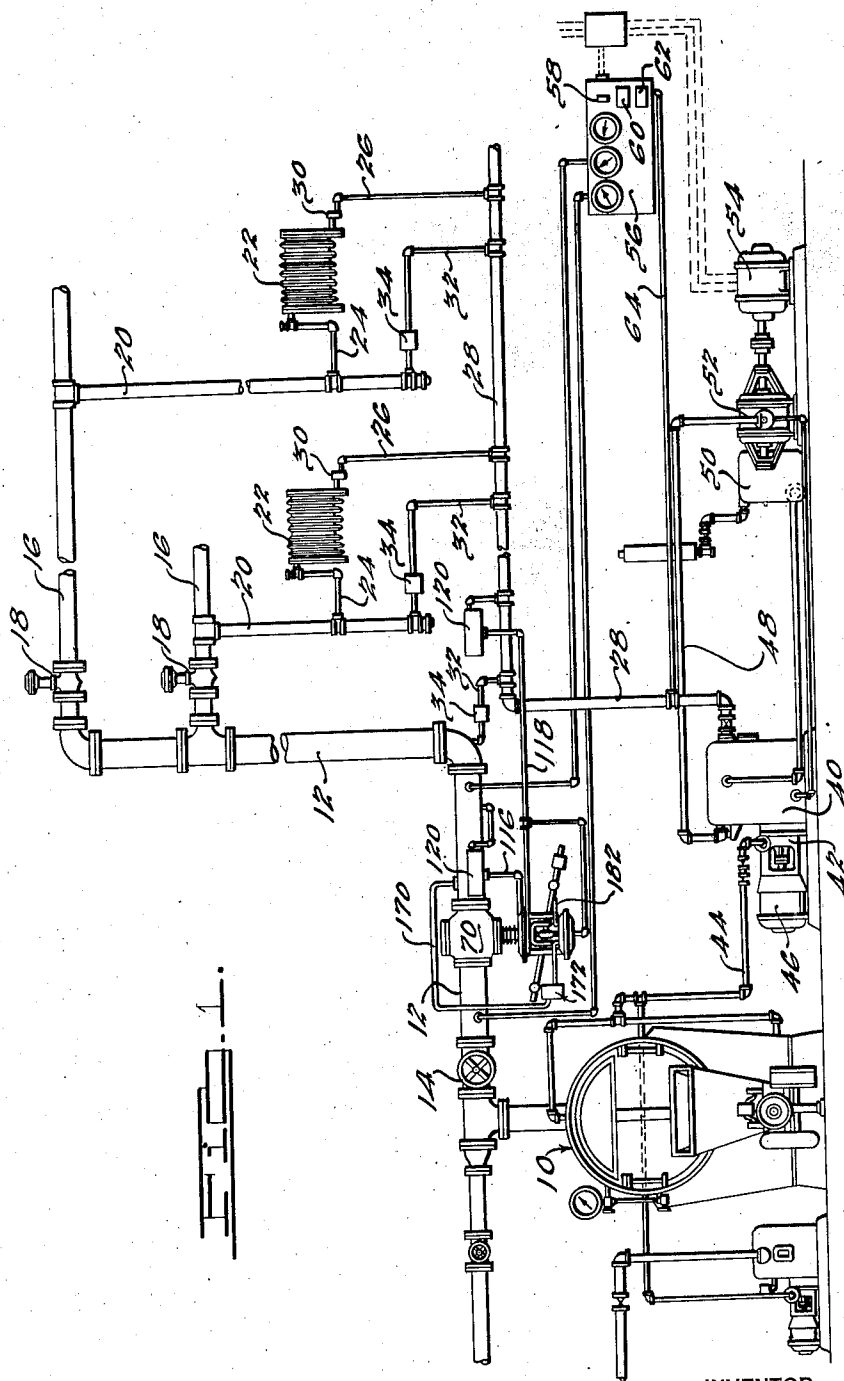
J. T. READER

2,312,191

STEAM HEATING SYSTEM

Filed Oct. 14, 1940

2 Sheets-Sheet 1



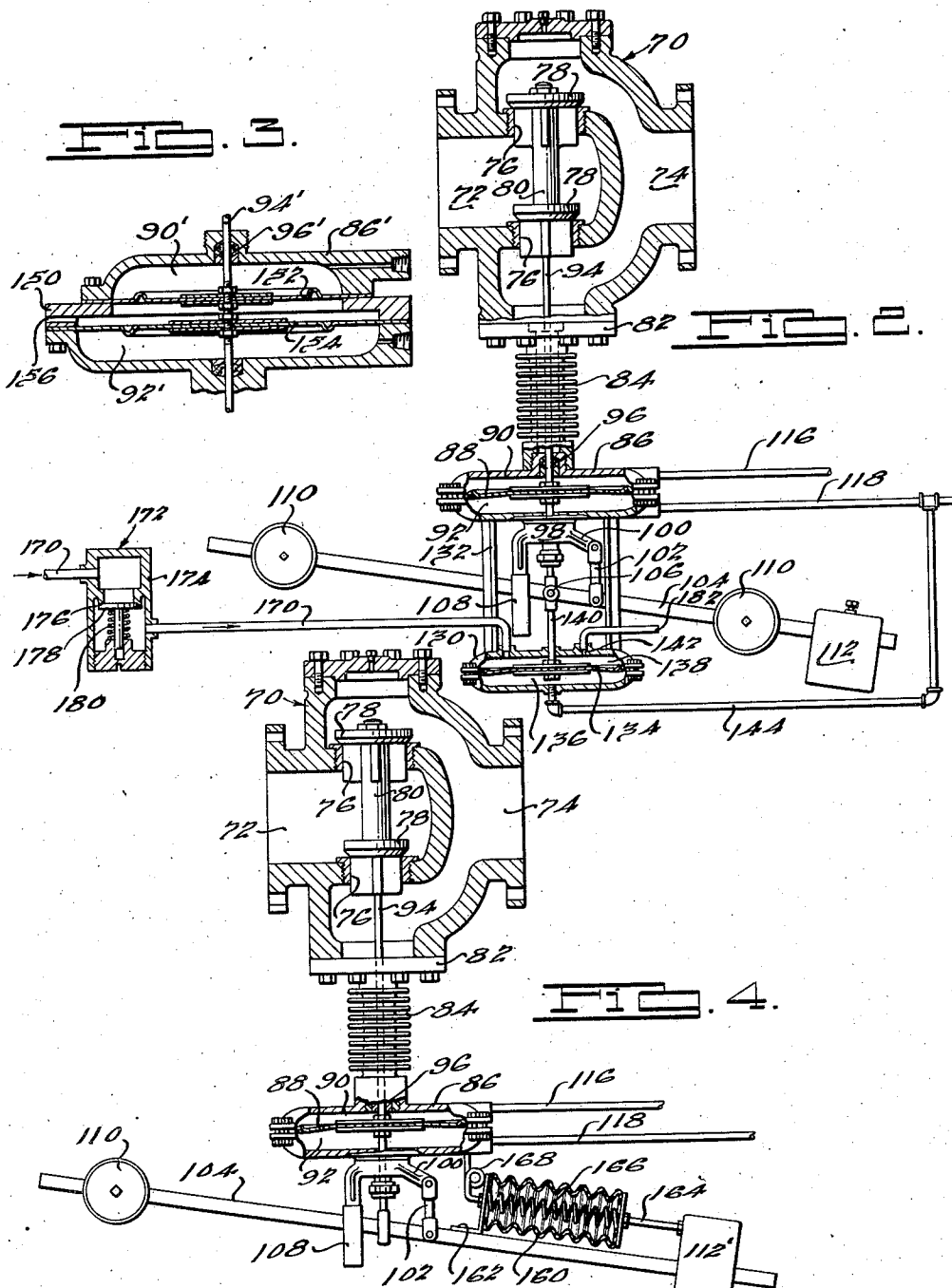
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UNITED STATES PATENT OFFICE

2,312,191

STEAM HEATING SYSTEM

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12 Claims. (Cl. 237-9)

This invention relates to steam heating systems for buildings and has for its principal object the provision of a steam heating system of improved characteristics in operation and control and which will effect economies in operation.

Objects of the invention include the provision of a steam heating system provided with pumping means at the outlet end of the system for purging the system of non-condensable gases and water of condensation together with means for controlling the flow of steam into the system, so constructed and arranged as to tend to reduce the delivery of steam into the system as each cycle of operation of the pumping means is initiated; the provision of a steam heating system having pumping means at the outlet end of the system for purging the same of air, non-condensable gases and water of condensation cyclically operated in accordance with the demands of the system, and a pressure reducing valve for controlling the flow of higher pressure steam into the inlet end of the system, together with control means for the pressure reducing valve so constructed and arranged that at the beginning of each cycle of operation of the pumping means the pressure reducing valve will tend to close and reduce the supply of steam to the system whereby to enable the pumping means to quickly purge the system of the air, non-condensable gases and water of condensation; and the provision of a steam heating system of the class described in which initial reduction of pressure in the system at the outlet end thereof upon the initiation of each cycle of operation of the pumping means is effective to cause an initial closing movement of the pressure reducing valve controlling the admission of steam to the system and until the operating pressures throughout the system have reached an approximate state of equilibrium.

Other objects of the invention include the provision of a steam heating system for buildings or the like so constructed and arranged that the differential of pressure between the inlet and outlet sides of the system is automatically reduced as the pressure in the system is reduced; the provision of a steam heating system in which the pressure existing at the outlet end of the system is employed as a primary control in the introduction of steam into the inlet end of the system; the provision of a steam heating system of the sub-atmospheric pressure type wherein the flow of steam into the system is controlled primarily by the degree of vacuum at the discharge end of the system; the provision of a

steam heating system including a valve for introducing steam into the system and a vacuum pump at the discharge end of the system for maintaining the system under a predetermined degree of vacuum, together with means responsive to the pressure in the system at the discharge end and at the inlet end thereof serving to control the steam admittance valve but is so constructed and arranged as to decrease the differential of pressure between the inlet and outlet sides of the system as the degree of vacuum on the outlet end of the system is increased; and the provision of a steam heating system including control means therefor so constructed and arranged as to relieve steam traps or the like employed in the system of excessive pressure differences, thereby increasing the effective life of the steam traps.

Further objects of the invention include the provision of a steam heating system for buildings or the like in which a valve is provided at the inlet end of the system for admitting steam from a source of supply thereto, and a vacuum pump is provided at the discharge end of the system for maintaining the system under a desired degree of vacuum, means being provided for controlling the valve comprising pressure responsive means including a movable wall connected to the valve and having one side thereof exposed to the effects of the pressure at the inlet end of the system and the opposite side thereof exposed to the effects of the pressure of the system at the outlet end thereof, whereby it tends to maintain the differential of pressure in the system constant, together with means for varying the effect of said pressure responsive means on said valve comprising an additional pressure responsive element including a movable wall subject to the pressure of the system at the outlet end thereof on one face thereof and to the atmosphere or other source of fixed pressure on the opposite face thereof and so constructed and connected to the valve as to vary the effects of the first mentioned movable wall to decrease the differential between the inlet and outlet ends of the system as the degree of vacuum on the outlet end thereof is increased; and the provision of a construction as above described in which the relative areas of the two pressure responsive elements may be changed to enable the rate of change of the pressure differential of the system between maximum and minimum values to be varied to meet the requirements of the maximum and minimum pressure differentials required in the system.

Still further objects of the present invention are the provision of a construction in a system of the type described in which means are provided for shutting off the supply of steam to the system whenever the primary pressure responsive element is ruptured to such an extent as to prevent its functioning; the provision of a steam heating system of the type described employing a pair of pressure responsive elements for controlling the pressure reducing valve so constructed and arranged that the introduction of steam to the system at excessive pressures will automatically cause the pressure reducing valve to be closed, thereby to shut off the flow of steam to the system; and the provision of safety means in a structure of the type described which will automatically prevent undesirable high steam pressures to be built up in the system.

The above being among the objects of the present invention the same consists in certain novel features of construction and combinations of parts to be hereinafter described with reference to the accompanying drawings, and then claimed, having the above and other objects in view.

In the accompanying drawings which illustrate suitable embodiments of the present invention and in which like numerals refer to like parts throughout the several different views,

Fig. 1 is a more or less diagrammatic, fragmentary view of a steam heating system constructed in accordance with the present invention;

Fig. 2 is an enlarged, transverse sectional view taken centrally through the steam control valve mechanism shown in Fig. 1;

Fig. 3 is an enlarged fragmentary, vertical sectional view taken centrally through a modified diaphragm construction which may be employed in place of the diaphragm construction shown in Fig. 2, to obtain the same result; and,

Fig. 4 is a view similar to Fig. 2 but illustrating a modified form of construction.

The present invention relates to those types of steam heating systems for buildings or the like in which steam from a suitable source of supply is passed through a pressure reducing valve into the heating main at the inlet side of the system, and in which suitable pumping means are provided at the outlet end of the system for removing the air and non-condensed vapors, gases and water of condensation from the system, as well as to maintain the outlet side of the system under pressures of suitably low value. Although it is possible to use the present invention in connection with systems maintained wholly or partly at or above atmospheric pressures, it will usually be employed in conjunction with so-called vacuum systems in which the outlet side of the system in particular is maintained under a partial vacuum or sub-atmospheric pressure, as these systems are capable of employing exhaust gases from steam operated turbines, engines or the like and in any event, regardless of the source, are generally recognized as more efficient and economical in operation than other types of heating systems. Accordingly, while for the purpose of brevity in description the discussion of the present invention will be limited to its application to the vacuum type of system, its application to other types of systems will be readily recognized by those skilled in the art upon the disclosure herein without the necessity of further explanation of the present invention thereto.

A type of steam heating system of the vacuum type that has recently met with a considerable amount of success includes a pressure reducing valve at the inlet side of the system to the stem of which is connected a diaphragm enclosed in a casing forming a chamber at each side of the diaphragm. The chamber on one side of the diaphragm is connected to the steam main of the system immediately adjacent the point at which the reducing valve introduces steam thereinto, such chamber being the one in which the presence of a vacuum therein, if the opposite face of the diaphragm were subjected to atmospheric pressure, would tend to open the valve. The opposite chamber, that is the chamber on the opposite side of the diaphragm is connected to the discharge side of the system and preferably to the vacuum return line thereof directly connected to the vacuum or other pressure reducing pumping means positioned at that point. It will be appreciated that the result of this construction is the provision of an automatically operated pressure reducing valve controlling the admittance of steam to the system and serving to maintain a constant differential of pressure between the inlet and outlet sides of the system regardless of variations of pressure at the outlet side of the system. The amount of differential pressure maintained between the inlet and outlet side of the system is controlled by means of springs, weights or the like constantly acting on the valve, through the diaphragm or otherwise, tending to move the valve either towards closed or open position and usually towards open position.

The above described heating system was a material improvement in the art for the reason that the engineer or other operator of the system could vary the flow of steam through the system to accommodate the various heating requirements by simply varying the degree of vacuum on the outlet side of the system by suitable control of the vacuum pump thereof and at the same time, changing the springs, weights or the like on the pressure reducing valve to correspond. In other words, the engineer could adjust the vacuum pump to produce a lesser degree of vacuum and the pressure reducing valve a greater degree of differential when the heating requirements of the system increased, and adjust the vacuum pump to provide a greater degree of vacuum and the pressure reducing valve a lesser degree of differential when the heating requirements of the system decreased.

However, when the vacuum pump is operating after starting up automatically, the constant differential reducing pressure valve remains open and admits excess steam to the inlet side of the system because, as the vacuum increases on the lower side of the diaphragm, which is connected to the return end of the system, the vacuum on the upper side of the diaphragm which is connected to the inlet side of the system increases correspondingly and the opening through the valve tends to remain unchanged. The supply pressure to this valve is, of course, not changed in any respect because of the operation of the vacuum pump, the pressure at the downstream side of the valve is reduced by operation of the pump and consequently a greater amount of steam flows to the system when the pump is operating under this method of operation.

As readily understood in the art, the higher the absolute pressure in a heating system of the type described the greater is the pressure differ-

ential required between the inlet and outlet sides of the system to obtain the proper flow of steam through the system to obtain uniform heating conditions in all of the radiators of the system. This is because of the fact that under such conditions a greater amount of steam of higher specific gravity subject to greater friction losses is flowing through the system. The greater degree of vacuum on the steam in the system, the less pressure differential is required to cause the proper flow thereof through the system because the quantity and specific gravity of the steam flowing is less and the drop in pressure required for a proper flow is less because of the smaller frictional losses. Accordingly, with the system described, conventional practice is to adjust the pressure reducing valve, as by shifting of the weight or weights thereon, varying the tension of the spring or springs thereof, or otherwise, so as to obtain the desired differential of pressure between the inlet and outlet sides of the system under conditions of maximum heating requirements. If, under such conditions, minimum heating requirements are attained, the same differential of pressure between the inlet and outlet sides of the system still remains unless the operator adjusts the pressure reducing valve itself, as by shifting the weight thereon or by varying the tension of the springs thereof, to reduce the differential of pressure as controlled thereby.

Unless such differential of pressure is adjusted some material disadvantages result unless the system and particularly the radiator and drip traps thereof are in substantially perfect condition. In other words, by maintaining a constant differential between the inlet and outlet sides of the system when such differential is not required to cause a proper flow of steam through the systems under low absolute pressure conditions, the differential of pressure on the opposite side of the thermostatic traps on the radiators and on the opposite sides of the drip traps becomes excessive and cause these traps to close more tightly to maintain this excess difference in pressure. Naturally, those traps located closest to the source of heat supply, where the friction loss due to steam travelling through the pipes is very little, will have to maintain a greater differential of pressure than those located at the far end of the system where the supply pressure has been reduced due to friction. When these traps located nearest the heat supply become slightly worn, this greater difference in pressure causes short circuiting from the steam supply to the vacuum pump, causes a waste of steam through this by-passing, and this steam in turn tends to lessen or destroy the vacuum carried in the system. The circulation to the furthest radiators then becomes sluggish or ceases entirely and uneven and wasteful heating results. In addition, all of the traps in the system must remain closed during the greatest part of the time or this excess differential could not be maintained, and this makes it difficult for the condensation, air and non-condensable gases to be eliminated from the radiators, aggravating the unsatisfactory condition still more. Accordingly, it will be appreciated that unless the pressure differential existing between the inlet and outlet sides of the system is reduced as the absolute pressure in the system is reduced, conditions arise which prohibit the most advantageous operation of the system to be realized.

The desirability of providing a vacuum heating system having means for automatically reducing

the differential of pressure as the absolute pressure in the system is lowered has already been recognized, and one means of accomplishing the result is shown in United States Letters Patent No. 1,851,434, issued March 29, 1932 to I. C. Jennings. In the Jennings construction, however, the primary regulation of the system involves a variation in the amount of steam introduced to the system either by generating more or less steam in the boiler, opening or closing the manually operated control valve between the boiler and the steam main of the system to a greater or lesser extent, or by shifting the weight or the springs which load the pressure reducing valve associated therewith, the differences in pressure thus set up between the inlet and outlet sides of the system being utilized to control the operation of the vacuum pump to produce a corresponding greater or lesser degree of vacuum at the outlet end of the system.

The results sought to be attained by the Jennings patent can, by the practices of the present invention, be obtained in a simpler, quicker and more economical manner by a relatively simple modification in the construction of the fixed differential system first described and by employing variations in the absolute pressure of the system at the discharge end thereof to control the admittance of steam to the system, rather than by varying the admittance of steam to the system to control the degree of vacuum in the system as in Jennings. Additionally, it is to be noted that a system constructed in accordance with the present invention has an inherent advantage over the Jennings system in that in the system of the present invention each time a cycle of operation of the vacuum pump is initiated the reducing valve tends to close and reduces the flow of steam into the system, facilitating the expulsion of air, non-condensable gas and water of condensation from the system, while in the Jennings system an accelerated flow of steam results under the same conditions with all of the attendant disadvantages. Briefly, this is accomplished by adding to a pressure reducing valve of the fixed differential type previously described an additional pressure operated element subject to a substantially fixed pressure, and which may, therefore, be atmospheric pressure, on one side, and to the pressure at the outlet end of the system on its other side, and utilizing the movement of or effective force on such pressure operated element to vary the effects of the main diaphragm on the pressure reducing valve. In other words, this second mentioned pressure operated element connected to the outlet end of the system on one side and to the atmosphere on the other side will produce a force varying in proportion to the variations in pressure at the outlet end of the system, and if this force is added to the force set up on the corresponding side of the diaphragm of the conventional fixed differential pressure reducing valve, as by being directly connected to such diaphragm or to the stem of the valve, or by varying the tension of the spring or weight which loads the valve, then the pressure reducing valve instead of maintaining a constant differential of pressures between the inlet and outlet sides of the system will maintain a pressure differential which will decrease as the absolute pressure at the outlet side of the system decreases. Thus in accordance with the present invention it is possible by simply controlling the vacuum pump to produce a desired degree of vacuum at the outlet end of the sys-

tem, to control the amount of steam flowing through the system, as well as the effective head or differential of pressure on such steam which causes the flow thereof through the system.

Referring now to the accompanying drawings and particularly to Fig. 1 which illustrates a typical system embodying the present invention, the numeral 10 indicates generally a suitable steam boiler of any approved type which discharges steam therefrom into a steam main 12. A shut-off valve 14 is shown in the main 12 adjacent the boiler 10 so as to enable the system to be completely cut off from the boiler where desirable or necessary as, for instance, in the case of repairs to the system. Various branches 16, each provided with a shut-off valve 18 lead off from the main 12 and each branch 16 is provided with additional branches 20 to each of which one or more heat diffusing media, which may be of any suitable or conventional type, but for the purpose of simplicity in description and drawing are here shown as radiators 22, are connected by means of pipes 24. The term "radiator" when used in the claims is to be interpreted to mean any suitable or conventional heat diffusing media. The outlet sides of the radiators 22 are connected by pipes 26 to a vacuum return line 28, a thermostatic trap 30 being provided in each of the pipes 26 at the outlet side of each radiator in accordance with conventional practice. The lower ends of the branches 20, which extend below the corresponding radiators 22, as well as other low points in the system, are also connected to the vacuum return line 28 by means of pipes 32 in which some suitable type of sealing means are preferably located. Such sealing means may take any usual or desirable form such as a water leg, orifice, trap or the like but for the purpose of illustration are shown as traps 34.

The vacuum return line 28 discharges into a receiver 40 in which the condensed steam is separated from the non-condensable gases and vapors, such condensed steam being drawn out of the receiver and returned to the boiler by means of a pump 42 and pipe line 44, the pump 42 being driven by a motor 46 of a float controlled type conventionally employed in the art for this purpose. The receiver 40 is connected by a pipe line 38 with a vacuum pump 52 which discharges into a separator 50. The pump 52 may be driven in any suitable manner as, for instance, by a steam or other engine, steam turbine, electric motor or the like, an electric motor 54 being shown by way of illustration.

Operation of the motor 54 effects operation of the vacuum pump 52 which in turn places the interior of the receiver 40 and consequently the vacuum return line 28 under a partial vacuum, the condensed steam flowing into the receiver from the vacuum return line 28 being separated out in the receiver and returned to the boiler in accordance with conventional practice. The vacuum pump 52 may be controlled in any suitable way, that is, by operating the motor 54 continuously or intermittently, and where continuously it may, if desired, be accomplished by suitably varying the speed of the motor or other prime mover 54 and consequently the pump 52 to obtain the desired degree of vacuum in the system.

The motor 54, and consequently the pump 52, may be automatically controlled in accordance with the demands on the system as based on outside temperatures. For instance, a plurality of

commercial type thermostats located so that they would be affected by outside temperatures, could each be connected to a suitable vacuum operated regulator for the motor 54, and each thermostat adjusted so that its corresponding regulator would make contact at a different temperature than the rest, and the corresponding regulator serve to effect operation of the motor 54 to maintain a degree of vacuum in the system commensurate with the heating requirements based on the then existing outside temperature. However, a simpler method, although not automatic, is shown in the drawings by way of illustration and comprises a control panel 56 having three control buttons 58, 60 and 62, respectively, thereon. The control buttons 60 and 62 are each associated with a conventional type of pressure operated switch device each of which has a conventional type of pressure responsive element (not shown) associated therewith and connected by means of a pipe 64 to the vacuum return line 28 so that when the motor 54 is controlled through either one or the other of the latter buttons it will automatically cause operation of the motor 54 to maintain a substantially constant and respectively predetermined suction pressure in the vacuum return line 28. As a matter of illustration it may be assumed that when the button 60 is operated the motor 54 will be controlled to maintain the vacuum return line 28 under a suction pressure of twenty inches of mercury and when the button 62 is operated to control the motor 54 the vacuum return line 28 will be maintained under a suction pressure of fifteen inches of mercury. The button 58 may be assumed to operate to control continuous operation of the motor 54 and pump 52.

In order to variably control the flow of steam into the main 12 from the boiler 10 a pressure reducing valve indicated generally at 70 is interposed in the main 12 adjacent the valve 14 but on the down-stream side thereof. While any suitable type of pressure reducing valve may be employed for this purpose, one conventional type of valve is shown in detail in Fig. 2 by way of illustration and referring to such figure it will be noted that it comprises a casing or housing having an inlet 72 and an outlet 74, together with a pair of ports 76 connecting the inlet and outlet. The ports 76 are each formed to provide a valve seat at their upper edges with each of which a valve 78 is arranged in cooperating relationship. The valves 78 are rigidly connected together by means of a post 80, the construction thus providing a balanced valve of a conventional type familiar to those skilled in the art.

The lower face of the valve 70 is closed by a cap 82 carrying a post 84 to the lower end of which is fixed a two-part housing 86 centrally divided by a flexible diaphragm 88 sealed at its margins thereto and forming chambers 90 and 92 interiorly of the casing 86. A stem 94 fixed at one end to the valve assembly, including the valves 78 and post 80, concentrically therewith extends downwardly through the post 84 and into the casing 86 where it is fixed to the center of the diaphragm 88, a suitable packing indicated generally at 96 serving to seal the stem 94 in its passage through the post 84. This assembly may be loaded towards open valve position in any suitable or conventional manner as, for instance, by springs, weights, or the like. Weights are shown by way of illustration and arranged in a conventional manner. To accomplish this the lower face of the casing 86 is provided with a boss 98 there-

on in which the stem 96 is also suitably sealed and the boss 98 is provided with an offset arm 100 to which one end of the link 102 is pivotally connected. The opposite end of the link 102 is pivotally connected to a bar 104 to which the lower end of the stem 94 is also pivotally connected as at 106. On the opposite side of the pivot 106 the boss 98 is provided with a rigid bifurcated arm 108 within which the bar 104 is guided for vertical movement. The bar 104 has a plurality of weights adjustably mounted thereon longitudinally thereof, the weights 110 ordinarily remaining fixed once the system is adjusted and the weight 112 is readily adjusted along the length of the bar 104 and is normally the only one employed in adjusting the load on the valve during normal operation.

Referring now to Fig. 1 it will be noted that the chamber 90 above the diaphragm 88 is connected by a pipe line 116 to the main 12 at a point relatively close to the valve 70 and the chamber 92 below the diaphragm 88 is connected by a pipe line 118 with the vacuum return line 28. A tank 120 is preferably interposed in both lines 116 and 118 and these tanks become filled with condensed steam providing a constant head of water on the opposite sides of the diaphragm 88 so as to eliminate possible variations in the control due to variations in the amounts of condensed steam which might otherwise act on the opposite sides of the diaphragm.

The construction thus far described is the conventional fixed differential type of system previously discussed, the construction and arrangement of the valve 70 and the control therefor serving to maintain a constant differential of pressure between main 12 on the outlet side of the valve 70 and the vacuum return line 28, the amount of steam passing through the system and consequently the heating effect of the system varying inversely with the degree of vacuum in the return line 28. For instance, if it is ascertained that the maximum pressure drop through the system to the most remote radiator in sub-zero weather is, as a matter of illustration, three pounds or six inches of mercury, and, if steam at a temperature corresponding to one pound gauge pressure is required to heat the building, under these conditions, then with one pound gauge steam pressure and the differential valve properly adjusted the vacuum in the return line would be four inches of mercury or thirteen pounds absolute. If, in moderate weather, the vacuum at the pump was increased to fifteen inches of mercury or seven and one-half pounds absolute, then steam would circulate if introduced into the system under a vacuum of nine inches of mercury or approximately ten and one-half pounds absolute. If, in real mild weather, a vacuum of twenty inches of mercury or five pounds absolute was carried in the return line, then the steam would circulate at a vacuum equal to fourteen inches of mercury or approximately eight pounds absolute. However, due to the less quantities of steam required by this system under the latter two conditions, the pressure drop, due to friction in the system, becomes less and excess differential ensues. This can only be caused by the radiator and drip traps closing during the majority of the time to maintain this excess differential and which they will not do if in worn condition. Under these conditions, this excess differential causes short circuiting of the steam through the traps, higher return temperature, loss of vacuum, faulty circulation and wastage of steam.

To overcome these difficulties the operator should adjust the weight 112 on the rod 104, or such other means as is employed to load the reducing valve, to reduce the differential at which the valve operates. In other words, whenever a change in the heating requirements of the system is necessary, two adjustments must be made by the operator if proper operating conditions are to result. The first of these changes is a change in the degree of vacuum in the return line 28 as controlled by the vacuum pump 52, and the second is a change in the differential required to actuate the valve 70 as controlled by the position of the weights on the rod 104. As a matter of fact, however, most operators fail or neglect to adjust the differential of the reducing valve and for that reason such systems operate at maximum efficiency only during coldest weather.

The difficulties in connection with the heating system described above may be avoided by modifying the control for the pressure reducing valve so that the pressure differential maintained between the opposite ends of the system thereby will vary in accordance with the variations of absolute pressure at the discharge end of the system. This, of course, may be accomplished by providing a pressure responsive element responsive to variations in pressure at the outlet end of the system and employing such elements to modify the action of the valve as controlled by the diaphragm 88. It may be accomplished by connecting the pressure responsive element to the movable element of the valve, or by employing it to change the load on the valve the same as would be accomplished by shifting the weights associated therewith where weights are used to preload the valve, or by varying the tension of the spring where springs are employed to preload the valve. Such pressure responsive element, in order to be effective for the purpose described, must, of course, exert a force proportional to changes in pressure in the outlet end of the system and where a pressure responsive element is provided such pressure responsive element must be subjected to such pressure variations on one side and to a substantially fixed pressure on the other side. While such fixed pressure may be obtained from any suitable source, atmospheric pressure will be the simplest and most economical to employ as will be readily appreciated.

A diaphragm such as the diaphragm 88 and an associated casing is perhaps the simplest form of pressure responsive element for effecting this purpose and may be directly connected to the movable element of the valve to accomplish the desired results. This is the construction illustrated in Figs. 1 and 2 and referring particularly to Fig. 2 is accomplished as follows. A diaphragm casing indicated generally at 130 is mounted below the casing 86 in downwardly spaced relation with respect thereto by means of legs 132. The casing 130 is of the same general construction as the casing 86 and is interiorly provided with a diaphragm 134 which divides the interior thereof into a lower chamber 136 and an upper chamber 138. A stem 140 secured to the diaphragm 134 extends upwardly through the casing 130 and at its upper end is suitably connected to the stem 94 by the same pivot pin 106 which connects the stem 94 to the rod 104. Consequently the diaphragms 88 and 134 are connected together for equal movement. The upper half of the casing 138 is provided with an opening 142 therein connecting the chamber 138 to the atmosphere. The chamber 136 is connected by a pipe line 144

with the pipe line 118 and consequently to the vacuum return line 28 and is, therefore, subjected to the same pressures as exist in the vacuum return line. Thus the diaphragm 134 is subjected to a constant pressure on its upper face, namely atmospheric pressure, and to the pressure at the outlet end of the system on its lower face and consequently will exert a force on the stem 94 and consequently on the valve assembly 70-80 which at all times is proportional to the pressure in the outlet end of the system. This force is in addition to the equivalent force which will be exerted on the lower face of the diaphragm 88 but which in the case of the diaphragm 88 is offset by the varying pressure in the chamber 80 and which pressure acts on its upper face. The result is that as the pressure in the outlet end of the system decreases the relative differences in pressures acting on the opposite faces of the diaphragms 88 and 134 tending to move the valve 70 towards closed position increases and as the pressures in the outlet end of the system increase the relative difference in pressures acting on the diaphragms 88 and 134 tending to close the valve decrease, thus providing for a greater differential between the inlet and the outlet end of the system. Obviously by varying the effective diameter of the diaphragm 134 the force exerted through the diaphragm 134 tending to change the differential as controlled by the diaphragm 88 may be varied so that the actual differential of pressures acting through the diaphragms to control the valve at various pressures in the outlet end of the system may be varied as desired to meet any condition encountered in service. At the same time, adjustment of the weights 110 and 112 on the rod 104 permits a desired differential between the inlet and outlet ends of the system to be provided for at any particular operating pressure of the system.

It will be appreciated from the above description that in a steam heating system constructed in accordance with the present invention the amount of steam flowing through a system may be controlled by simply varying the operation of the vacuum pump 52 to produce any desired degree of vacuum in the return line of the system, and that any variation in the vacuum in the return line will automatically operate to establish a correspondingly desired differential of pressure between the inlet and outlet ends of the system and that such differential of pressure will increase with the increase in absolute pressure in the return line and will decrease with decrease in absolute pressure in the return line. It will also be appreciated that where the control valve is properly constructed and adjusted it will automatically operate to establish that differential of pressure between the outlet and inlet ends of the system most favorable for optimum operating conditions for any normal operating pressure that is selected for the outlet end of the system either by the operator or by automatic devices. It will also be appreciated that the added expense required to obtain this advantageous condition of operation is substantially negligible.

One extremely beneficial effect of the above described construction is as follows. With an ordinary pressure reducing valve in a system of the type described, the moment operation of the vacuum pump is initiated, the differential between the outlet and the inlet is increased with the result that excess amounts of steam are admitted to the system. The admission of this additional steam to the system makes it more difficult for the vacuum pump to remove the air, non-condensable

gases and condensed water from the system and requires a much longer operation of the vacuum pump to reduce the vacuum to the desired degree. With the valve construction employed in conjunction with the present invention each time a cycle of operation of the vacuum pump 52 is initiated the reduced vacuum is first apparent in the outlet side of the system and is immediately made apparent on the underside of the diaphragms, thus tending to close the pressure reducing valve and reducing the amount of steam that is admitted to the system. It will be appreciated, of course, that the corresponding reduction of pressure in the outlet end of the system will shortly be apparent at the inlet end of the system but, because of the addition of the lower diaphragm 134, a proportionally greater pull will be exerted on the diaphragm tending to close the valve than would be the case with a conventional type of control. The result of this construction is that upon initiation of each cycle of operation of the vacuum pump the pressure reducing valve tends to close and reduce the amount of steam being admitted to the system, thus enabling the vacuum pump to remove the air, non-condensable gases and condensed water, from the system in a much shorter time than would otherwise be possible.

The above described advantage is not only important from the standpoint of more quickly purging the system of air, non-condensable gases and condensed water with consequent shortening of the operating period of the pump and its operating motor but it also is effective in reducing the peak load of steam used by the system. In this connection those skilled in the art will understand that where steam is purchased from a central heating company on a demand basis, the customer, in addition to a flat rate for all steam consumed during the year, is also charged an extra demand rate. This demand rate is determined ordinarily by the averaging of the several largest hourly rates of steam consumption during certain periods of the heating season. If these maximum hourly peaks can be reduced, very considerable savings are effected. By reducing the quantity of steam admitted to the system each time operation of the vacuum pump is initiated, the high rate of steam flow inherent in the usual types of pressure reduction valves under such conditions is avoided and the maximum demand of the system is thereby lessened. Additionally, the flow of condensation to the pump at such times, and which is used as a basis for determining steam consumption, is reduced.

Another advantage of the use of the type of valve under discussion in a system of the type described, although not essential to the operation of the system nor affecting the beneficial results above described, is that it admirably lends itself to the provision of a safety means for the system. In the use of conventional pressure reducing valves employing a diaphragm or other similar pressure responsive element, should the diaphragm become ruptured, as is not uncommon, pressures on opposite sides of the diaphragm or other pressure responsive element are equalized and the valve consequently moves to open position allowing the full pressure of the steam supply main or other source of steam to be applied directly to the entire heating system. This does no particular harm where the supply of steam is under relatively low pressure except to increase the temperature of the heated space to an excessive extent, but where the supply of steam is un-

der a relatively high pressure, for instance 100 pounds per square inch or greater, dangerous conditions arise, for instance, because of the high temperatures to which the various parts of the heating system may be brought to and possible rupture of weakened portions of the same. Such possibilities may be automatically avoided by a simple expedient in the use of the valve above described in connection with the present invention. This is accomplished by providing a pipe line such as 170 between the steam main 12, on the downstream side of and preferably adjacent the valve 70 and the interior of the casing 130 above the diaphragm 134, and providing a pressure responsive valve indicated generally at 172 in the pipe line 170 so constructed and arranged that it will open to permit the passage of steam through it only upon the presence of a predetermined pressure of steam in the supply line 120. While any suitable type of pressure responsive valve may be employed for this purpose, that shown in Figs. 1 and 2, and in detail in the latter view, by way of illustration consists of a casing 174 having an inlet at one end and an outlet at the other end with a valve seat 176 interposed therebetween. A valve 178 is arranged in cooperating relationship with respect to the seat 176 and is constantly urged towards seated position by means of a coil spring 180. The force of the spring 180 determines the pressure at which the valve 178 leaves the seat 176 to permit the flow of steam through the pipe line 170 to the casing 130. For instance, where the maximum pressure desired in the heating system is ten pounds gauge, the valve 172 may, for example, be constructed to open at a gauge pressure of fifteen pounds per square inch. The capacity of the pipe line 70 is made greater than the capacity of the vent opening 142 so that should the upper diaphragm 88 become ruptured and permit the pressure reducing valve to admit excessive quantities of steam to the heating system materially above the intended maximum pressure, as soon as steam in the main 12 on the discharge side of the valve 70 reaches the maximum force the valve 172 is designed to operate, in the example assumed fifteen pounds, the valve 178 will open and permit steam under this high pressure to flow into the upper part of the casing 130. Because the vent opening 142 is of less capacity than the pipe line 170, under such conditions a positive pressure will be built up in the casing 130 above the diaphragm 134 and will act to move the pressure reducing valve 70 to closed position thereby to prevent further admission of steam to the system and preventing any condition from arising which would permit dangerous pressures to become apparent in the system. Where such safety device is employed it is preferable to connect the vent opening 142 to some suitable point of discharge as, for instance, the outside of the building, by means of a pipe such as 182.

It will be appreciated from the foregoing that the addition of the diaphragm 134 to the conventional fixed differential type of reducing valve in a steam heating system has the effect of increasing the area of the lower face of the diaphragm 88 in the conventional construction without increasing the area of the upper face thereof, so that differences in pressure at the outlet end of the system will have a greater effect on the control of the valve than the same differences in pressure on the upper face of the diaphragm. This suggests the possibility of employing a construction embodying two diaphragms the smaller

of which is subjected to the pressure at the inlet end of the system and the larger of which is subjected to the pressure at the outlet end of the system to obtain the same result. Such a construction is illustrated in Fig. 3 wherein parts equivalent to the parts illustrated in Fig. 2 are indicated by the same numerals except that such numeral bears a prime mark.

Referring to Fig. 3 it will be noted that the diaphragm casing 86', similar to the diaphragm casing 86 previously described, is made in two parts but in this case the lower half of the casing is of greater diameter than the upper half. The two halves of the casing in this case are spaced from each other by means of a spacer 150 having a stepped lower face. A diaphragm 152 is clamped and sealed between the spacer 150 and the upper half of the casing 86' and another diaphragm 154 is clamped and sealed between the lower face of the spacer 150 and the lower half of the casing 86', this second diaphragm having a materially larger effective area than the diaphragm 152, for instance twice as great. The stepped lower face of the spacer 150 permits the diaphragm 154 to be effective beyond the effective outer diameter of the diaphragm 152 as will be appreciated. The spacer 150 is provided with one or more openings 156 communicating the space between the diaphragms 152 and 154 with the atmosphere.

As will be readily understood the chamber 90' between the diaphragm 152 and the upper half of the casing 86' is connected to the steam main 12 in the same manner as the chamber 90 previously described, and the chamber 92', corresponding to the chamber 92 previously described, is connected to the vacuum return line 28 of the system. The two diaphragms are rigidly connected together at their centers through the stem 94' of the valve so that they are constrained to equal movement. As will be realized, with this construction the effective area of the diaphragm subject to the pressure at the outlet end of the system is greater than the effective area of the diaphragm subject to the pressure at the inlet end of the system and consequently variations in pressure at the outlet end of the system will have a greater effect on controlling the position of the valve 70—80 than the pressures at the inlet end of the system, and as the degree of vacuum in the chamber 92' increases, its relative effect on overcoming the load of the weight 112 will increase as compared to the relative increase of the partial vacuum in the chamber 90' tending to add its effect to the load 112 and, consequently, the differential of pressures as controlled by the valve 70 will be reduced. In other words, the same ultimate result is obtained by the construction shown in Fig. 3 as is obtained by the construction illustrated in Fig. 2.

As previously mentioned, the desired result may also be obtained by employing a pressure responsive element subject to the pressures at the outlet end of the system for varying the load producing element of the reducing valve, as, for instance, by varying the tension of the spring where a spring is employed for such loading purposes, or by shifting the position of a weight with respect to its fulcrum where a weight is employed for loading the valve. In Fig. 4 a construction is illustrated in which this latter effect is obtained. Referring to Fig. 4 it will be noted that the construction is identical to that illustrated in Fig. 2 with the exception that the lower diaphragm casing 130 and its diaphragm is elimi-

nated. The lefthand weight 110 is shown mounted on the rod 104 although the righthand weight 110 has been eliminated primarily for the purpose of clarification. The weight 112 has been replaced by a weight 112' of slightly different construction and readily slidable along the rod 104. In this case a metal bellows 160 has one end thereof rigidly secured to a bracket 162 fixed to the rod 104 on the righthand side of the link 102 and the bellows extends in parallel relation to the rod 104. The opposite end of the bellows 160 is connected by a short rod 164 with the weight 112'. A coil spring 166 within the bellows 160 constantly urges the movable end of the bellows 160 to the right or outwardly of the rod 104 to thus position the weight 112' in a position to exert a maximum load on the valve 78-80. The interior of the bellows 160 is connected by a flexible tube 168 with the chamber 92 and is thus placed under the same degree of vacuum as the chamber 92 and consequently the same degree of vacuum as exists in the vacuum return line 28.

In the construction illustrated in Fig. 4 it will be appreciated that as the degree of vacuum in the vacuum return line 28 increases, or in other words as the absolute pressure in the vacuum return line decreases, it will act upon the bellows 160 to shorten the overall length of the same and will consequently draw the loading weight 112' inwardly towards the fulcrum of the bar 104, thus decreasing the effect of the weight 112' in loading the valve 78-80 and thus reduce the differential of pressures between the inlet and outlet ends of the system as controlled by the valve. As the pressure in the outlet end of the system increases, the pressure on the interior of the bellows 160 will decrease thereby permitting the spring 166 to move the weight 112' outwardly away from its fulcrum and increase the load on the valve so as to adjust it to maintain a greater differential of pressures between the inlet and outlet ends of the systems. The ultimate effect obtained is, of course, equivalent to that obtained in the constructions illustrated in Figs. 2 and 3, the only difference being that the effect is obtained by a different means.

Formal changes may be made in the specific embodiment of the invention described without departing from the spirit or substance of the broad invention, the scope of which is commensurate with the appended claims.

What is claimed is:

1. In a steam heating system of the class including a steam main, a return line, a plurality of radiators connected between said main and said line, pumping means connected with the return line for removing air, non-condensable gases and water of condensation therefrom and a reducing valve for controlling the admission of steam to the main, the combination with said reducing valve of loading means constantly urging said valve toward open position, and means for varying the effect of said loading means comprising a first chamber means subject to the pressure existing in said steam main and having a movable wall means so connected to said loading means as to oppose the effect of said loading means on said valve, and a second chamber means having movable wall means subject to the pressure existing in said return line and so connected to said loading means as to oppose the effect of the first mentioned movable wall on said loading means, the area of the last mentioned wall means exceeding the area of the first men-

tioned wall means whereby variations in pressure in said return line have a greater influence in varying the effect of said loading means on said valve than identical changes in pressure in said steam main.

2. In a steam heating system of the class including a steam main, a return line, a plurality of radiators connected between said main and said line, pumping means connected with the return line for removing non-condensable gases therefrom and a reducing valve for controlling the admission of steam to the main, the combination with said reducing valve of pressure responsive means operatively connected thereto, said pressure responsive means including chamber means having movable wall means subject to the pressure existing in the inlet end of the said system and tending to move said valve in one direction and chamber means having movable wall means subject to the pressure existing at the outlet end of said system and tending to move said valve in the opposite direction, said movable wall means being so connected to said valve that the force resulting from the difference in pressures acting on said movable wall means tends to close said valve, the area of the last mentioned movable wall means being in excess of the area of the first mentioned wall means whereby the force exerted by the last mentioned wall means tending to move the valve in one direction increases at a proportionally greater rate than the force exerted by the first mentioned wall means opposing the force of the second mentioned wall means as the absolute pressure in the outlet end of the system decreases.

3. In a steam heating system of the class including a steam main, a return line, a plurality of radiators connected between said main and said line, pumping means connected with the return line for removing non-condensable gases therefrom and a reducing valve for controlling the admission of steam to the main, the combination with said reducing valve of means constantly urging said valve towards open position, and pressure actuated means for moving said valve against the force of the last mentioned means, said pressure actuated means including movable wall means connected to said valve and subjected to the pressure of said system in said main tending to urge said valve in one direction and subject to the pressure existing in said return line tending to urge said valve in the opposite direction, the last mentioned means being so constructed and arranged as to present a greater area to the effects of the pressure in said return line than to the effects of the pressure in said steam main whereby to exert a force on said valve varying with the variations of pressure in said system to a greater degree than the force exerted on said valve through variations of pressure in said steam main.

4. In a steam heating system of the class including a steam main, a return line, a plurality of radiators connected between said main and said line, pumping means connected with the return line for removing non-condensable gases therefrom and a reducing valve for controlling the admission of steam to the main, the combination with said reducing valve of loading means constantly urging said valve towards open position, a diaphragm connected to said valve and subject to variations in pressure in said steam main on one face thereof and subject to variations in pressure in said return line on the opposite face thereof, the connection between said

valve and diaphragm being such that the difference in pressure on opposite sides of said diaphragm opposes the effects of said loading means and an additional diaphragm connected to said valve subject to variations in pressure in said return line on one face thereof and subject to a substantially constant pressure on the opposite face thereof for supplementing the effects of the first mentioned diaphragm on said loading means.

5. In a steam heating system of the class including a steam main, a return line, a plurality of radiators connected between said main and said line, pumping means connected with the return line for removing non-condensable gases therefrom and a reducing valve for controlling the admission of steam to the main, the combination with said reducing valve of loading means constantly urging said valve towards open position, a first diaphragm connected to said valve subject to variations of pressure in said steam main on one face thereof and subject to a substantially constant pressure on the opposite face thereof, a second diaphragm connected to said valve subject to variations in pressure in said return line on one face thereof and subject to a substantially constant pressure on the opposite face thereof and acting in opposition to said first diaphragm, the difference in forces acting on said diaphragms opposing the effect of said loading means on said valve, the effective area of said second diaphragm exceeding the effective area of said first diaphragm whereby the force exerted by said second diaphragm on said valve varies to a greater extent than the force exerted by said first diaphragm on said valve upon equal changes in pressure at opposite ends of said system.

6. In a steam heating system of the class including a steam main, a return line, a plurality of radiators connected between said main and said line, pumping means connected with the return line for removing non-condensable gases therefrom and a reducing valve for controlling the admission of steam to the main, the combination with said reducing valve of loading means constantly urging said valve towards open position, a diaphragm operatively connected to said valve and subject to the pressures existing in the steam main on one face thereof and to the pressures existing in said return line on the opposite face thereof, the connection between said valve and diaphragm being such that the difference in pressures acting on said diaphragm opposes the effect of said loading means on said valve, and an additional pressure responsive means subject to the pressure existing in said return line on one face thereof and to a substantially constant pressure on the opposite face thereof operatively connected to said loading means for varying the loading effects thereof during variations of pressure in said return line whereby to feed greater amounts of steam to said system upon increase in absolute pressure in said system and feed lesser amounts of steam to said system with decrease in absolute pressure in said system.

7. In a steam heating system of the class including a steam main, a return line, a plurality of radiators connected between said main and said line, pumping means connected with said return line for removing air and non-condensable gases therefrom, means for effecting cyclic operation of said pumping means, and a reducing valve for controlling the admission of steam to the main, the combination with said reducing

valve of means connected thereto for controlling the operation thereof comprising movable wall means different areas of which are subject to the pressure in said main and return line, respectively, said movable wall means having a greater area thereof subjected to the pressure of said return line than to the pressure of said steam main and being so constructed and arranged with respect to said reducing valve as to tend to close said valve upon increase in pressure in said steam main and diminution of pressure in said return line, whereby upon initiation of each cycle of operation of said pumping means said movable wall means tends to close said valve.

8. In a steam heating system of the class including a steam main, a return line, a plurality of radiators connected between said main and said line, pumping means connected with said return line for removing air and non-condensable gases therefrom, means for effecting cyclic operation of said pumping means, and a reducing valve for controlling the admission of steam to the main, the combination with said reducing valve of means connected thereto for controlling the operation thereof comprising pressure responsive movable wall means subject to the pressure in said main and return line, respectively, a greater area of said pressure responsive movable wall means being subjected to the pressure of said return line than to the pressure of said steam main and that area of said pressure responsive movable wall means subject to the pressure in said return line in excess of the area thereof subject to the pressure in said main being at least partially opposed by a substantially constant pressure, whereby a reduction in pressure in said system is accompanied by a greater force tending to move said valve towards closed position than the corresponding increase in force tending to move said valve towards open position.

9. In a steam heating system of the class including a steam main, a return line, a plurality of radiators connected between said main and said line, a pressure reducing valve for controlling the admission of steam to the main, and a pressure responsive element subject to the pressure differences between said steam main and said return line for controlling said valve, the combination with said valve of means for closing the same upon the occurrence of conditions equalizing the pressures on opposite sides of said pressure responsive element comprising a second pressure responsive element connected to said valve, means connecting said steam main to one face of said second pressure responsive element, means for discharging steam from said second pressure responsive element at a lesser rate than that at which it may be delivered thereto from said steam main, and pressure responsive means normally closing communication through said connecting means operable to permit the flow of steam therethrough upon the presence of an abnormal positive pressure in said steam main.

10. In a steam heating system of the class including a steam main, a return line, a plurality of radiators connected between said main and said line, a pressure reducing valve for controlling the admission of steam to the main, and a pressure responsive element subject to the pressure differences between said steam main and said return line for controlling said valve, the combination with said valve of means for closing the same upon the occurrence of conditions equalizing the pressures on opposite sides of said pressure responsive element comprising a casing,

a diaphragm in said casing connected to said valve, said casing having a vent therein on one side of said diaphragm, means providing a passageway between said steam main and the vented side of said casing of greater capacity than said vent, and means associated with said passage normally blocking the flow of steam therethrough but operable upon the presence of an abnormal pressure in said steam main to admit a flow of steam from said steam main to said second pressure responsive element whereby to effect a closing movement of said valve.

11. In a steam control valve comprising a casing forming a steam passage and a valve movably mounted therein for controlling the flow of steam therethrough, means for controlling the position of said valve comprising, in combination, a housing fixed with respect to said casing, a diaphragm dividing said housing into a pair of chambers, means sealing said chambers from the atmosphere and said chambers being respectively formed for connection to the steam side and the return side of a steam heating system, a second housing fixed with respect to said first housing, a diaphragm dividing said second housing into a pair of chambers, means connecting said diaphragms for equal movement, said second housing being formed to connect one of said chambers

with the return side of said steam heating system, means for connecting the other of said chambers of said second housing with the steam side of said steam heating system, a valve in said connection operable to admit steam to said last mentioned chamber only upon the presence of a predetermined maximum pressure in said connection, and means having a lesser flow capacity than said connection venting said last mentioned chamber to the atmosphere.

12. In a steam control valve comprising a casing forming a steam passage and a valve movably mounted therein for controlling the flow of steam therethrough, means for controlling the position of said valve comprising, in combination, a housing fixed with respect to said casing, a pair of diaphragms dividing said housing into three chambers, one of said diaphragms being of greater diameter than the other thereof, means for venting the chamber formed between said diaphragms with the atmosphere, means for connecting the remaining chambers to the steam side and the return side, respectively, of a steam heating system, means connecting said diaphragms for equal movement, and means connecting said diaphragms with said valve.

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