

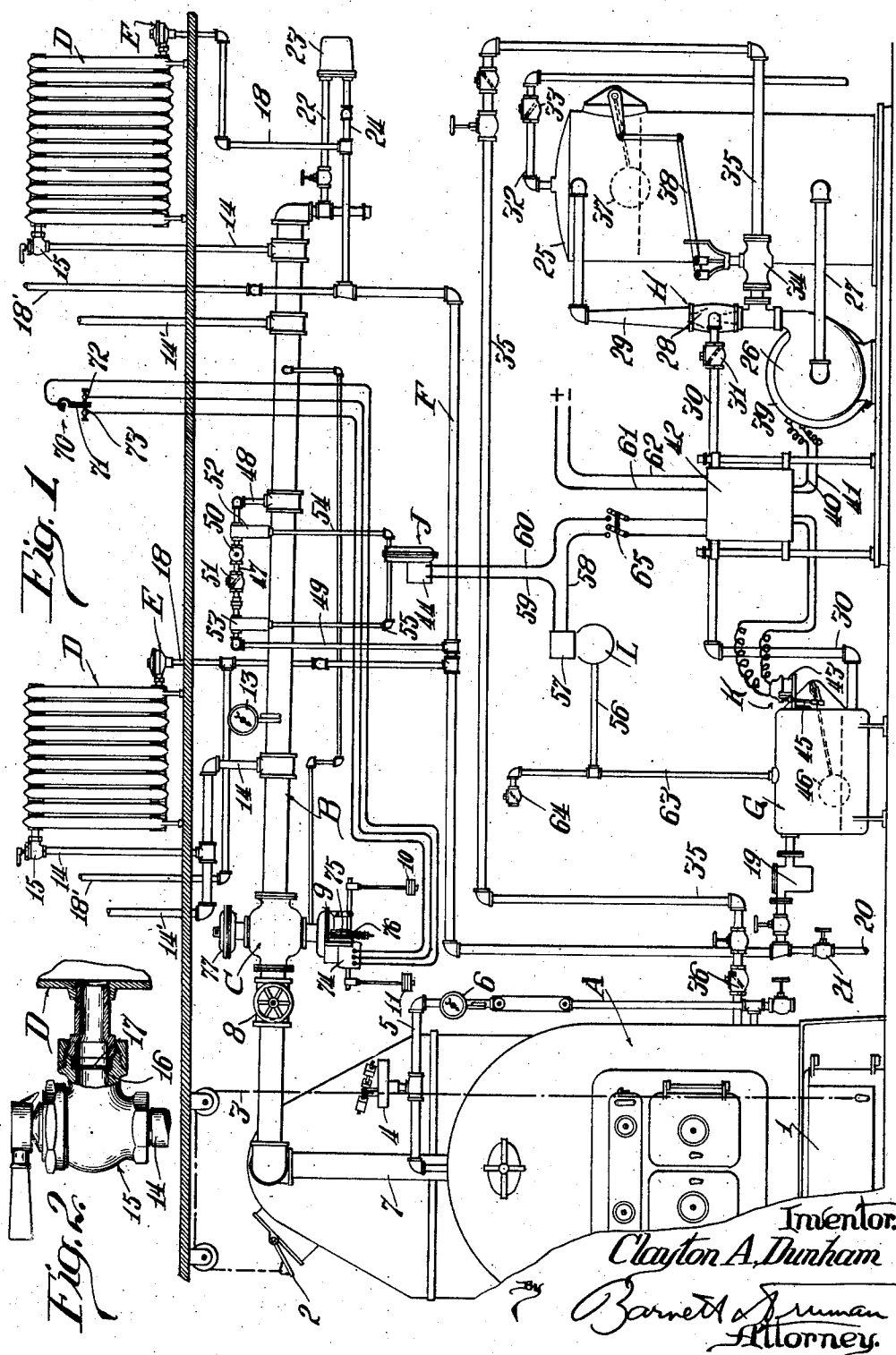
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METHOD OF HEATING BY STEAM

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METHOD OF HEATING BY STEAM

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This invention relates to the art of heating by steam at sub-atmospheric pressures, and its principal object is to provide a novel method of increasing the flexibility of the system and the range of temperatures that may be maintained, by not only controllably varying the sub-atmospheric pressure of the steam, but by also controllably varying the volume of the body of steam maintained in the condensing space or radiator at any given sub-atmospheric pressure.

This present invention involves certain improvements on and additions to the method of heating disclosed and claimed in my prior Patent 1,644,114 granted October 4, 1927. In said prior patent 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 are kept free of air and condensate and full of steam. In mild weather the steam will be maintained at a lower pressure, and consequently at a lower temperature than in cold weather. It is thus possible, through a very considerable range of temperatures, and utilizing the same constant amount of radiating surface, to maintain the desired heat output, 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 weather, this being accomplished by varying the temperature of the steam confined in the radiator.

It will be noted that in such a system, in order to lower the temperature of the steam and hence the heat output from the radiator, it is necessary to decrease the steam pressure, that is, increase the vacuum maintained within the heating system or portions thereof. In actual practice it is not economical in heating service to maintain vacuums in excess of approximately 26 inches of mercury. The radiators are necessarily designed for maximum heating requirements, and if these radiators are filled to their entire capacity with steam at the minimum temperature corresponding to the maximum vacuum that may

be practically maintained, the heat output may even yet be excessive in extremely mild weather.

The present invention has for its immediate object the provision of a steam heating system capable of maintaining the desired inside temperatures in even the mildest weather. This is accomplished by only partially filling the individual radiators, in proportion to their heating surface, with steam at the determined sub-atmospheric pressure. In other words, the heat output is regulated not only by determining the temperature of the steam by varying its sub-atmospheric pressure, but also by varying the volume of this body of sub-atmospheric steam maintained in each individual radiator. This is practically accomplished by varying the amount of sub-atmospheric steam admitted to and the amount of non-condensable gases that are withdrawn from the radiators. In the preferred exemplification of this method, the radiators are kept entirely free of non-condensable gases at all steam pressures above the determined maximum vacuum so that the entire condensing capacity of the radiator is available and the heat output is varied entirely by varying the pressure of the steam confined therein. After the maximum vacuum is attained, in order to obtain a further decrease in the heat output, the amount of steam admitted to the radiator is further decreased and a predetermined portion of the non-condensable gases are permitted to accumulate in the radiator, thus decreasing the volume or amount of steam maintained within the radiator. In this manner the heating system may be utilized in even the mildest weather for maintaining the desired indoor temperatures simply, automatically and with greater fuel economies than have been previously obtainable.

The principal object of this invention is to provide an improved method of heating, such as briefly described hereinabove and disclosed more in detail in the specifications which follow.

Other objects and advantages of this invention will be apparent from the following detailed description of one form of apparatus

capable of carrying out this improved method, and the improved method of operating this apparatus as hereinafter disclosed.

In the accompanying drawings:

5 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, partially in section, through one of the radiator inlet valves.

10 The apparatus here disclosed is essentially the same as that utilized in my former patent, hereinabove referred to. This apparatus will first be briefly described, together with its operation as a sub-atmospheric steam heating system, and then the improved method of operation forming the particular subject matter of this invention will be disclosed.

15 Many of the devices and mechanisms used in this system are well known in the art, may be constructed in a variety of forms, and are here indicated diagrammatically.

Referring now to the drawings, A indicates the steam generator which furnishes steam through the supply main B and reducing valve C to the radiators D. Condensate 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 condensate, 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.

20 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. A gauge 6 is positioned in the pipe 5 for indicating the pressure at which the steam is being generated.

25 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 atmospheric pressure and on the other side to the steam pressure in supply main B. A second smaller balancing diaphragm indicated at 77 may be opposed to the main diaphragm.

65 This reducing valve C is distinguished by the

fact that the reducing 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.

The valve C may also be subject to the control of a thermostat 70 located in one of the rooms to be heated. This thermostat includes a movable contact 71 adapted to engage a fixed contact 72 when a certain maximum temperature is reached and to engage another fixed contact 73 when a determined lower temperature is reached. These contacts complete circuits so as to cause a motor 74 to successively rotate a crank-arm 75 through arcs of 180°. When this crank-arm is in one position (corresponding to the maximum temperature) it will operate, through suitable link and lever mechanism indicated at 76, to close the valve C. This valve operating mechanism is disclosed more in detail in my co-pending application Serial No. 396,209, filed September 30, 1929.

When the crank-arm is in the other position it will return the valve to the control of the diaphragm 9. In this way the valve is automatically closed to cut-off the further flow of steam to the radiators whenever a desired temperature is attained in the space to be heated, regardless of normal operation of the reducing valve.

105 Instead of the reducing valve C, as here shown, an automatic temperature-controlled reducing valve of any suitable form may be substituted, for example, the valve disclosed in my prior Patent No. 1,644,114, hereinabove referred to. When such a valve is used, the sub-atmospheric pressure of the steam supplied to the radiators will be varied automatically in accordance with temperature requirements, but otherwise the operation of the system is the same as hereinafter set forth.

115 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 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. Although the heating sys-

tem 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 the respective localities, it is sometimes desirable to adjust the supply of heating medium to any one individual radiator in accordance with unusual local temperature conditions, and a thermally operated inlet valve controlled by a thermostat located in the vicinity of the radiator may be used instead of the ordinary inlet valve 15. One suitable example of such a thermally operated valve is disclosed in my prior Patent 1,644,114, hereinabove referred to.

As indicated in Fig. 2, an orifice plate 16 is interposed in the pipe leading from the inlet valve to the radiator, this plate restricting the flow 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 in 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, and depending upon the volume and condensing capacity of the particular radiator, so that all of the radiators regardless of their form, capacity or position, will receive the proper quantity of steam. Further characteristics and functioning of these orifice plates will be referred to more in detail hereinafter, when the particular improvements forming the subject matter of this new method of heating are set forth.

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 or other non-condensable gases 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 water and non-condensable gases, or at least a determined portion thereof, so that all or a definite portion of the radiator may be completely filled with steam. At the same time it is essential that no material amount of steam should leak into the return pipes. A fluid-filled thermostatic trap capable of properly performing this service is now well known in the art and is described in detail in my prior patent hereinabove referred to.

The liquid condensate and non-condensable gases flow downwardly 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 non-condensable

gases accumulating in the supply main B are vented through the pipe 22, thermostatic trap or float and thermostatic trap 23 and pipe 24 to the return main F, and are afterwards transported along with the condensate 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 30, these fluids being carried along with the water of the hurling circuit and discharged into the tank 25. A one-way check valve 31 in pipe 30 prevents the return of these fluids to the accumulator tank. The gases discharged into tank 25 are vented to the atmosphere through pipe 32 provided with outwardly opening check valve 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 surplus water through pipe 35 to the boiler.

The motor 39 which drives the pump 26 is connected by wires 40 and 41 with the starter 42, which is under the separate and independent control of two distinct switch mechanisms 43 and 44. Switch 43 is controlled through lever mechanism 45 by a float 46 positioned in the accumulator tank G. When a certain amount of condensate has gravitated through return main F into this tank, the float 46 will be lifted sufficiently to close the switch 43, which results in starting the motor 39, and the vacuum producing mechanism commences to function to withdraw the condensate and gases in tank G 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 44 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 44. The diaphragm of differential pressure regulator J is subject, on its opposite sides, to the pressures existing in the supply and return mains. For this purpose an equalizing pipe 47 has one leg 48 connected with supply main B and the other leg 49 connected with return main F. Positioned in the central portion of equalizing pipe 47 are a normally open cut-off valve 50 and a one-way check valve 51

opening toward the supply main B. This equalizing pipe will never permit the pressure in the supply side of the system to fall below the pressure existing in the return side, since should such conditions arise, the check valve 51 will open to permit the pressures to equalize. A pair of similar surge tanks 52 and 53 are located in the high and low pressure sides respectively of equalizing pipe 47, and these tanks are connected by pipes 54 and 55, respectively, with the high and low pressure chambers of differential pressure regulator J, at the two sides of the controlling diaphragm therein. When the difference in pressure between the supply and return mains falls below a certain predetermined and adjustable minimum, the differential controller J will be operated to close the switch 44, thus starting the motor 39 and the pumping mechanism will operate, as already described, to withdraw liquids and gases 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 regulator J will operate to open the switch 44 and thus stop the exhausting mechanism.

A maximum vacuum regulator, indicated at L, is in communication, through pipe 56 and pipe 63 with the accumulator tank G. When a certain predetermined maximum vacuum is reached in return main F and tank G the regulator L will operate to open a normally closed switch mechanism 57 which is connected in series with switch mechanism 44 and starter 42 through wires 58, 59 and 60. A cut-out switch 65 may be positioned in this circuit, this switch being closed when automatic operation of the heating system is desired. It will now be apparent that as long as the sub-atmospheric pressure in the system is above the predetermined maximum vacuum permitted, the switch 57 will remain closed and switch mechanism 44 will be operative to control the motor 39 and maintain the proper pressure differential between the supply main B and return main F. After the maximum vacuum permitted has been attained in the return main, switch 57 will be opened so as to break the operating circuit of switch mechanism 44, whereupon the motor 39 will stop and the regulator J will no longer be effective to start the exhausting mechanism when the pressure differential falls below the previously desired minimum. The power mains leading to starter 42 are indicated at 61 and 62.

The vent pipe 63 leads from the upper portion of accumulator tank G and is provided with an outwardly opening check valve 64. As long as the sub-atmospheric pressures prevail in the heating system, check valve 64 will be maintained closed by the outer at-

mospheric pressure, but this pipe 63 will be effective to vent gases from the tank G whenever the pressures in the return side of the system are permitted to rise above atmospheric pressure. In the normal operation, as hereinafter set forth, check valve 64 will be closed and pipe 63 is ineffective to vent gases, all of the gases being discharged through pipe 30 to tank 25 and thence vented through pipe 32.

In the normal operation of this sub-atmospheric steam system, as thus far described, the reducing valve 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° 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 and also in the radiators D, the temperature of the steam in the radiators 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. 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. It will also be noted that if the volume of this body of steam constantly maintained in the radiator is decreased, the heat output of the radiator will be correspondingly decreased, thus providing a means for still further reducing the heat output in extremely mild weather, and this additional step is utilized in the improved method hereinafter set forth.

While the degree of vacuum existing in the system may be varied from atmospheric pressure, or slightly above, to as low as perhaps 26 inches of vacuum in order to obtain the desired heating effect from the radiators, it is also essential that a substantially constant and relatively small difference in pressure be maintained between the supply and return sides of the radiators, this pressure differential being just sufficient to insure the proper circulation of steam and provide for withdrawing the condensates and noncondensable gases from the radiators. Accordingly, the vacuum producing system is adjusted to operate to maintain this fixed pressure differential between the supply and return sides of the radiators, but as hereinafter explained, in order to maintain this fixed differential, it will also function to maintain

the desired degree of vacuum throughout the system.

When starting the operation of the system, heat is applied to the boiler and the exhausting mechanism H is started to create a suction in the system. At this time the system will be empty of steam and the thermostatic traps E will be open. There will be no substantial pressure differential between the return and supply mains and the suction created by the exhausting mechanism H will extend throughout the system, lowering the pressure in the boiler so that steam is rapidly generated and drawn into the supply mains and radiators. When the desired minimum pressure is obtained in the supply main B, the reducing valve 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 rise somewhat higher, although it may still be sub-atmospheric, and the fire can be so regulated that this pressure will not rise materially above the vacuum maintained in supply main B. If steam at higher temperatures is required for other purposes the pressure in the boiler may be increased to any desired extent. Steam attempting to pass through the traps E will close the valves in these traps until such time as sufficient condensate has accumulated to open these valves and permit its withdrawal. The pumping or exhausting mechanism H will continue to operate until the sub-atmospheric pressure in return main F (which is now cut off from the supply main B by the closed traps E) has been lowered until the necessary pressure differential has been attained, whereupon the control mechanism J will operate the switch 44 to stop the motor 39. As steam condenses in the radiators D, the pressure in the radiators and supply main B will be lowered below the sub-atmospheric pressure for which the valve C is set, and this valve will open and admit more steam to the supply main and radiators, thus keeping the radiators full of steam at the desired sub-atmospheric pressure. The thermostatic traps E will automatically open to permit the accumulated condensate and noncondensable gases to pass out into the return main F and will again be closed when steam attempts to pass through these traps. This entry of air and condensate into the return main F will somewhat raise the pressure in this main so that the difference in pressure between the return main and supply main may fall below the necessary minimum, whereupon the control mechanism J will operate to close switch 44 and start the motor 39 of the pumping mechanism, which will begin functioning at once to again reduce the pressure in the return main F. The pumping mechanism H will only operate at such intervals as is nec-

essary 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 generator.

The general object of this system is to obtain a substantially constant emission of heat from the radiators at a rate just sufficient to replace the heat lost from the building and thus maintain a constant temperature in the rooms. In the operation of the system as thus far described, this is accomplished by changing the temperature of the body of steam of substantially constant volume 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, while maintaining the return main pressure lower, by a substantially constant pressure differential, than the supply main pressure. When the pressure and temperature of the steam in the radiators has been reduced to a practical minimum, the heat output from the radiators can be still further reduced by decreasing the volume of the body of steam, or the amount of steam, maintained in each radiator, and the means for accomplishing this step of the method will now be described.

As already noted, the regulating plate 16 positioned between each inlet valve and the adjacent radiator, is provided with a metering orifice 17 designed to permit a steam flow from the supply pipe to the radiator directly proportional to the heat emitting capacity of the radiator. This orifice area will be proportioned so that for the normal pressure difference maintained between the supply and return mains at all pressures up to the maximum, steam will be supplied to each radiator at a rate just sufficient to keep it substantially filled. Inasmuch as the area of orifice 17 is proportioned to give a determined steam flow sufficient to fill the radiator when a given pressure differential is maintained between the two sides of the orifice, it follows that for any pressure differential less than this only a fraction of the normal amount of steam will flow through the orifice.

The system will operate as set forth hereinabove as long as the pressures and temperatures in the system are above the maximum vacuum for which regulator L is set, or in case a maximum regulator L is not provided, above the maximum vacuum that the exhausting mechanism is capable of maintaining in the return side of the system. The regulator L is not absolutely necessary, but its use is desirable since it will stop the pump and thus save power when the maximum vacuum is attained. For all sub-atmospheric pressures above this maximum vacuum, the predetermined pressure differ-

ential for which regulator J is adjusted will be maintained between the supply and return sides of these radiators, and the radiators will be kept free of condensate and non-condensable gases so that a body of steam of substantially constant volume will fill each radiator, although the pressure of this steam and consequently its temperature is adjusted to secure the desired heat output. It might here be mentioned that due to the various gases that are freed from the water when steam is generated, there is quite an appreciable volume of gas developed in the system, aside from the air which leaks into the system, and these accumulated gases are the "non-condensable gases" which have been frequently referred to in this description. It is these gases that must be eliminated from the radiators, along with the condensate, in order to permit the radiators to be completely filled with steam.

When the maximum vacuum (for example 26 inches of mercury) has been attained, the regulator L will open the switch 57, and regulator J is no longer effective to cause the exhausting mechanism to operate. Further reduction of the sub-atmospheric steam pressure in the supply main and radiators, due to the adjustment of reducing valve C and to the condensation of steam in the radiators, will further lower the pressure on the supply side of the system, but since the exhausting mechanism is no longer in operation the pressure in the return side of the system will not be lowered below the maximum vacuum established by regulator L. Consequently the pressure differential between the supply and return sides of the radiators will be decreased, and this pressure difference will no longer be sufficient to entirely remove the non-condensable gases from the radiators, or to draw in enough steam to entirely fill the radiators. Accordingly, a certain amount of these gases will accumulate in each radiator, thus decreasing the space available for steam in the radiator, or in other words, decreasing the effective steam capacity of the radiator. The result is that a smaller body of the low temperature steam is maintained in each radiator, and the heat output of the radiator is correspondingly decreased. It will be understood that when, due to condensation of steam in the radiators, the sub-atmospheric pressure in the radiators and supply main falls below that for which reducing valve C is set, this valve will open to admit more steam and thus raise the pressure to the desired minimum. Also when the pressure in the return main rises above the maximum vacuum for which regulator L is set, switch 57 will again be closed and since switch 44 is closed, due to the fact that the pressure differential for which regulator J is set is not now established, the exhausting mechanism will again operate until the desired maximum vacuum

is again attained. In this way a state of substantial equilibrium is maintained, permitting the supply of a diminished volume of steam to the radiators and the withdrawal of condensate and a certain proportion of the non-condensable gases.

As an alternative to the operation as hereinabove set forth, the differential pressure regulator J can be adjusted so as to maintain a diminished pressure differential, or the exhausting mechanism H may be adjusted to run more slowly, so that at all pressures (including those above the maximum vacuum for which regulator L is adjusted) the radiators will not be completely evacuated of non-condensable gases, and a diminished supply of steam will be admitted so that the effective steam capacity of the radiators will be correspondingly reduced. The steam supply now being restricted so as to only partially fill the several radiators, the constant heat output of the radiators will be correspondingly reduced.

It should be noted that when the reducing valve C is thermostatically controlled the system will be operative as above set forth even though the valve is not manually set to obtain the desired low temperature. In case the rooms reach the desired temperature before the radiators are entirely filled with steam the thermostat will close the valve to cut off the steam supply. The system will then adjust itself as already described to a condition wherein the radiators are filled with certain proportions of steam and non-condensable gases both under high vacuum.

Due to the improvements hereinabove set forth, the flexibility and the range of temperatures that may be maintained by this sub-atmospheric heating system are greatly extended, and proper indoor temperatures may be maintained in even the mildest weather.

The novel feature of controllably adapting the principle of only partially filling radiators with steam to use with steam under low sub-atmospheric pressures, has many distinct advantages. By utilizing steam under a low pressure or high vacuum, a greater proportion of the radiating surface may be heated without overheating the building, this giving a more comfortable inside temperature and maintaining a more healthful humidity in the air in the room. The system can be more easily controlled to give the desired heating effect at each individual radiator, owing to the low heat content per unit of volume of the heating medium. This modified sub-atmospheric heating system has certain advantages over a system in which the radiators are completely evacuated at all sub-atmospheric pressures, since the amount of work imposed on the exhausting mechanism is reduced. After certain maximum high vacuums have been attained in a system of this

type, the exhausting mechanism cannot be economically operated, and this improved system permits the use of the exhausting mechanism to completely evacuate the radiators at all those moderate sub-atmospheric pressures at which the mechanism can be most efficiently operated, and permits a control of the system in still milder weather by cutting down the volume of steam condensed in the radiators rather than by reducing the temperature and pressure of this steam to an impractical minimum.

I claim:

1. The method of heating by steam which consists in introducing steam into a partially evacuated condensing space in amounts limited to give pressures therein below atmospheric pressure, withdrawing condensate as formed and a portion of the non-condensable gases from said space without permitting the escape of steam therefrom, and controlling the heat output from the condensing space by 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, and also by varying the proportions of steam and non-condensable gases within the condensing space.

2. The 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 condensate as formed and a portion of the non-condensable gases while retaining the steam therein, by maintaining a sub-atmospheric pressure in the return duct lower than the pressure in the supply duct, limiting the inflow of steam to the supply duct so as to give a pressure in the condensing space below atmospheric pressure, and varying the pressure-differential between the supply and return ducts so as to vary the amount of steam admitted to and of non-condensable gases withdrawn from the space.

3. The 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 condensate as formed and a portion of the non-condensable gases while retaining the steam therein, by maintaining a sub-atmospheric pressure in the return duct lower than the pressure in the supply duct, limiting the inflow of steam to the supply duct so as to give a pressure in the condensing space below atmospheric pressure, further restricting the rate of inflow of steam to the condensing space so that for a given pressure differential between the supply and discharge ducts just sufficient steam will be admitted to fill the space, and controllably decreasing this pressure differential to further restrict the amount of steam admitted to the space and the proportion of non-con-

densible gases withdrawn therefrom and thus controllably varying the effective steam capacity of the condensing space.

4. The 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 pressures, maintaining a sufficient difference in pressure between the supply and discharge sides of the condensing space to determine the movement of fluids there-through, and regulating the heat output by varying the pressures in the spaces and also varying the said pressure differential.

5. The method of heating by steam which consists in controlling the inflow of steam to a condensing space so that a body of steam is maintained in the available portion of this space at a determined pressure below atmospheric, maintaining a partial vacuum in the outlet from the space sufficient to withdraw condensate and a portion of the non-condensable gases, and varying the pressure differential between this vacuum and the pressure of the sub-atmospheric steam to determine the amount of steam admitted to and of non-condensable gases withdrawn from the space and thereby determine the volume of the space available for condensing steam.

6. The method of heating by steam which consists in varying the sub-atmospheric pressure of a body of steam in a confined space to determine its temperature until a predetermined minimum pressure and temperature is attained in the confined body of steam, eliminating from said space the condensate as formed and all of the non-condensable gases at all pressures above the predetermined minimum, and restricting the volume of steam admitted and of non-condensable gases withdrawn after the minimum steam pressure has been attained to vary the volume of the body of confined steam.

7. The method of heating by steam which consists in introducing the steam from a common supply duct at sub-atmospheric pressures 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, varying the pressure of the steam in the supply duct to vary the temperature of the steam in said spaces, maintaining a pressure in the discharge duct sufficiently lower than that in the supply duct to effect movement of fluids into the condensing spaces and the withdrawal therefrom of condensate as formed and of a portion of the non-condensable gases, and varying the pressure differential between the discharge and supply ducts to determine the proportions of steam admitted and of non-condensable gases withdrawn and hence determine the effective steam capacity of the condensing spaces.

8. The method of heating by steam which

consists in introducing the steam from a common supply duct at sub-atmospheric pressures 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, varying the pressure of the steam in said spaces, maintaining down to a predetermined minimum pressure a pressure in the discharge duct sufficiently lower than that in the supply duct to effect movement of steam into the condensing spaces and the withdrawal therefrom of condensate as formed and of all non-condensable gases without permitting the escape of steam, and after said predetermined minimum pressure is attained in the supply duct, further lowering the pressure of the steam supplied to the condensing spaces whereby the pressure differential between the supply and discharge ducts is decreased and non-condensable gases are permitted to accumulate in determined amounts in the condensing spaces thus restricting the steam capacity thereof.

9. The 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 pressures, restricting the flow of steam into the condensing space and maintaining a difference of pressure between the supply and discharge sides of said space so as to bring about a determined movement of fluids through said space, and varying the said pressure difference to determine the amount of steam admitted to and condensed in said condensing space.

10. The 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 pressures, restricting the flow of steam into the condensing space and maintaining a difference of pressure between the supply and discharge sides of said space so as to bring about a determined movement of fluids through said space, and regulating the heat output by varying the pressures in the said spaces and also varying the pressure differential.

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