Oct. 4, 1927. 1,644,114

C. A. DUNHAM

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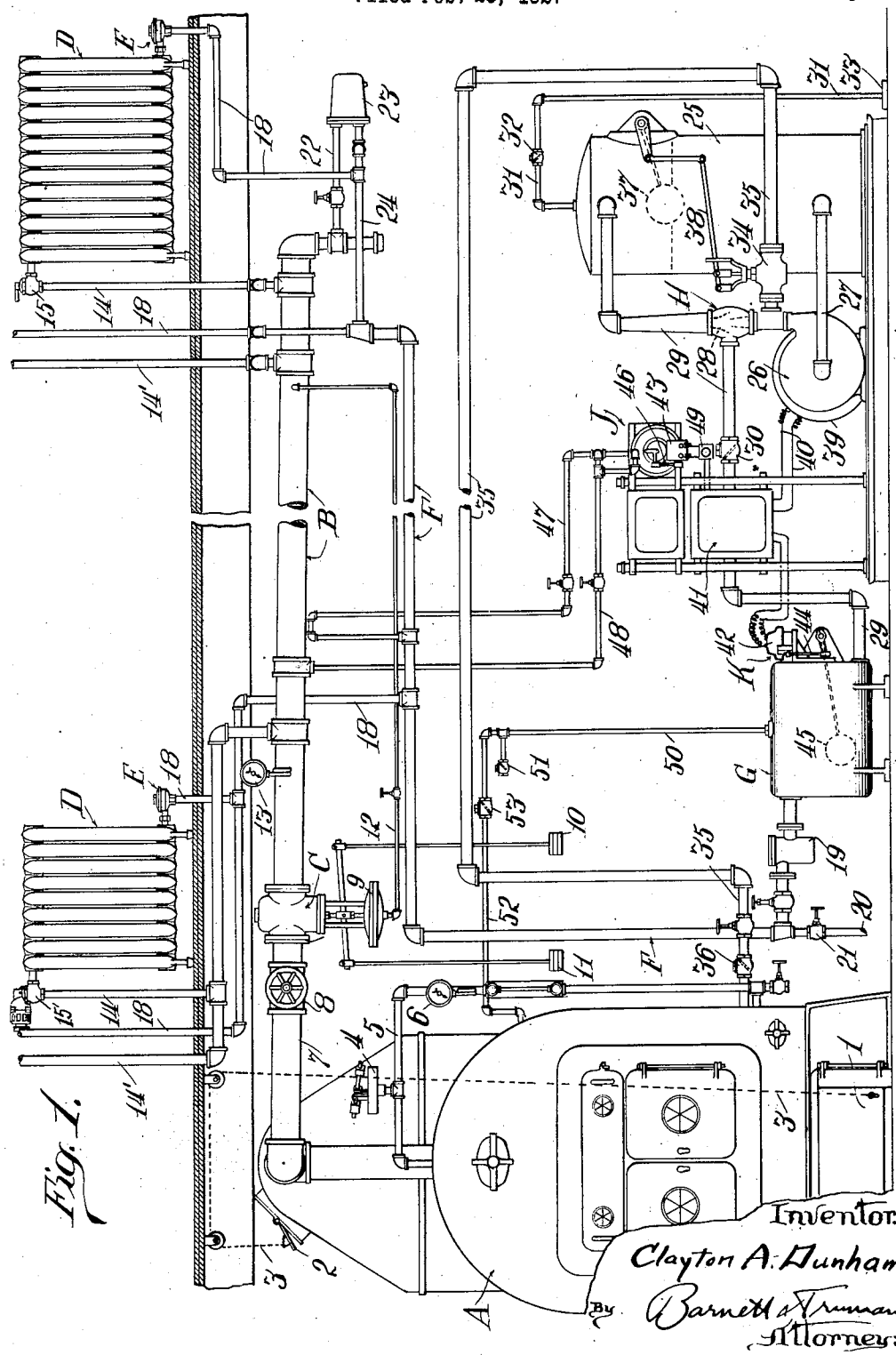


Fig. 1.

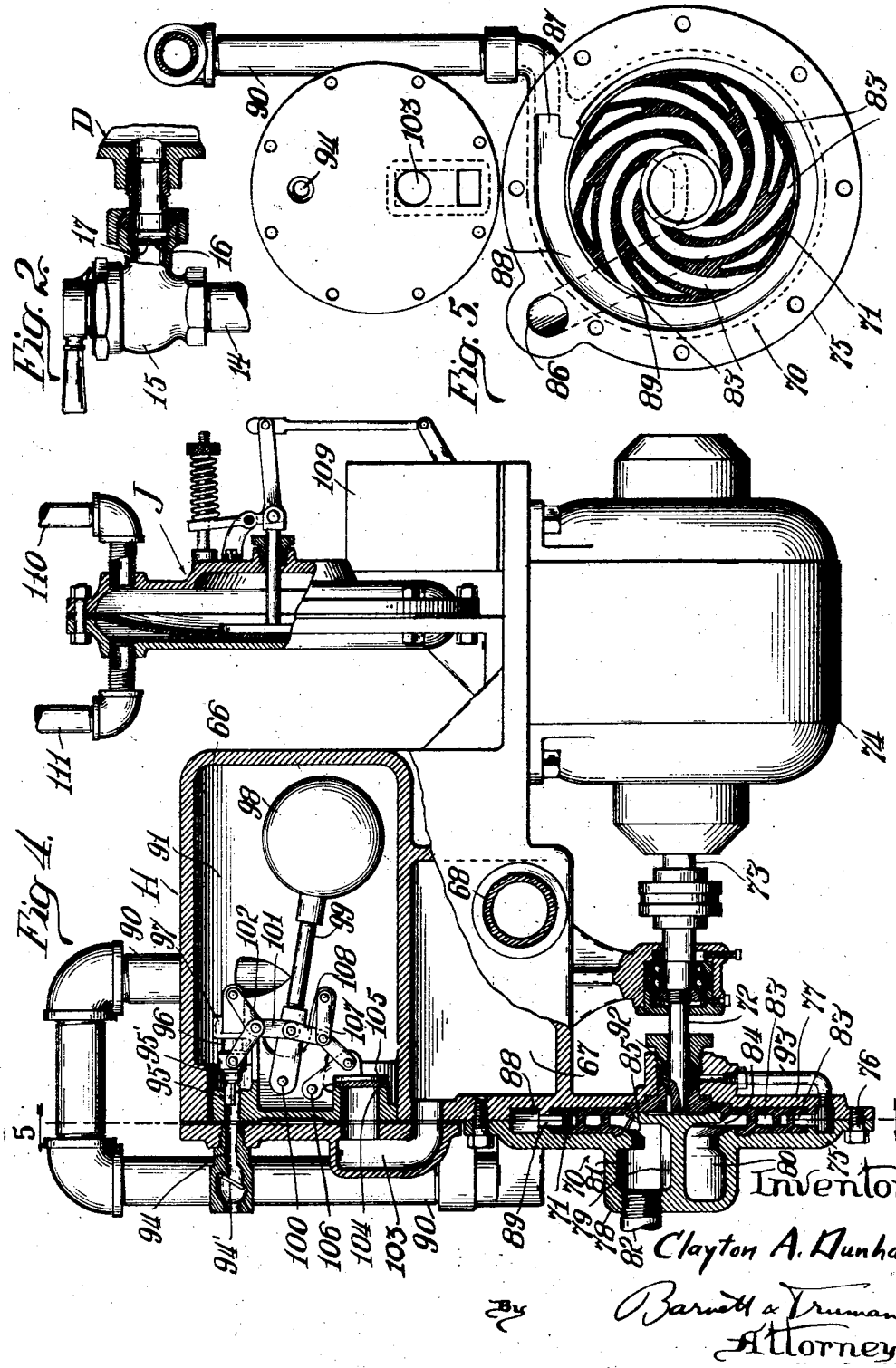
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METHOD OF HEATING BY STEAM

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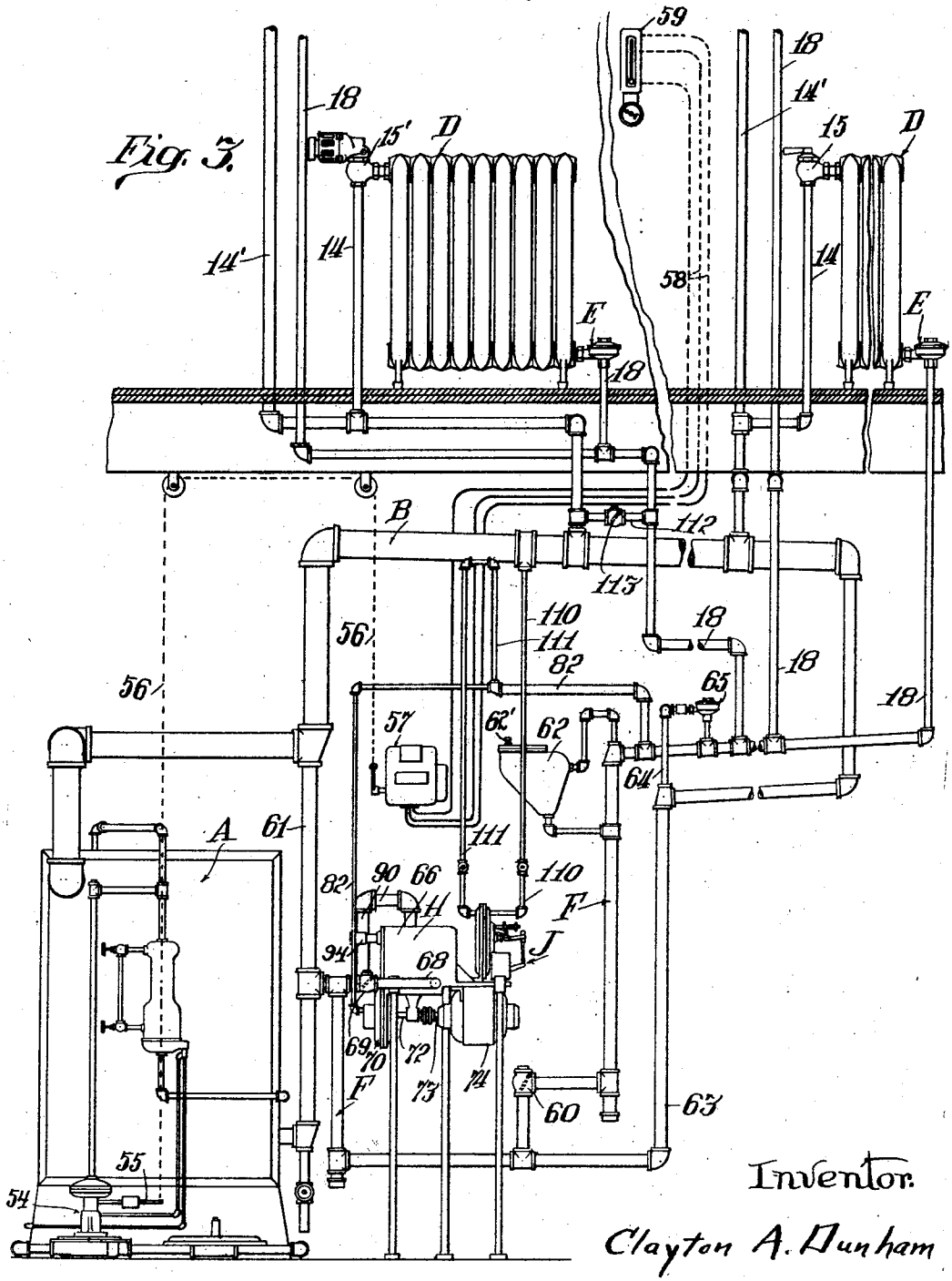
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METHOD OF HEATING BY STEAM

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Fig. 3.



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Fig. 7.

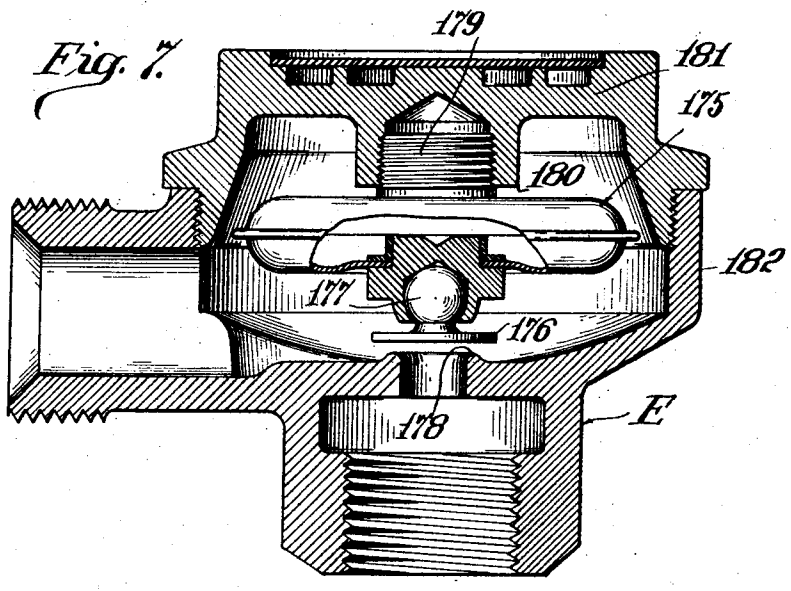
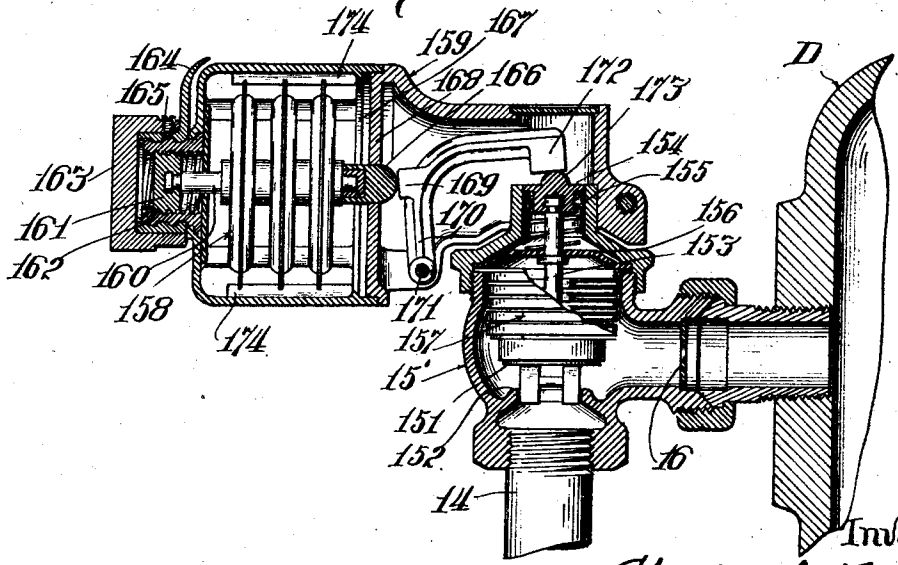


Fig. 6.



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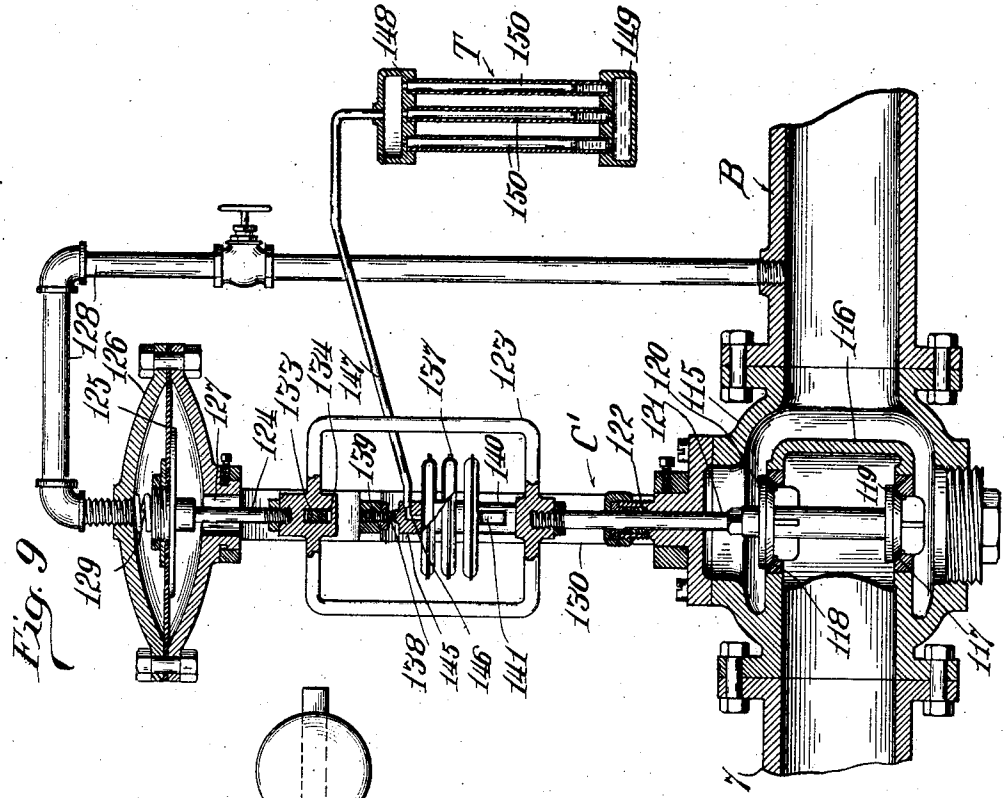


Fig. 9

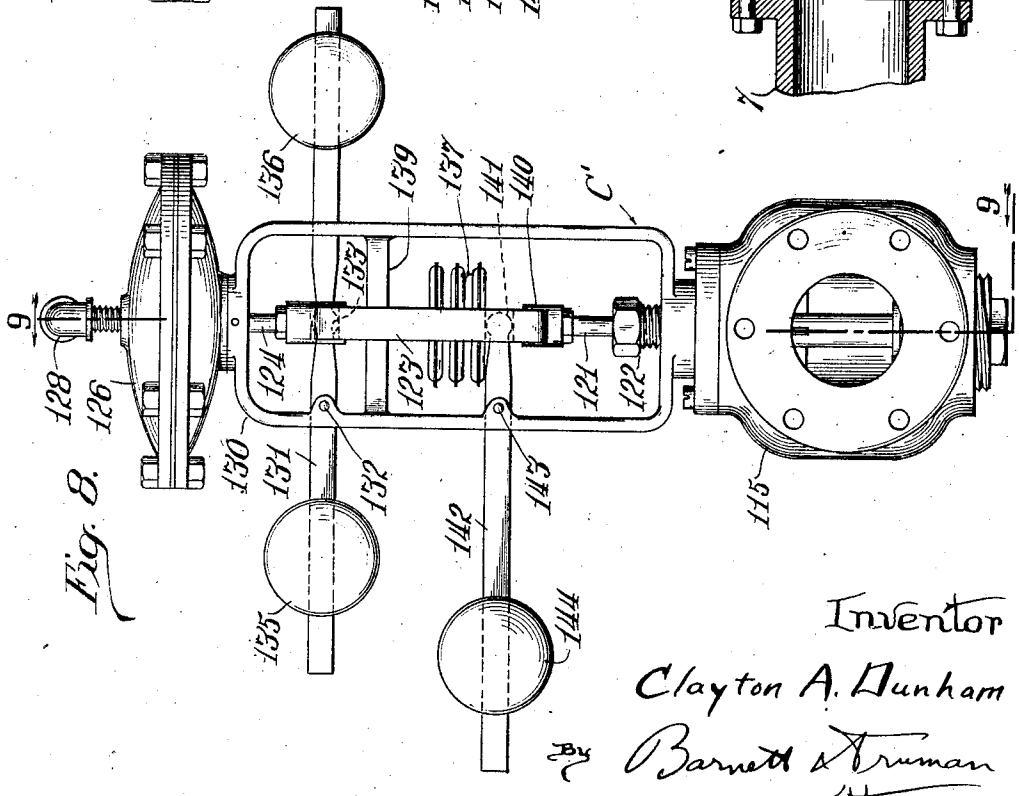


Fig. 8.

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UNITED STATES PATENT OFFICE.

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METHOD OF HEATING BY STEAM.

Application filed February 28, 1927, Serial No. 171,616, and in Canada January 6, 1927.

This invention relates to the art of steam heating and its principal object is to provide a novel method of heating by steam in accordance with which the steam is circulated through the radiators or condensing spaces at sub-atmospheric pressures which are varied according to the amount of heat required for maintaining the room or other space at the desired temperature. At all times the radiator or radiators will be kept free of air and condensate and full of steam. In mild weather, however, the steam will be maintained at a lower pressure, and consequently at a lower temperature, than in cold weather. Inasmuch as the pressure of the steam in the radiators may, by maintenance of a high vacuum throughout the system, be varied over a very considerable range, it is possible with the same amount of radiating surface to obtain just the quantity of heat required, and no more, whether the outside temperature be low or relatively high, by maintaining the radiator at a high temperature in cold weather and at a much lower temperature during mild periods. As a result a saving of fuel is effected which may be very considerable, especially in climates where there are occasional cold days interspersed with periods of relatively mild weather. By controlling the radiator temperature over ranges varying, for example, from 120° up, in accordance with weather conditions, there will be no disagreeable and unhealthful overheating, during relatively mild weather, and the tenants of the building will not be tempted to open windows in order to reduce temperature, which is a very common cause of waste of fuel, particularly in hotels and apartment houses.

In the accompanying drawings:

Fig. 1 is an elevation showing the principal elements of a preferred form of heating system operating according to this invention.

Fig. 2 is an elevation, partly in section, through one of the radiator inlet valves.

Fig. 3 is an elevation, similar to Fig. 1, showing a modified form of heating system.

Fig. 4 is an enlarged elevation, partly in section, showing the vacuum producing mechanism used in the system illustrated in Fig. 3.

Fig. 5 is a vertical section taken substantially on the line 5—5 of Fig. 4.

Fig. 6 is a central vertical section through a thermally controlled radiator inlet valve, that may be used instead of the simpler form shown in Fig. 2.

Fig. 7 is a central vertical section through one of the thermostatic traps.

Fig. 8 is an elevation of a temperature controlled reducing valve that may be used in lieu of the one shown at C in Fig. 1.

Fig. 9 is a central vertical section taken substantially on the line 9—9 of Fig. 8.

Many of the devices and mechanisms used in these systems are well known in this art, may be constructed in a variety of forms, and are here indicated rather diagrammatically. Only those features which are not well known to those skilled in the art have been indicated and described in detail.

Referring first to Fig. 1, A indicates the steam generator which furnishes steam through the supply main B and reducing valve C to the radiators D. Condensates and air are drawn out of the radiators through thermostatic traps E through return main F to the accumulator tank G. The vacuum producing mechanism indicated generally at H withdraws the condensates, vents the air, and forces the water back to the generator A, besides maintaining the desired vacuum throughout the system. The means indicated generally at J controls the vacuum producing mechanism so as to maintain a fixed difference in pressure between the supply and return mains, and the suction mechanism is also under control of a float operated switch mechanism K which responds to the level of the accumulated liquid condensate in the tank G.

The steam generator A may be of any desired form, the example here shown being an ordinary boiler, heated by a solid-fuel furnace provided with dampers 1 and 2, connected by a chain 3 with a pressure operated damper-controller 4 connected in the steam pipe 5 which is in communication with the boiler. 6 is a gauge positioned in the pipe 5 for indicating the pressure at which the steam is being generated.

Steam passes from the boiler through supply pipe 7 and cut-off valve 8, to and through the reducing valve C into the supply main B. The reducing valve C may be of the well known form embodying balanced cut-off valves whose movements to closed or open positions are governed by the enclosed pressure diaphragm 9 and the weights 10 and 11.

The diaphragm 9 is subject on one side to the steam pressure in supply main B, by means of the pipe 12 connected at one end to the housing of the diaphragm and at the other to the supply main at a point sufficiently remote from the valve C to be uninfluenced by pressure disturbances in the vicinity of the valve. This reducing valve C differs from similar valves heretofore in use in the fact that the balancing weights 10 and 11 are so proportioned and positioned that a desired sub-atmospheric pressure may be maintained in the supply main B, while a somewhat higher pressure (usually also sub-atmospheric) exists in the supply pipe 7 leading from the boiler. By properly adjusting the weights 10 and 11 (or other equivalent spring or weight devices which may be used), any desired degree of vacuum may be maintained in the supply main B. Preferably a pressure gauge 13 is provided to indicate this vacuum or sub-atmospheric pressure.

Instead of the manually adjusted reducing valve C, shown in Fig. 1, an automatic temperature controlled valve may be substituted, for example, one of the form shown at C′ in Figs. 8 and 9. As there shown, the valve casing 115 is interposed between the supply pipe 7 and the supply main B. This casing has an interior web 116 provided with two ports 117 and 118, which are adapted to be closed by a pair of valves 119 and 120 mounted on a stem 121 which extends out of the valve casing through stuffing box 122. Valve stem 121 is secured to the lower end of a yoke 123, and the upper end of this yoke is secured to a stem 124, which is in turn secured at its upper end to the flexible diaphragm 125 mounted in the diaphragm casing 126. The space under the diaphragm 125 is open to the atmosphere through an opening 127 in the bottom of casing 126, and the space above the diaphragm is connected by pipe 128 with supply pipe B on the low pressure side of the pressure reducer C′. An expansion spring 129 is confined between the upper section of diaphragm casing 126 and the upper side of diaphragm 125, and tends to force the valve stem downwardly and the valves 120 and 119 to closed position. The diaphragm casing 126 is supported on the upper end of a yoke structure 130, which is supported at its lower end on the valve casing 115. One arm of a lever 131, which is pivoted at 132 in the yoke structure 130, has a circular portion 133 bearing in a slot 134 formed in the upper end of yoke 123. Adjustable weights 135 and 136 are arranged on the respective arms of lever 131. It will be seen that the spring 129 and any preponderance of weight 136 over weight 135 are always tending to close valves 119 and 120, whereas the opposing force which tends to open the valves is the difference between atmospheric pressure acting on the lower surface of diaphragm 125 and the sub-atmospheric pressure or vacuum above this diaphragm. The weights 135 and 136 can be so adjusted that when the vacuum in supply main B reaches a predetermined maximum, the pressure acting upwardly upon the diaphragm 125 will overcome the force of these weights and of the spring 129 and open the valves 119 and 120, permitting steam under a higher pressure (although this also may be sub-atmospheric) to pass from pipe 7 into the supply main B and hence raise its pressure. The pressure reducer C′ as thus far described operates substantially the same as the pressure reducer C shown in Fig. 1.

A flexible corrugated vessel 137 is secured by means of an upstanding threaded stem 138 to a crosspiece 139 of the yoke structure 130. The expansible vessel 137 is provided with a downwardly projecting boss 140, slotted to receive the circular end 141 of a lever 142, pivoted at 143 in the yoke structure 130 and carrying an adjustable weight 144. This weight tends to compress the vessel 137. Interposed between the flexible vessel and the threaded stem 138 is a boss 145 formed with a port or passage 146 leading from the interior of the flexible vessel 137 to a tube 147 which extends to the thermostat T. This thermostat, as here shown, consists of upper and lower headers 148 and 149, connected by a plurality of tubes 150. The thermostat contains a fluid which expands and contracts with fluctuations in temperature. On rise of temperature to the point at which the thermostat is designed to act, the pressure of the fluid in the thermostat T, pipe 147, and flexible vessel 137 overcomes the force of weight 144, the flexible vessel 137 expanding and through boss 140, yoke 123 and valve stem 121, moving the valves 120 and 119 to closed position. It will be observed that the arrangement is such that even though the vacuum in supply main B has become sufficient to permit the atmospheric pressure to deflect the diaphragm 125 and open the valves, if a sufficiently high temperature is reached, the thermostat T will operate to close the valve, or partially throttle the ports 117 and 118. As will be pointed out hereinafter, the thermostat T may be positioned within the room or space to be heated, so as to respond to the temperature maintained by the heating system, or this thermostat may be arranged outside of the building so as to respond to changes in outside temperature, which will, of course, affect the amount of heat that must be given off by the heating system in order to maintain the desired inside temperature.

Referring now again to Fig. 1, the risers 14 lead from the supply main B to furnish steam to the several radiators D, two of

which are here shown by way of example, although it is to be understood that any desired number of radiators may be used. The risers 14′ here shown, lead to radiators on a floor above those indicated in the drawings. Steam passes from the riser 14 through any suitable inlet valve, such as 15 or 15′, into the radiator D. This inlet valve will normally be open when the radiator is in service to permit free passage of steam from the supply main to the radiator, but the valve may be closed when any individual radiator is not to be used for heating purposes. As indicated in Fig. 2, in connection with the simpler form of inlet valve 15, an orifice plate 16 is interposed in the pipe leading from the valve to the radiator, this plate restricting the inflow of steam so that for average pressures in the supply piping, the maximum quantity of steam that the radiator will receive is fixed and proportioned to the condensing capacity of the radiator. The orifices 17 of the plates 16 of the various radiators of the system will differ in size, dependent upon the relative positions of the several radiators with respect to the source of supply of steam, so that all of the radiators, regardless of their position, will receive substantially the same maximum quantity of steam.

Although the heating system as a whole is adjusted to meet the general prevailing temperature conditions, and the several radiators are positioned and proportioned to satisfy the average heating requirements at that locality, it is often desirable to adjust the supply of heating medium to the individual radiator in accordance with unusual local temperature conditions, and a thermally operated inlet valve 15′ adapted to perform this function is indicated at the upper left hand corner of Fig. 1 and is shown in more detail in Fig. 6. The valve disc 151 is adapted to cooperate with the valve seat 152 to shut off the flow of steam through the valve 15′. Valve disc 151 is carried by valve stem 153, swiveled at its upper end to the plunger 154. The expansion spring 155 confined between plunger 154 and the fixed bridge plate 156 always tends to move valve 151 to open position. The flexible bellows diaphragm 157 serves to prevent the escape of steam through the upper portion of the valve casing. A thermostat 158, consisting of a plurality of connected cells, each filled with an expansible fluid, is mounted in a lateral extension 159 of the valve housing. A stem 160 projecting from one end of the thermostat assembly is non-rotatably connected to a block 161 threaded within the nut 162, which is rotatably mounted in one end of the housing 159. An adjusting knob or handle 163, carrying a pointer 164, which cooperates with a suitable index scale, is connected to nut 162, for example by binding screw 165. A stud 166 mounted on the other end of the thermostat assembly is adapted to reciprocate through centrally positioned guide passages in the insulating plates 167 and the partition wall 168 of housing 159. The boss 166 bears against an arm 169 of the lever 170, which is pivoted at one end 171 in the housing 159, and bears at its other end 172 upon a boss 173 upon the upper side of plunger 154. The housing 159 is provided with suitable openings 174 to permit the free circulation of air about the thermostat 158. As the temperature rises, the thermostatic fluid in the cells 158 will expand, thus pushing the boss 166 against the lever 170, which in turn depresses the plunger 154 and stem 153 to close the valve 151. Conversely, when the temperature drops, the thermostat 158 will contract and permit the valve 151 to be opened by spring 155. The thermostat 158 may be adjusted in the housing 159 to vary its operating temperature range by moving the knob 163 connected with adjusting nut 162. It will be apparent that when this thermally controlled inlet valve 15′ is used, an unusual rise in temperature adjacent the radiator will so effect this valve as to shut off the supply of steam to this particular radiator, and thus permit the temperature in this locality to drop to normal. The orifice plate 16 may be used with this thermally controlled valve 15′ in the same manner as with the manually operated inlet valve 15 shown in Fig. 2.

At the outlet of each radiator D is a thermostatically operated steam trap E, which normally retains the steam within the radiator, but permits the outflow of accumulated liquid condensate and air through pipe 18 to the return main F. In order to effectively operate the differential vacuum heating system, as set forth hereinafter, it is essential that the radiator be continually purged of all air and water, so that the radiator is completely filled with steam. At the same time it is essential that no material amount of steam should leak into the return pipes, else the vacuum-producing means will be unable to keep up the necessary vacuum in the system. A thermostatic trap capable of properly performing this service is the fluid-filled thermostatic trap shown in the drawings, and more specifically indicated in Fig. 7. The hollow thermostatic disc 175 contains a volatile fluid, which quickly expands at certain temperatures to expand the disc. The valve plate 176 is supported through ball joint 177 from the lower face of thermostatic disc 175, and is adapted to cooperate with the valve seat 178 to close the outlet leading to the return pipe 18. A threaded stud 179 on the upper face of disc 175 is adjustably mounted in a boss 180 projecting downwardly from the cover plate 181 of the

valve casing 182. When the radiator is filled with steam, the casing 182 of valve E will also be filled with steam and the diaphragm 175 will be expanded so as to hold valve plate 176 in closed position against valve seat 178. Any accumulation of water or air in the casing 182 will so lower the temperature of the thermostatic disc 175 that the disc will contract and raise the valve 176 permitting the water or air to flow out to the return main. This will permit steam to again fill the casing 182, immediately expanding the disc 175 and closing the valve before any material amount of steam has escaped into pipe 18. This form of thermostatic trap will operate effectively throughout a wide range of pressures, extending from super-atmospheric pressures to the lowest vacuum that may be maintained in this system.

The liquid condensate and air flows downward by gravity, assisted by the suction of the vacuum producing mechanism hereinafter described, through the return main F and suction strainer 19 into the accumulator tank G. The drain outlet 20 is normally closed by the valve 21. The water of condensation and air accumulating in the supply main B is vented through the pipe 22, thermostatic trap or float and thermostatic trap 23 and pipe 24 to the return main F, and is afterwards handled along with the condensates from the radiators.

The suction producing mechanism H, as here shown, comprises a tank 25, partially filled with water, from the lower portion of which a pump 26 withdraws water through pipe 27 and forces this water upwardly through jet exhauster 28 and pipe 29 back into the upper portion of tank 25. This hurling water circuit produces a suction in the casing of ejector 28, which draws up the water and air from the lower portion of the accumulator tank G through pipe 29′, these gases and condensates being carried along with the water of the hurling circuit and discharged into the tank 25. A one-way check valve 30 in pipe 29′ prevents the return of these materials to the accumulator tank. The gases discharged into tank 25 are vented to the atmosphere through pipe 31, provided with check valve 32. The pipe 31 is here shown as discharging into a sewer connection at 33. A second outlet from the centrifugal liquid pump 26 passes through valve 34, pipe 35, and check valve 36 to the steam generator A. A float 37 in the tank 25 operates, when the level of accumulated liquid in the tank 25 has reached a certain height, through the link and lever connections 38 to open the valve 34 and permit the pump 26 to force water through pipe 35 to the boiler.

The motor 39 which drives the pump 26 is connected by wires 40 with the starter 41, which is under the separate and independent control of two distinct switch mechanisms 42 and 43. Switch 42 is controlled through lever mechanism 44 by a float 45 positioned in the accumulator tank G. When a certain amount of liquid condensates have gravitated through return main F into this tank, the float 45 will be lifted sufficiently to close the switch 42, which results in starting the motor 39, and the vacuum producing mechanism commences to function to withdraw the condensates and air in tank F and discharge them into the tank 25. Here the gases are vented, and when sufficient water has accumulated, it is returned to the boiler in the manner already described.

Switch 43 is controlled by the differential pressure regulator J, which comprises a movable diaphragm adapted in a well known manner to open or close the switch 43 through the lever connections 46. The diaphragm of differential pressure regulator J is subject, on its opposite sides, to the pressure existing in the supply and return mains, one side being connected through pipe 47 with the return main F, and the other side connected through pipe 48 with the supply main B. Since pipes 47 and 48 will become filled with liquid condensate, they are initially filled with water and the vertical legs of the two pipes 47 and 48 must be of the same vertical height, as shown, in order to equalize the water head pressing on each side of the diaphragm of the pressure regulator. When the difference in pressure between the two mains falls below a certain minimum, switch 43 will be closed, whereupon the motor 39 will be started and the pumping mechanism will operate, as already described, to suck liquids and air from the tank G and hence from the return main F. This will lower the pressure in the return main F and the pump will continue to operate until a desired maximum pressure differential is established between the return and supply mains, whereupon switch 43 will be opened to stop the motor 39.

In the normal operation of the system as so far described, the reducing valve C or C′ is adjusted so as to maintain the desired degree of vacuum in the supply main B. As is well known, steam will be generated at atmospheric pressure at 212 degrees Fahrenheit. Under higher pressures, steam will be generated at higher temperatures, and conversely under a vacuum, steam will be generated at lower temperatures, the temperature of the steam depending upon the degree of vacuum existing in the system. This principle is utilized in this heating system so that by varying the sub-atmospheric pressure in the supply main B, the temperature of the steam delivered to the radiators D is correspondingly varied, so that steam at comparatively low temperatures may be

maintained in the radiators when prevailing weather conditions necessitate only a mild radiation of heat from the radiators. Obviously, steam may be more economically generated at lower temperatures, and it is more efficient and economical to maintain a constant supply of steam at a comparatively low temperature, than an intermittent supply of steam at a higher temperature.

While the degree of vacuum existing in the system may be varied from atmospheric pressure or slightly above, to as low as perhaps 24 inches of vacuum, in order to obtain the desired heating effect from the radiators, it is also desirable that a substantially constant and relatively small difference in pressure be maintained between the supply and return sides of the radiators in order to insure the proper circulation of steam and provide for withdrawing the condensates and air. Accordingly, the vacuum producing system is adjusted to operate to maintain this fixed pressure differential between the supply and return mains, but, as hereinafter explained, in order to maintain this fixed differential, it will also function to maintain the desired degree of vacuum throughout the entire system.

When starting the operation of the system, heat is applied to the boiler, and the pumping mechanism H is started to create a suction in the system. Since the thermostatic traps E are now open, this suction will continue throughout the system, lowering the pressure in the boiler so that steam is rapidly generated and drawn into the supply mains and the radiators. Steam passing through the traps E will close these valves until sufficient condensate has accumulated to open these valves and permit its withdrawal. When the desired minimum pressure is obtained in the supply main B, the reducing valve C or C′ will close and will thereafter open and close intermittently or adjust itself at intervals sufficient to maintain the desired sub-atmospheric pressure of steam in the supply main B. The pressure in the generator A may build up to a somewhat higher pressure, although it may still be sub-atmospheric, and the fires can be so regulated that this pressure will not rise materially above the vacuum maintained in supply main B. Where steam at higher temperatures is required for other purposes the pressure in the boiler may be increased to any desired extent, that is to atmospheric pressure or above. The pumping mechanism H will continue to operate and reduce the pressure in return main F until the desired differential below the pressure in supply main B is reached, whereupon the pressure regulator J will open switch 43 and the vacuum-producing mechanism H will cease to operate. Thereafter the pumping mechanism H will only operate at such intervals as is necessary to maintain the pressure differential between the supply and return mains, or when the accumulation of liquid in the accumulator tank G necessitates its removal to tank 25 and thence to the boiler.

The object sought to be attained by this system is the substantially constant emission of heat from the radiators at a rate just sufficient to replace the heat lost from the building. This is accomplished not by turning the radiators on or off at intervals, but by changing the temperature of the steam maintained in the radiators, and this in turn is accomplished by varying the sub-atmospheric pressure of this steam. This pressure variation is accomplished by adjustment of the reducing valve C or C′, and also by control of the fires under the boiler. It will be apparent that, other conditions being equal, less heat will be required to properly heat the building when the outside temperature rises, that is there will be less heat lost from the building at this time. If the thermostat T is placed outside the building so as to be responsive to temperature outside the building, it will be apparent that the reducing valve C′ will be automatically adjusted to properly compensate for changes in outside temperature. If the outer temperature rises, the valve C′ will be shut off, thus lowering the pressure of the steam in main B, and hence lowering the temperature of the steam supplied to the radiators D. On the other hand, much the same results may be accomplished by positioning the thermostat T within the building and adjusting the weights 144, 135 and 136 so that the reducing valve will properly respond to changes in the temperature maintained in the building.

In any case, local temperature variations in the vicinity of any individual radiator may be compensated for by using the thermally controlled inlet valves 15′ which will throttle the steam supply to that particular radiator without affecting the remainder of the system. In general, it may be considered that all of the radiators normally remain open and in constant communication with the steam supply.

Although this system is designed to normally operate under an adjustable vacuum, as hereinabove described, it is possible to operate the system at or above atmospheric pressure, for example, at night when the fires are banked and it is desirable to reduce the cost of operating the vacuum pump. At such times, the valve C will be suitably adjusted, and the differential pressure regulator will be thrown out of service by turning the snap switch 49. The pumping mechanism H is now controlled only by the float 45 in tank G. Condensates and air will gravitate into the tank G, and the gases will be vented from this tank through pipe 50 provided with check valve 51. When this system is normally operating under a vacu-

um, atmospheric pressure will hold the valve 51 closed, and all gases must be drawn through pipe 29′ into the tank 25 and then vented through pipe 31, as already described. When sufficient liquid has accumulated in the tank G, the lifting of float 45 will start the motor 39 and the pumping system H will withdraw this liquid into tank 25 and thence through pipe 35 to the boiler. At all other times, the pumping system H will remain idle. An equalizing pipe 52 provided with check valve 53 connects the pipe 50 with the steam space in the boiler. When heat is on and the system is operating under vacuum control, there will necessarily be a greater pressure on the steam side of the system, that is, in the generator A, the supply main B, etc. than on the return side of the system, that is the return main F, accumulator tank G, etc. At such times the check valve 53 will be held closed by the boiler pressure. Should, however, the source of heat supplied to the boiler be shut off, the steam side of the system, including the radiators, by natural condensation of steam therein may have a high vacuum created in it, and this vacuum may be even a higher vacuum than exists on the return side of the system, as caused by the previous action of the pumping system H. This might cause air to be drawn back into the radiators from the return main F. Under this condition, check valve 53 will open, equalizing the vacuum on the two sides of the system so that natural gravitation of water from the radiators through the return main F into the tank G may be accomplished.

A somewhat simpler form of apparatus, operating under the principles of this invention, is illustrated in Figs. 3, 4 and 5. This system is best adapted for small installations, such as home-heating systems. The main portions of this system which correspond to those already described are indicated by the same reference characters, and some of them need no further description. In this instance, the boiler A is heated by an automatic gas heater indicated generally at 54. The control lever 55 on this gas heater is connected by chain 56 with a motor 57, electrically connected through wires 58 with a thermostat 59, located in the apartment whose temperature is to be regulated. In this system, the reducing valve is not used, but the degree of vacuum maintained in the system is regulated by control of the application of heat to the boiler A.

As in the system first described, steam is supplied from the main B through risers 14, and inlet valves 15, to the radiators D, and condensates pass through the traps E and pipes 18 to the return main F. Return main F is provided with the non-return valve 60, and is connected directly with pipe 61 which in turn is connected with the boiler above and below the water level therein, so that liquid condensates in the return main will gravitate directly into the boiler. An air eliminator 62, of any approved form, having an air-check valve 62′, is connected with return main F above the normal water level therein, so as to vent air and gases from the return main. A drip pipe 63 leads from the end of supply main B into the return main F beyond the valve 60. Air is vented from drip pipe 63 through pipe 64 and trap 65 into the upper portion of the return main, from which it is vented through air eliminator 62, as already described.

The vacuum mechanism H used in this system is of a different type from that previously described and functions only to withdraw air from the system and thus reduce the pressure, but is not used to assist in returning the liquid condensate to the boiler. Referring more particularly to Figs. 4 and 5, the housing 66 comprises a lower chamber or tank 67, which communicates through pipe 68 provided with check valve 69 with the return main F adjacent its connection with the boiler feed pipe 61. Tank 67 is positioned at such a height that it will normally remain substantially full of water to supply the pump hereinafter described, but any excess of water, due to the accumulation of condensates, will flow through check valve 69 into the boiler feed. The pump or exhausting apparatus 70 comprises a rotary impeller 71, keyed to a shaft 72 connected with the armature shaft 73 of motor 74. The impeller operates in a casing consisting of a front plate 75 secured by screws 76 to a back plate 77 which is shown as a web depending from tank 67. The front and back plates are recessed for the impeller, which fits snugly between the same. The front plate is formed with a boss or extension 78 divided by web 79 to provide a water chamber 80 and an air chamber 81. The air chamber 81 is connected by a pipe 82 with the return main F at a point above the normal liquid level therein. The impeller 71 is formed with a plurality of ducts 83, which extend from the central portion of the impeller to its periphery and are preferably curved in the direction opposite to the direction of rotation of the impeller, as indicated in Fig. 5. The inlet end of each of the ducts 83 first passes over the port 84 of water chamber 80 and then over the port 85 of air chamber 81.

The front plate 75 is formed with a water passage 86 leading from the tank 67 to the water chamber 80 of the pump. Front plate 75 is also formed with a discharge port 87, and the impeller is arranged eccentrically in the casing so that a peripheral water outlet space 88 is provided, which increases in width in the direction of the movement of

the water toward the outlet 87, the outlet space 88 being connected with the recess in which the impeller works by a relatively narrow slit 89. The air and water mixture passes from outlet port 87 through a pipe 90 into the air eliminator tank 91, which is also formed in the housing 66 above the tank 67.

Shaft 72 of the impeller is provided with a stuffing box 92, and a pipe 93 connects this stuffing box with the pump housing for the purpose of lubricating the bearing.

When the impeller 71 is continuously rotated, air from the chamber 81, and hence from the return main of the heating system, will be drawn into the ducts 83 between the slugs of water drawn from chamber 80, and the water and air mixture will be expelled through pipe 90 into the chamber 91.

The tank 91 is provided with an air vent 94, having an inner valve seat 95, and an outer check valve 94′, which opens outwardly. The vent 94 is adapted to be closed by a valve 95′ mounted on a stem 96 slidable through a fixed bracket 97. A float 98 carried by a lever 99 pivoted to the casing at one end 100, is connected through link 101 and toggle 102, with the valve stem 96, so that when the float 98 is elevated by the accumulation of water in the tank 91, the toggle will close the vent valve 95′. A water discharge duct 103 leads from chamber 91 down to chamber 67, the duct 103 having a valve seat 104 at its upper end, normally closed by the valve 105, pivoted at 106 within the casing. Toggle 107 and link 108 connects valve 105 with the float lever 99. When sufficient liquid has accumulated in the tank 91, the elevation of float 98 will close the air vent 94 and open the valve 105 to permit the accumulated liquid to be discharged into the lower water supply tank 67. Practically the same water is continuously circulated through the pump and tanks 67 and 91, acting as a motor fluid for withdrawing gases from the return main and hence lowering the pressure throughout the heating system.

The differential pressure regulator J may be of much the same form already described in connection with the system of Fig. 1, and is adapted, through the operation of switch 109, to control the pump motor 74. The differential pressure regulator is connected at one side through pipe 110 with the supply main B, and at the other side through pipe 111 with pipe 82, leading to the return main F.

An equalizing pipe may be provided between some selected points in the supply and return sides of the system. In the example here shown, a pipe 112 connects the steam riser 14 with the return riser 18. A one-way valve 113 in this pipe will remain closed unless the pressure in the supply pipe falls below that in the return pipe, in which case it will open and allow the pressures to equalize. This equalizing connection functions much the same as the pipe 52 and valve 53 hereinabove described in connection with the form of the invention shown in Fig. 1.

The operation of this modified form of apparatus is much the same as that already described in connection with the apparatus shown in Fig. 1, except for the fact that the liquid condensate is permitted to gravitate directly to the boiler, and the pumping mechanism H functions merely to maintain the desired vacuum in the system. This pumping mechanism is connected primarily to maintain a fixed pressure differential between the supply and return mains, but as in the form of apparatus first described, it operates in connection with the control of the boiler heating mechanism to vary, as desired, the sub-atmospheric pressure maintained in the boiler and supply main B. In this apparatus, the thermostat 59 may be set to maintain a desired temperature in the apartment. It does this by controlling the gas heater 54, which cooperates with the pumping mechanism H to vary the pressure existing within the boiler A and supply main B, and hence the temperature of the steam generated and supplied to the radiators D. A thermostat such as 59, if properly adjusted, might be positioned outside the building so as to control the heater in accordance with the variations in the outside temperature.

Throughout the disclosure of both forms of this apparatus, numerous cut-off valves and similar devices have been illustrated, but not described, since the function and operation of such devices are well known and operate here the same as in prior systems.

It should be noted that in these heating systems, the radiator inlet valves 15 are not to be used to regulate the quantity of steam admitted to the radiators and thus regulate the temperature. If a radiator D is to be used for heating purposes, the inlet valve 15 is left open so that a full and constant supply of steam is admitted to the radiator, and the temperature or radiating capacity of the radiator is governed entirely by varying the pressure and hence the temperature of the steam supplied to the radiator. The same is true if the thermal valves 15′ are used. The valve will normally remain open, but may be automatically closed in response to unusual temperature variations in the particular space served by that radiator. In this way, a substantially constant moderate heating effect is obtained instead of intermittently applying a more intense heat, and in addition, great economies are obtained by producing the heating medium only at the temperature required.

Many of the advantages of this invention could be obtained if steam from a central

heating plant or exhaust steam were used, the pressure of the steam admitted to this vacuum system being lowered by a reducing valve, such as that shown at C in Fig. 1 or at C′ in Figs. 8 and 9. The control of the heat given out by the radiators could be accomplished in the same manner as described hereinbefore, the vacuum throughout the system (except in this case the boiler), being adjustable, and a fixed pressure differential being maintained across the radiators.

When properly regulated the radiators will emit heat at a rate just sufficient to replace the heat lost from the building and thus maintain a constant temperature. This may be done by occasional manual adjustment of the fire-controls or reducing valve, in accordance with changes in prevailing weather conditions, or the adjustments may be made automatically by the thermostatic controls.

In the preceding description and in the claims which follow, the pressure difference which is maintained between the supply and return sides of the system is referred to as a "substantially constant pressure difference." It should be understood that it is not essential that this pressure difference be absolutely constant, but it is only necessary that the difference be sufficient to insure a proper return of the condensate and air from the radiators. A somewhat higher pressure difference is not objectionable, but it is preferably to maintain as low a pressure difference as will suffice to insure complete removal of air and condensate in order to minimize the work thrown upon the pumping system. The regulator need only maintain this pressure difference within a certain range. In general, a somewhat greater pressure difference is desirable at the higher pressures than at the lower pressures (or greater vacuum), and the pressure difference maintained may taper gradually, or by steps, as the pressure in the system is lowered. Or the operation will be entirely satisfactory if an absolutely constant pressure difference is maintained at all degrees of vacuum. All such variations are anticipated as coming within the terms of "a substantially constant pressure difference", or equivalent expressions, in the following claims. I do not claim herein any of the apparatuses shown and described as this application is restricted to the method of steam heating as hereinabove set forth. It is fully realized that this method might be practiced by employment of apparatuses quite different from those shown for the purpose of illustrating embodiments of the invention. It is therefore my intention to cover by patent all modifications of the invention within the scope of the appended claims. The apparatus shown as a whole in Fig. 3 hereof is disclosed in all substantial respects in and claimed in my co-pending application, Serial No. 704,142 filed April 4, 1924. The apparatus shown as a whole in Fig. 1 hereof is claimed in a co-pending application, filed August 1, 1927, Serial No. 209,967. Broadly considered the apparatus of the present application is disclosed and claimed in my co-pending application, Serial No. 669,363, filed October 18, 1923.

Having thus described my invention, what I claim and desire to secure by Letters Patent is:

1. Method of heating by steam which consists in introducing steam into an evacuated condensing space in amounts limited to give pressures therein below atmospheric pressure, withdrawing non-condensible gases and condensate, as formed, from said space without permitting escape of steam therefrom, and controllably varying the sub-atmospheric pressure in said space by increase or decrease of the amount of steam introduced to vary the temperature of the steam in accordance with the amount of heat required.

2. Method of heating by steam which consists in introducing steam into a condensing space having separate supply and discharge ducts, effecting the withdrawal from said space of non-condensible gases and condensate, as formed, while retaining the steam therein, by maintaining a sub-atmospheric pressure in the return duct, lower, by a relatively constant difference sufficient to keep up circulation, than the pressure in the supply duct and limiting the inflow of steam to the supply duct so as to give a pressure in said condensing space below atmospheric pressure.

3. Method of heating by steam which consists in introducing steam into a condensing space having separate supply and discharge ducts, effecting the withdrawal from said space of non-condensible gases and condensate, as formed, while retaining the steam therein, by maintaining a sub-atmospheric pressure in the return duct, lower, by a relatively constant difference sufficient to keep up circulation, than the pressure in the supply duct, limiting the inflow of steam to the supply duct so as to give a pressure in said condensing space below atmospheric pressure and controllably varying the quantity of steam introduced into said space to vary the temperature of the steam therein in accordance with the amount of heat required.

4. Method of heating by steam, which consists in introducing steam into an evacuated condensing space in amounts limited to give pressures therein below atmospheric pressure, withdrawing non-condensible gases and condensate, as formed, from said space without permitting escape of steam therefrom and varying the quantity of steam introduced into said space in accordance with

temperature changes at some determined place.

5. Method of heating by steam which consists in introducing steam into an evacuated condensing space in amounts limited to give pressures therein below atmospheric pressure, withdrawing non-condensible gases and condensate, as formed, from said space without permitting escape of steam therefrom, controllably varying the sub-atmospheric pressure in said space by increase or decrease of the amount of steam introduced to vary the temperature of the steam in accordance with the amount of heat required, and controlling the generation of steam in proportion to the amount introduced into said condensing space.

6. Method of heating by steam which consists in introducing the steam from a common supply duct at sub-atmospheric pressure into a plurality of condensing spaces, having a common discharge duct, through restricting orifices which limit the amount of steam introduced into each space to the capacity of such space to condense it, maintaining a pressure in the discharge duct sufficiently lower than that in the supply duct to effect movement of fluids through said condensing spaces and withdrawal of non-condensible gases and condensate, as formed, therefrom, and varying the pressure of steam in the supply duct to vary the temperature of the steam in said spaces in accordance with the amount of heat required.

7. Method of heating by steam which consists in introducing the steam from a common supply duct at sub-atmospheric pressure in a plurality of condensing spaces, having a common discharge duct, through restricting orifices which limit the amount of steam introduced into each space to the capacity of such space to condense it, maintaining a pressure in the discharge duct sufficiently lower by a relatively constant difference than that in the supply duct to effect movement of fluids through said condensing spaces and withdrawal of non-condensible gases and condensate, as formed, therefrom, and varying the pressure of steam in the supply duct to vary the temperature of the steam in said spaces in accordance with the amount of heat required.

8. Method of generating and utilizing steam for heating consisting in generating the steam and condensing it in communicating spaces, both of which are at sub-atmospheric pressure and maintaining a sufficient difference of pressure between the generating space and the discharge duct of the condensing space to bring about movement of the fluids through said spaces.

9. Method of generating and utilizing steam for heating consisting in generating the steam and condensing it in communicating spaces, both of which are at sub-atmospheric pressure and maintaining a sufficient difference of pressure between the generating space and the discharge duct of the condensing space to bring about movement of the fluids through said spaces and the removal from the condensing space of substantially all non-condensible gases and condensate as formed, without permitting the escape of steam, and regulating the temperature of the steam in the condensing space by controlling the rate of steam generation.

10. Method of generating and utilizing steam for heating consisting in generating the steam and condensing it in communicating spaces, both of which are at sub-atmospheric pressure and maintaining a sufficient difference of pressure between the generating space and the discharge duct of the condensing space to bring about movement of the fluids through said spaces and the removal from the condensing space of substantially all non-condensible gases and condensate as formed, without permitting the escape of steam, and regulating the temperature of the steam in the condensing space by controlling the rate of steam generation in response to temperature changes at a determined place.

11. Method of generating and utilizing steam for heating consisting in generating the steam and condensing it in communicating spaces, both of which are maintained at sub-atmospheric pressure, and regulating the heat output by varying the pressures in said spaces.

12. Method of heating by steam which consists in eliminating from a body of steam at sub-atmospheric pressure non-condensible gases and condensate to keep said body at constant volume, and varying the pressure of the steam to vary its temperature and consequently the amount of heat which it gives off according to that required by the space being heated.

13. The method of heating by steam which consists in maintaining in the outlet duct of the steam condensing space a vacuum which withdraws from said space the condensate as formed and any non-condensible gases and controlling the inflow of steam into said space so that a body of steam is maintained therein which fills the space with substantial completeness at a determinate pressure below atmospheric pressure.

14. The method of heating by steam which consists in maintaining in the outlet duct of the steam condensing space a vacuum which withdraws from said space the condensate as formed and any non-condensible gases and controlling the inflow of steam into said space so that a body of steam is maintained therein which fills the space with substantial completeness at a determinate pressure below atmospheric pressure and increasing or decreasing the pressure in said space by con-

trolling the amount of inflow thereto in accordance with the amount of heat required.

15. Method of heating by steam which consists in introducing steam into an evacuated condensing space having a supply duct and a single discharge duct, separate from the supply duct, in amounts limited to give pressures in said space below atmospheric pressure, maintaining a lower pressure in the discharge duct than in the condensing space to withdraw into said discharge duct from said space non-condensible gases and condensate, as formed, and controllably varying the sub-atmospheric pressure in said space, by increase or decrease of the amount of steam introduced therein, to vary the temperature of said steam in accordance with the amount of heat required, while preventing escape of steam from said condensing space at all pressures therein.

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