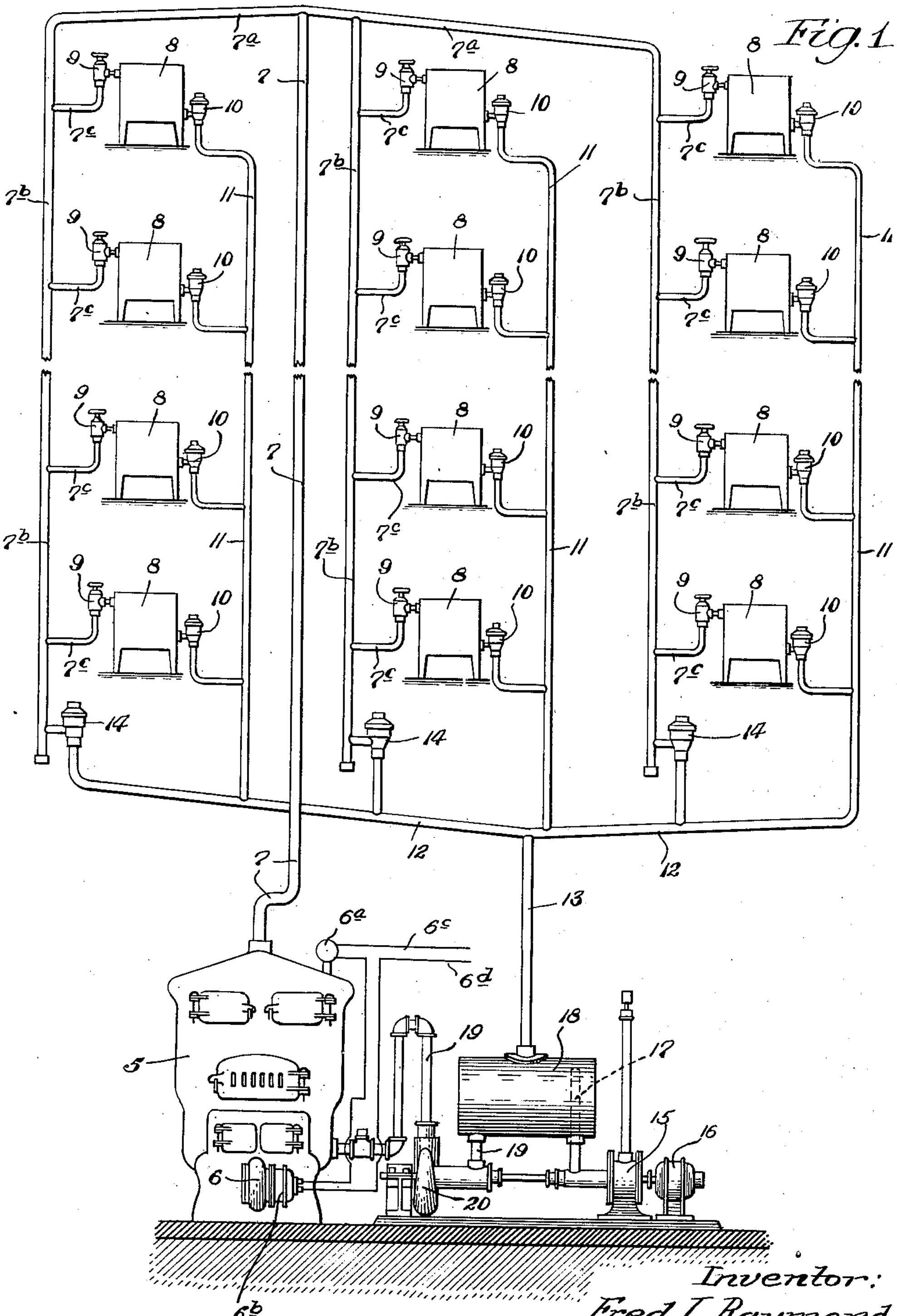
Dec. 21, 1937. F. I. RAYMOND 2,103,178

STEAM HEATING SYSTEM AND METHOD OF SUPPLYING STEAM TO THE RADIATORS THEREOF

Filed March 22, 1934 2 Sheets-Sheet 1

Fig. 1



Inventor:
Fred I. Raymond,
By Dyrenforth, Lee, Chritton and Wiles,
Att'ys.

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Fig. 2.

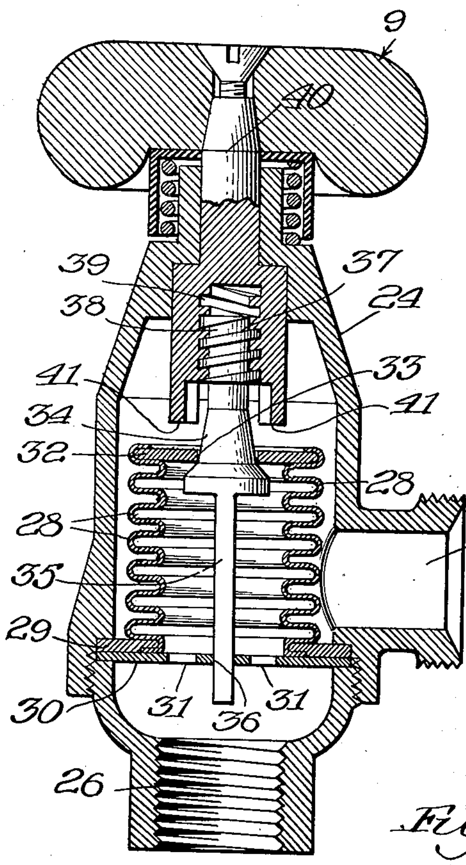


Fig. 3.

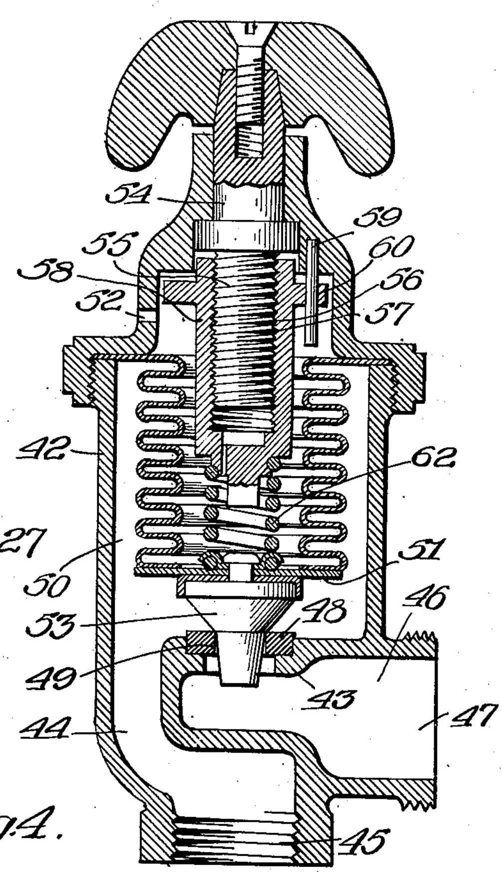


Fig. 2a.

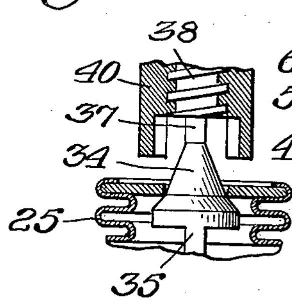
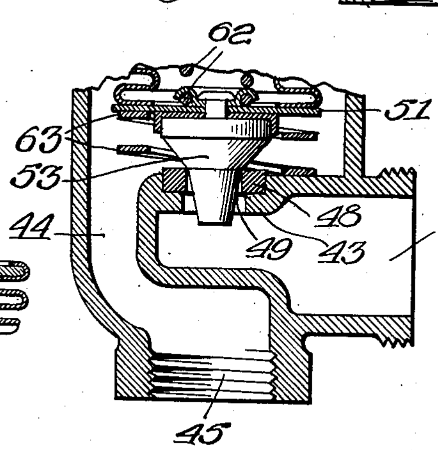


Fig. 4.



Inventor:
Fred I. Raymond,
By Dyrenforth, Lee, Chritton & Wiles,
Att'ys.

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UNITED STATES PATENT OFFICE

2,103,178

STEAM HEATING SYSTEM AND METHOD OF SUPPLYING STEAM TO THE RADIATORS THEREOF

Fred I. Raymond, River Forest, Ill.

Application March 22, 1934, Serial No. 716,914

6 Claims. (Cl. 237—9)

My invention relates primarily to steam heating systems, whether of the so-called steam, vapor, or vacuum type, comprising radiators in the several rooms of a building, a system of supply piping for conducting steam to each of the radiators from a central point, and a separate system of return piping for collecting the condensate from the several radiators and conducting it back to a desired point, my present invention being a continuation, in part, of my application for United States Letters Patent Serial No. 272,330, filed April 23, 1928.

One of my objects is to provide for the distributing of proportionate quantities of steam to the various radiators of a steam heating system of the so-called "orificed type", at reduced capacities as well as at maximum capacity. While this object has been the object of previous systems of the so-called "orificed type" there are certain practical limitations in the apparatus that have hitherto been used which limitations have prevented the prior systems from accomplishing the full measure of performance that I am able to secure by my invention.

Another object is to provide for the distributing of the same proportionate quantities of steam to the radiators at the top of a tall building as to the radiators at the bottom of the building at all capacities, a result which has not been hitherto attempted so far as I can ascertain. The need for it arises out of the fact that the pressure differential tending to force steam into the radiators at the top of the building is greater than the differential at the bottom of the building due to the buoyancy of the steam in the system of supply piping as compared with the heavier air in the system of return piping. This difference in differential is most pronounced in tall buildings because the difference in weight between the column of air in the return piping and the column of steam in the supply piping is directly proportional to the height of the column. This difference in differential between that at the top and that at the bottom of the building may be called the altitude head. It is a serious handicap in the operation of previous systems because it remains practically constant at all capacities and as the differential in pressure is reduced for operation at lower capacities, the altitude head becomes an increasing proportion of the total differential.

As the differential in pressure is reduced, the point is finally reached where the differential at the bottom of the building will be zero while the differential at the top of the building will still be equal to the altitude head. The seriousness of this defect will be realized by considering the case of a building in which the top radiator is 217 feet higher than the bottom. Based on the density of saturated steam at 212° F. and that of dry air at 100° F. the altitude head would be equal to .1'' of mercury. If the radiators of a system in such a building were equipped with orifices at the entrances to the radiators so sized that the radiators at the top and bottom would each receive 100% of the desired quantities of steam when the differential at the bottom orifice was 1.0'' of mercury, then when the differential was reduced by throttling the supply of steam to the system to a point where the differential at the bottom was zero, here would still be a differential of .1'' at the top radiator. This differential of .1'' at the top orifice would produce approximately 30% as much flow through the top orifice as with the design differential of 1.1'' for the top orifice for its rated capacity. Thus in such a system in a building 217 feet high, it would be necessary to supply 30% of the rated capacity of steam to the top radiator before any steam could be delivered to the bottom radiator.

Some of the manufacturers of previous so-called "orificed systems" have realized this inherent limitation of altitude head, and have sought to minimize it by using a design differential much higher than 1'' of mercury such as 2'' or 4'' and even 8'' and 10''. By doing so they have been able to keep the altitude head a much smaller proportion of the total head. However, at these higher differentials, the velocity of the steam through the orifices is so great that it causes a hissing sound which is audible in the rooms and objectionable for that reason.

Another limitation of previous orificed systems, which limitation I overcome by my invention, arises out of the fact that the flow of steam through an orifice is substantially proportional to the square root of the pressure differential across the orifice. Thus the quantities of steam which will flow through an orifice designed to give 100% of capacity at 1'' differential are as follows:

Pressure differential	Percent of flow
1.0'' Hg	100
.81''	90
.64''	80
.49''	70
.36''	60
.25''	50
.16''	40
.09''	30
.04''	20
.01''	10
.00''	0

From the above table it is evident that the differentials required at low capacities are very minute quantities. Not only is extremely accurate and sensitive pressure controlling apparatus required, but it also becomes extremely difficult to produce these same pressure differentials or the same relative pressure differential in all parts of the system. While it is theoretically possible to place additional orifice plates in the branch steam lines of such a system and thereby correct for drop in differential due to different sizes and lengths of the supply pipes, it becomes an extremely delicate and tedious operation in actual practice. Moreover, even after all corrections have been made for resistance to flow in the supply piping, the defect of unequal flow due to altitude head still remains.

The first referred to object of my invention can be best understood by comparing the following table of pressure differentials at which I might choose to operate my system with the table of pressures given above.

Pressure differential	Percent of flow
1.00	100
.9	90
.8	80
.7	70
.6	60
.5	50
.4	40
.3	30
.2	20
.1	10
.0	0

By comparison it will be noted that for 20% capacity with my system, I would require a differential of .2'' Hg as opposed to .04'' Hg under previous systems. The differential would be five times as great with my system as in previous systems at 20% of capacity provided both systems were designed to give 100% flow at the same differential. Similarly, my system would employ ten times as much differential at 10% of capacity as previous systems. Because of this greater differential at reduced capacities, the pressure controlling apparatus would not need to be nearly so sensitive as with previous systems. Also the effect of piping resistance would be of much less importance. Also there would be considerable advantage from the standpoint of instructing an operator to have a system in which twice as much pressure differential would give twice as much flow. It would be simpler too to build controlling apparatus which operated to produce pressures directly proportional to required capacities than it is to build controls to operate on a square root basis of increment.

My approach to the accomplishment of the second object of my invention can be best understood by reference to the example previously given of .1'' Hg altitude in a building 217' high. In that example I pointed out that the .1'' differential due to altitude head would produce approximately 30% flow through the top orifice while the flow at the bottom was zero. This defect can be overcome if an orifice were installed in the upper radiator which would give 0% of flow at .1'' pressure differential. Both the limitations of square root flow and altitude head could be overcome if orifices were to be installed in the top and bottom radiators which would give the following performance:

Pressure differential at bottom	Percent of flow at bottom	Pressure differential at top	Percent of flow at top
1.0'' Hg	100	1.1'' Hg	100
.9''	90	1.0''	90
.8''	80	.9''	80
.7''	70	.8''	70
.6''	60	.7''	60
.5''	50	.6''	50
.4''	40	.5''	40
.3''	30	.4''	30
.2''	20	.3''	20
.1''	10	.2''	10
.0''	0	.1''	0

Having outlined my approach to a solution of the problem, it will now be simple to understand the means I have used.

I have obtained the first object of my invention by designing an orifice which automatically decreases in size by the proper amount as the pressure differential decreases. Thus I am able to decrease the flow through the orifice not only due to the reduced velocity of steam through the orifice due to reduction in differential but also due to the reduction in size of the orifice.

I have attained the second object of my invention by designing an orifice which can be adjusted to be completely closed at any desired pressure. Thus the orifice at the top radiator would be adjusted to be completely closed at .1'' Hg differential in a building 217 feet high whereas the bottom orifice would be adjusted to be completely closed at 0'' Hg differential.

Referring to the accompanying drawings:

Figure 1 is a view, in elevation, with parts broken away, of a heating system for a tall building and suitable for practicing my improved method.

Figure 2 is a view, in vertical section, of one form of radiator inlet valve which may be used, and of such construction as to be operated responsive to pressure differential at the inlet of the radiator.

Figure 2ª is a fragmentary view of the valve of Fig. 2 modified to adapt it for use with a larger radiator.

Figure 3 is a similar view of another form of radiator inlet valve which may be used and of a construction operated by absolute pressure only; and

Figure 4, a similar view, with parts broken away, of a modification of the valve of Fig. 3 and desirable for use where low pressure steam, or steam delivered under partial vacuum, is supplied.

Referring to the system shown, this system is an example of a steam heating system for a tall building in which an appreciable altitude head is encountered as above referred to, the radiators shown, a plurality of which are located on each floor of the building, being those which would be provided on the two lower and the two upper floors of a tall building as above explained, the mid section of the radiator piping assembly being omitted.

In this system a boiler indicated at 5 is represented as fired by an electrically driven oil burner 6 shown as provided with an adjustable pressure-controlled electric switch device 6^a interposed in series with the motor 6^b of the burner 6 in the electric current line wires 6^c and 6^d, the device 6^a in accordance with common practice being adjustable to vary the steam pressure generated in the boiler 5.

The boiler 5 connects by an upwardly extending pipe 7 with an overhead main 7^a from which steam is supplied to the down-feed risers 7^b constituting parts of the main 7^a and opening into the latter at different points therealong as shown. Each riser 7^b is shown as connected by pipes 7^c with a vertical series of radiators 8 each of which is provided with an inlet valve 9 adjustable as hereinafter explained to start to open at different pressures to compensate, as above explained, for the altitude head and for the other purpose hereinafter explained, and each of which opens progressively at different rates to provide a particular relation, preferably a straight-line relation, between the pressure and the quantities of steam entering the radiators.

The system is shown for the supplying of steam to radiators a plurality of which are located on each floor of a building, the radiators shown being those which would be provided on the two lower and the two upper floors of a tall building as above explained.

Each radiator 8 may be connected, as shown, at its outlet with a thermostatic trap valve 10 which functions to permit the outflow of air and condensate from the radiators, but closes automatically to prevent the escape of steam therefrom. The traps 10 open into return line pipes 11 connected with pipes 12 communicating with a downwardly extending pipe 13.

At the lower ends of the risers 7^b are relatively large thermostatic traps 14 connected with the return line pipes 12.

Preferably means are provided for insuring the withdrawal of air and condensate from the radiators through the return line pipes 11, 12 and 13 by the maintaining of a somewhat lower pressure in the return line than the pressure in the radiators or the feed pipes connected therewith. In the system shown such a means is employed comprising a vacuum pump 15 driven by a motor 16, the inlet of the pump communicating with an upstanding pipe 17 which opens into the upper end of a condensate tank 18 into which the return line pipe 13 discharges. The tank 18 at its bottom communicates with a pipe 19 which opens into the boiler 5 and through which the condensate is discharged into the boiler by a pump 20 interposed in the pipe 19 and driven by the motor 16.

As will be noted more in detail hereafter, the invention may be practiced where the heating medium is supplied at either high or low pressures, namely, in either a so-called pressure system or a vacuum system. If high pressure steam (that is, pressure above atmospheric) is used for supplying the radiators with steam, it may be desirable to maintain a super-atmospheric pressure in the return piping 11—13 instead of exhausting the air from this piping, it being desirable that only a small differential pressure be maintained between the supply risers and the radiators or return pipes.

Referring now to the inlet valves 9 for the radiators, and which may be any one of a number of different forms as for example as illustrated in Figs. 2, 2*a*, 3 and 4, the form shown in Figs. 2 and 2*a* and which operates responsive to the difference between the pressure in the radiator and the pressure in the supply line, comprises a casing 24 presenting a chamber 25 having an inlet 26 connected with the pipe 7^c and an outlet 27 connected with the inlet end of the radiator. Located in the chamber 25 and in spaced relation to the walls of the latter, is a flexible tubular metallic diaphragm 28 preferably of the expansible bellows type as shown, with deeply corrugated side walls, the lower end of the diaphragm 28 being rigidly clamped in place, to provide a pressure-tight joint, between a ring 29 and a disk 30 located in the chamber 25 and rigidly clamped in place to provide a sealed joint between sections of the casing, the disk 30 being apertured as by providing therein a series of openings represented at 31 to permit of the flow of the steam into the bellows-diaphragm. The upper end of the diaphragm 28 is closed by a valve plate 32 containing a central orifice 33 through which the steam supplied to the valve device 9 passes to the radiator under the control of a valve located in the orifice 33 and represented at 34, the valve 34 being of general cone shape and shown as mounted for longitudinal adjustment relative to the orifice 33, as by providing the valve with a depending stemlike portion 35 slidable in an opening 36 in the disk 30. It is desired that the valve 34 be held against turning movement and this is effected, in the particular construction shown, by forming the stemlike portion 35 of non-circular shape in cross section, as by cutting away the opposite sides of the lower cylindrical portion of the valve as shown, and so shaping the opening 36 in the disk 30 as to prevent turning of the valve.

The valve 34 is further provided with an upwardly extending stem portion 37 secured to an externally threaded nut 38 which engages the internal screw threads 39 of a valve stem 40 journalled in the casing 24 and held against longitudinal movement, whereby the valve 34 may be adjusted longitudinally of the orifice 33 by rotating the stem 40.

From the above it will be understood that the underside of the plate 32 and the orifice 33 are subjected to the pressure of the steam supply and the top surface of the plate 32 to the pressure in the radiator, the bellows diaphragm 28 acting as a spring tending to hold the bellows collapsed. Thus assuming that the valve stem 40 has been adjusted to a position in which the plate 32 just contacts at the wall of its orifice 33 with the sides of the cone 34, when the steam pressure at opposite sides of the plate 32 is equal, the raising of the steam pressure in the supply line, or the reducing of the pressure in the radiator as by the operation of the vacuum pump 15, either of which builds up pressure in the bellows 28, causes the plate 32 to rise relative to the cone and thereby open the orifice 33 proportionately to such movement of the plate 32.

In the designing of a system in accordance with my invention provision would be made whereby the openings provided at the orifices for the passage of steam to the radiators, when the cone-valves cooperating therewith occupy their extreme open positions responsive to the subjection thereof to the maximum differential pressure at which it is designed the radiators operate at full capacity, would be of such effectiveness as to supply the respective radiators with the requisite amount of steam for the functioning of the radiators at their full capacity, it being understood that the larger the radiator the larger the effective orifice in the full open position of the valve. The valve cones, from which the orifice plates move but a slight distance only in response to slight increase of pressure differential, would be so shaped that the amount of steam passing through the orifices is a substantially straight line function of pressure, rather than a hyperbolic function of pressure as in the case of non-variable orifices.

In practice I would prefer to equip all of the radiators with plates having orifices of the same size and compensate for different sizes of radiators by providing cones of different shapes, the larger radiators having cones of greater taper. This is illustrated in Figs. 2 and 2*a* wherein the valve of Fig. 2, provided for a radiator of approximately ordinary size, but smaller than that for which the valve of Fig. 2*a* is provided, would present less taper than the valve shown in Fig. 2*a*.

As will be understood, the valve **34** may be drawn up to set position in which the bellows **28** is under tension the degree of which determines the pressure at which the orifice initially opens, this being of advantage especially where different temperatures are to be maintained in different rooms, and also to compensate for altitude head in the particular heating system shown.

The valve as shown is provided on its stem **40** with stops **41** which extend into the path of upward movement of the orifice plate **32** and which form a backing for this plate permitting the operator to lift the valve **34** by manipulating the stem **40**, into a position in which it presses upwardly against the wall of the orifice **33** with such pressure as to cause the valve to function as a stop valve preventing all flow of steam into the radiator.

The valve shown in Fig. 3 and which may be used at each radiator in place of a valve of the construction in Fig. 2 and of a type operating responsive to absolute inlet pressure, as distinguished from differential pressure, comprises a casing **42** divided in its lower portion by an internal apertured web **43** into an inlet passage **44** leading from an inlet port **45** and an outlet passage **46** leading to an outlet port **47**, the ports **45** and **47** being coupled in any suitable manner with the pipe 7^c and the radiator **8**, respectively. Mounted in the orifice in the web **43** is an orifice plate **48** containing the orifice **49** which leads from the steam chamber represented at **50** to the outlet passage **46**.

Located in the chamber **50** and in spaced relation to the walls of the latter is a flexible tubular metallic diaphragm **51** preferably of the expansible bellows type, as shown, with deeply corrugated side walls, the upper end of the diaphragm which is open to the atmosphere as through a port **52** in the casing **42**, being rigidly clamped in place between sections of the casing **42** to provide a sealed joint between the diaphragm and the sections of the casing. The lower movable end of the diaphragm **51** is provided with a valve **53** of general frusto-conical shape and cooperating with the orifice **49** to control the amount of steam passing through the latter responsive to the degree of pressure of the steam entering the chamber **44** through the inlet **45**.

The valve also comprises a stem **54** rotatable, but held against longitudinal movement, in the casing **42**, the lower end of the stem **54** being externally threaded as represented at **55** at which it is screwed into the internal threads **56** provided in an upwardly opening socket **57** in a nut **58** held against rotation by a pin **59** secured in, and depending from, the top of the casing **42** and slidable in an opening **60** in a flange **61** on the nut, the nut **58** being thus movable up and down by rotation of the stem **54** in the appropriate direction. Interposed between the nut **58** and the lower end of the diaphragm **51** is a compression spring **62**.

As will be understood, the valve **53** is caused to open and permit steam to enter the radiator responsive to the flow of steam into the chamber **44** at a pressure depending upon the resistance of the valve **53** to upward movement and which resistance is controllable by varying the tension of the spring **62** all to the same end as explained above in connection with the construction shown in Fig. 2, it being possible to entirely close the valve against opening, by forcibly pressing the valve **53** against the valve seat **48**.

When high pressure steam, that is, steam at any pressure above atmospheric, is used in the heating system, the spring **62** will be a compression spring so as to aid the atmospheric pressure within the diaphragm and the expansive force of the diaphragm itself in maintaining a balance against the higher steam pressure exerted on the outside of the diaphragm. When low pressure steam, or steam delivered under a partial vacuum, is used in the system the spring **62** may be a tension spring to maintain the proper balance between the forces exerted on the two sides of the diaphragm **51**; or, as shown in the modification as illustrated in Fig. 4, a compression spring **63** may be added within the steam chamber **44** and positioned to press upwardly against the lower end of the flexible diaphragm **51**, the spring **62** in such structure being a compression spring, and thus assist the low pressure steam in balancing the higher atmospheric pressure within the diaphragm.

While I have illustrated and described certain particular constructions constituting embodiments of my invention and have illustrated certain particular forms of apparatus for practicing my novel method, I do not wish to be understood as intending to limit it thereto as the constructions shown may be variously modified and altered and the method practiced by other constructions of apparatus without departing from the spirit of my invention, and in this connection it may be stated that my invention, as to certain phases thereof, is not limited to a system for a tall building as explained, but may be used in a system of such low height, either wherein all of the radiators are on one floor or on a plurality of superposed floors, that no appreciable altitude head is encountered in using the system.

What I claim as new, and desire to secure by Letters Patent, is:

1. The method of supplying steam to a plurality of radiators connected by a system of supply piping to a source of steam supply which consists in increasing the freedom of flow of steam from the supply piping to the radiators as the differential between the pressure in the piping and the pressure in the radiators increases, and decreasing the freedom of flow of steam from the supply piping to the radiators as the differential between the pressure in the piping and the pressure in the radiators decreases, and so controlling the said changes in freedom of flow of steam as to cause the amount of steam passing into the

radiators to constitute a substantially straight line function of the said differential.

2. The method of supplying steam to a plurality of radiators connected by a system of supply piping to a source of steam supply and disposed at such relative altitudes that an appreciable altitude head exists, which consists in increasing the freedom of flow of steam from the supply piping to the radiators as the differential between the pressure in the piping and the pressure in the radiators increases, and decreasing the freedom of flow of steam from the supply piping to the radiators as the differential between the pressure in the piping and the pressure in the radiators decreases to the end of causing the amount of steam passing into the radiators to constitute a substantially straight line function of the said differential, and reducing the freedom of flow to the radiators at the higher altitude as compared to the freedom of flow to the radiators at the lower altitudes by quantities which are sufficient to compensate for the effect of the altitude head to the end of causing the same relative quantities of steam to be supplied to the radiators at the higher altitudes as to the radiators at the lower altitudes.

3. In a steam heating system, the combination of a source of steam, a plurality of radiators, a system of piping adapted to conduct the steam to the radiators, said radiators being disposed at such relative altitudes that an appreciable altitude head is produced in the system of piping, restricting orifices at the inlets of said radiators, means operating automatically to vary the effective size of said orifices in response to changes in pressure at said orifices, and means presenting resistance to initial flow of steam to the upper one of said radiators relative to the lower one thereof to substantially compensate for said altitude head.

4. The method of supplying steam to a plurality of radiators of different sizes through restricted openings of changeable size, which method comprises: varying the differential of pressure between the radiators and the source of steam supply; causing the effective area of the openings to increase as the differential increases; and causing the rate of increase to be greater proportionally as the size of the radiators is greater.

5. The method of supplying steam to a plurality of radiators of different sizes through restricted openings of changeable size, which method comprises: varying the differential of pressure between the radiators and the source of steam supply; causing said openings to be closed while said differential is below a given minimum and open when above said minimum; causing the effective area of the openings to increase as the differential increases; and causing the rate of increase to be greater proportionally as the size of the radiators is greater.

6. The method of supplying steam to a plurality of radiators of different sizes through restricted openings of changeable size, which method comprises: varying the differential of pressure between the radiators and the source of steam supply in accordance with temperature requirements; causing the effective area of the openings to automatically increase and decrease respectively as the differential increases and decreases; and causing the rate of variation in effective area of the openings at the respective radiators to be greater or less proportionally as the size of the radiators is larger or smaller.

FRED I. RAYMOND.