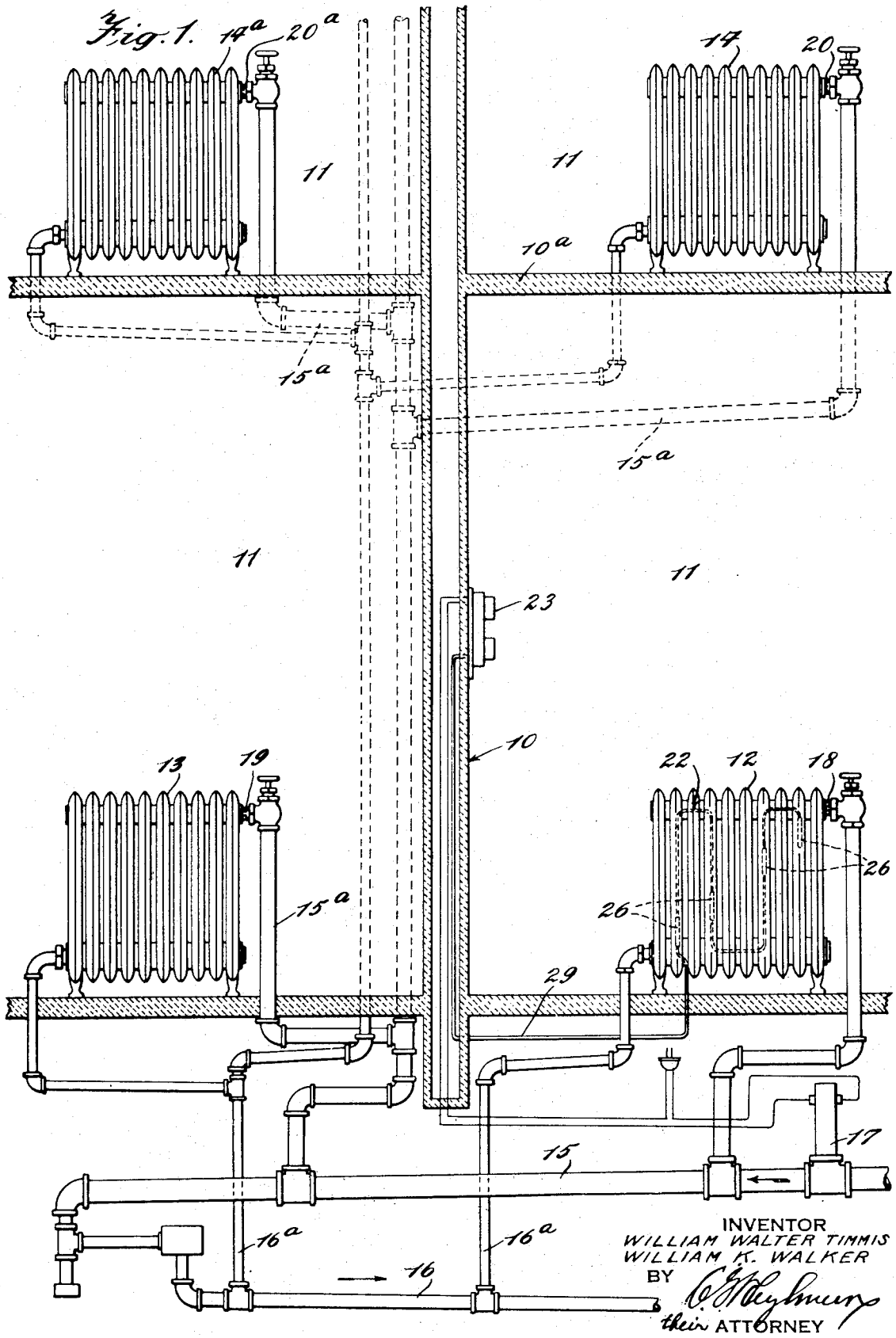
May 2, 1939. W. W. TIMMIS ET AL 2,156,322

HEAT EXCHANGE SYSTEM

Filed Feb. 17, 1936 2 Sheets-Sheet 1



INVENTOR
WILLIAM WALTER TIMMIS
WILLIAM K. WALKER
BY
their ATTORNEY

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Fig. 2.

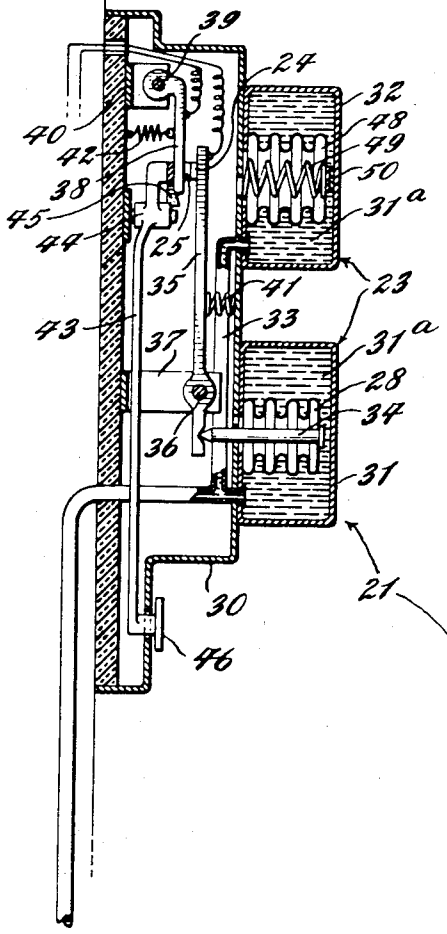
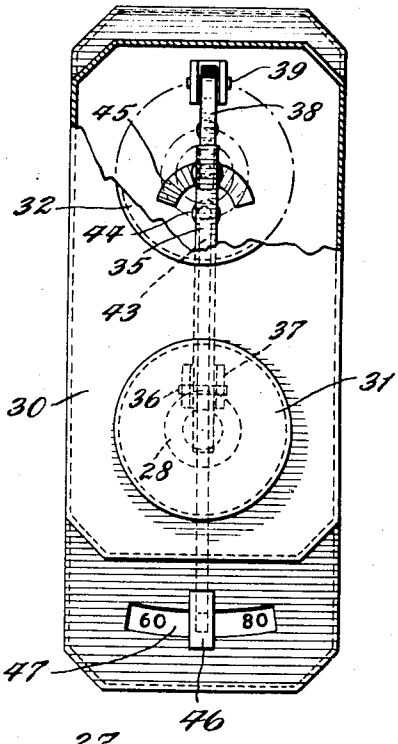


Fig. 3.



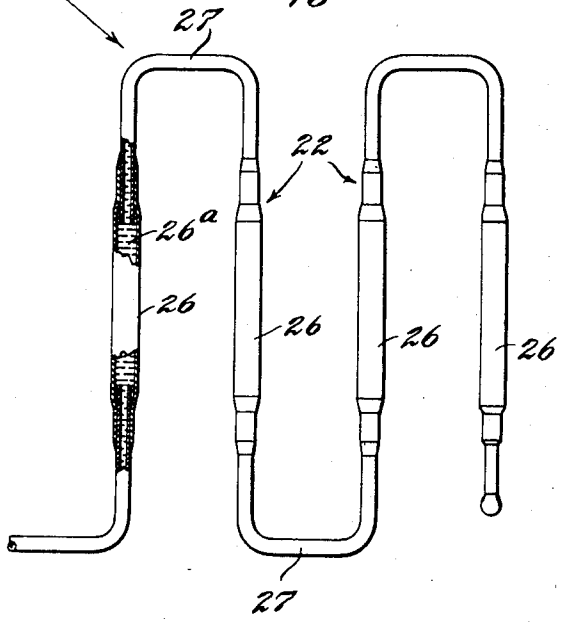
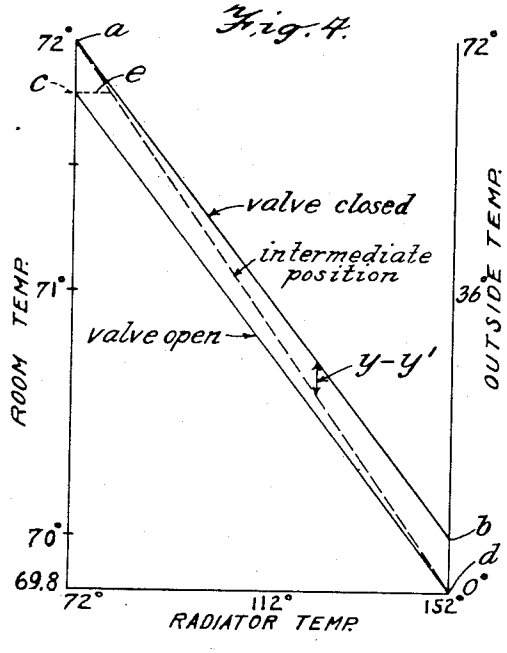


Fig. 4.



INVENTOR
WILLIAM WALTER TIMMIS
WILLIAM K. WALKER
BY
their ATTORNEY

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UNITED STATES PATENT OFFICE

2,156,322

HEAT EXCHANGE SYSTEM

William Walter Timmis, Glen Cove, and William K. Walker, New York, N. Y., assignors to American Radiator Company, New York, N. Y., a corporation of New Jersey

Application February 17, 1936, Serial No. 64,316

2 Claims. (Cl. 236—37)

Our invention relates to new and useful improvements in heat exchange systems, and more particularly contemplates a novel and improved method and apparatus for so controlling and operating a heat exchange system that the same will maintain such temperature conditions within the rooms or spaces of a building as may be desirable, or required, for the comfort of the occupants of such rooms or spaces.

Our invention has for its object to control the supply of operating or heat exchange fluid to a heat exchange element or elements in such manner as to cause or insure a regulated, continuous supply of heat to the space or spaces to be heated proportioned to the rate at which the building enclosing said space or spaces loses heat, and maintain the heat exchange elements at moderate mean temperatures normally higher than the room temperature.

Another object of the invention is to vary the heat exchange rate or output of a heat exchange element or elements in a manner corresponding to or commensurate with variations in the heat loss from or heat transfer to a building, such as corresponds to or results from variations in the weather or atmospheric conditions existing outside the building so as to substantially balance said heat loss or heat transfer and maintain desirable room temperatures under various weather conditions.

Another object of the invention is to establish and maintain a balance between the heat exchange rate of the heat exchange element and the heat transfer rate between the inside and the outside of the building by controlling the supply of operating fluid to said element in response to the temperature of the space or room as the same varies over a range reflecting outside weather conditions and in response to the temperature of said heat exchange element as the same varies over the operating or capacity range thereof.

Further, said invention has for its object to provide an improved apparatus for carrying out our said method.

Other objects will in part be obvious, and in part be pointed out hereinafter.

Our invention consists in the novel features of construction and in the combination and arrangement of parts, and in the steps constituting said method, hereinafter more fully described and the novelty of which will be particularly pointed out and distinctly claimed.

Present systems for controlling room temperature in response to the outside temperature, do not completely satisfy requirements for proper heat control, because the outside temperature may change without any immediate effect upon the inside or room temperature. The rate at which heat passes through the wall structure of a building depends on the difference in temperature between the inner and outer surfaces of said wall, and this difference also depends on other factors in addition to outside temperature, such as the heat capacity of the structure, wind, sun, rain, clouds, etc., the resultant of which is designated herein as the "weather conditions" or "atmospheric conditions". The thermometric outdoor temperature alone therefore is not a reliable index of the rate at which heat should be supplied for maintaining the space to be heated at a given temperature. The rate at which heat is supplied to the building space depends upon the rate at which the building loses heat. Hence, when a change in outdoor temperature occurs, there may be a considerable interval of time between the occurrence of the change and its sensible or appreciable effect on the temperature inside the building, and to translate such outside indication immediately into a corresponding adjustment of the inside temperature leads to undesirable results in the control of the room temperature.

In our method of control we cause the room temperature to vary through a definite range in proportion to the rate of heat loss resulting from variations in the outside temperature, the upper limit of said range corresponding to zero or a minimum heat loss resulting from outside temperature, say, for example, 72° F., and the lower limit of said range corresponding to a maximum or 100% heat loss resulting from an outside temperature of say, for example, 0° F., and vary the radiator output to balance the heat loss by controlling the supply of operating fluid or heat as a function of the measure of radiator output, namely, the difference between the radiator temperature and room temperature. In the preferred procedure we develop a force, as by means of a thermostatic bulb located within the room and subjected to room temperature, proportional to the heat loss through the walls of the building by allowing the room temperature to vary over a range proportional to the heat loss, and develop, as by thermostatic bulbs located on the radiator or heat exchanger so as to reflect the average temperature thereof, i. e., the mean temperature of the radiator as a whole, a force proportional to the radiator temperature, and coordinate or oppose said forces in such manner that the resultant thereof under all conditions of operation, is

effective in controlling the heat supplying means to establish and maintain a predetermined temperature difference between the radiator and the room, and hence a radiator output substantially balancing the heat loss from the building.

As the outside temperature varies over the normal range thereof, the room temperature and the radiator temperature vary in accordance with a predetermined curve or relationship to give a radiator output corresponding to and balancing the heat loss from the building. By causing variation of both the room temperature and the radiator temperature in accordance with such predetermined realtionship as the heat loss varies due to outside temperature variations, we are able to control the radiator heat output in accordance with changes in load or outside temperature, because we maintain a predetermined or controlled difference between the room and radiator temperatures.

In our invention the room temperature is caused to vary over a range in response to the variation of the outside temperature but within limits close enough not to be noticed as uncomfortable. It is this variability in room temperature over a slight range, in contradistinction to systems of control in which the room temperature is maintained or intended to be maintained substantially the same during all outside weather conditions, which enables us to establish and maintain the desired output of the radiator at any required rate over the entire range or capacity of the radiator.

We have thus introduced a new principle of control in which room temperature variations will be proportional to the outside temperature variations, and radiator temperature variations are coordinated therewith to produce equal but opposing forces acting to establish a radiator output balancing the heat loss, and this being accomplished without requiring the use of outside thermostats or other controlling means responsive directly to outside temperature conditions.

In the various systems of control embodying the present invention, we are able to maintain a continuous flow of heat from the radiator to the room, so that the radiator always feels warm and does not vary greatly in temperature when the rate of heat loss is constant, and the radiator does not become cool at times when the room temperature is such as to satisfy the requirements for heat. When the operating fluid is supplied intermittently, we maintain a comparatively even or mean radiator temperature varying only within a limited range, say, not to exceed a 20° temperature swing one way or the other from its mean value. When the invention is applied to a heat exchange system employing a "gradual acting" control of the operating fluid, the radiator temperature when once established remains substantially constant.

By controlling our system as above described, compensation can be made according to the conditions of heat delivery to the radiator and of heat loss from the building. The radiator output having been established at the desired value, the control will be effective to maintain such output, irrespective of the character of heat generation, distribution and transfer.

In our invention, under constant weather conditions, when the same is applied to an intermittent or "on and off" system, the fluctuations in radiator temperature from established value become immediately effective for reestablishing the predetermined radiator temperature by control of the operating fluid, burner, or the like. A swing in radiator temperature of a few degrees in either direction, say, an 8° swing, becomes immediately effective for controlling the operation to reestablish the radiator output, and this is accomplished without appreciably affecting the room temperature, which remains substantially constant, and, further, the radiator temperature is always maintained at a moderate mean value higher than the room temperature.

In the present invention, under constant weather conditions, the periodic control of the operating fluid to the radiator for maintaining the required output, is effected in response to the variation in the temperature of the radiator from an established value constituting a proportionate measure of the required output without reliance upon variation in the space temperature, as in the case of the ordinary room thermostat. As the outside weather conditions or heat losses from the building vary, corresponding variation in the temperature of the room is utilized for setting the radiator for operation at the required temperature. The radiator and room temperature ranges are of different magnitudes, so that a variation in room temperature of a few degrees in response to the variation in the outside weather conditions will be effective to establish radiator operating temperatures throughout the capacity range thereof corresponding to the heat losses.

The various steps constituting the method of our invention are fully set forth and rendered clear by reference to the accompanying drawings and following description thereof, in which drawings—

Figure 1 is an elevation of a heat exchange system employing one form of control constructed according to and embodying our said invention, and capable of use for carrying out the method of the invention;

Fig. 2 is an enlarged sectional view of the thermostatic means for controlling the operation of the system;

Fig. 3 is a front elevation, with parts broken away, of the thermostat located in the room or space to be heated, and

Fig. 4 is a graph or curve illustrating the principle of the invention.

Referring to the drawings, in Fig. 1 is shown a portion of a building, including a vertical partition wall **10**, and floors **10a** enclosing in part the rooms **11** containing the radiators **12**, **13**, **14** and **14a** connected individually through the branch connections or pipes **15a** to a supply main **15**, leading from a suitable source of operating fluid, preferably steam. The system is also provided with the usual return connections or pipes **16a** from the radiators to a return line **16**. The radiator and piping arrangement is of usual or well known form and need not be described in greater detail.

The supply of steam or other heating agent to the radiators is controlled by a suitable controller, for example, the electrically operated valve **17**, located in the main **15**, said valve being preferably of the intermittently operated type to control the flow of heating fluid or steam to the radiators, the use of said intermittently operated valve being preferred with steam as the heating medium, so that the steam can be supplied under design pressure. The steam pressure may be regulated at the boiler to maintain the same at a substantially constant or uniform design pressure adequate for always insuring delivery of steam to all of the radiators in proper proportions, or the usual pressure reducing valve (not shown) for the same purpose may be interposed at the inlet side

of the valve 17, when the steam is supplied from a public main.

While our invention is shown in connection with a system employing steam as above described, it is also applicable to systems employing other operating fluids, such as hot water or air, to systems employing electrically heated radiators supplied with current from a suitable source, to gradual acting systems, as hereinafter referred to, to systems in which the supply of steam is controlled by variation in the pressure thereof, and to vacuum systems. The invention is also particularly adapted for heating systems in which automatic firing devices are employed for heating the operating fluid, and in which the quantity of heat supplied to the heat exchange elements is controlled by control of the automatic firing device. The invention is also applicable to cooling systems employing refrigerants as the circulating medium to be controlled.

The extent of radiating surface or capacity of each radiator 12, 13, 14 and 14a is so designed with reference to the room size and exposure thereof as to supply sufficient heat to the room under the most severe condition of operation, such as in zero weather. For example, the radiator or amount of radiation for each room is so selected that when the outside temperature is at a given temperature, say, zero degrees Fahrenheit, and the radiator is supplied with steam or other heating fluid having such a temperature and in such quantity as to cause the radiator to operate at its full 100% capacity of designed heat output, the room or space will be heated to a desired temperature, say, 70° F. The several radiators may be and preferably are provided with inlet orifices, indicated generally at 18, 19, 20 and 20a, and which are sized to satisfy the requirements for steam and usually increase in area with the distance of steam travel from the source of supply, and thus compensate for drop in steam pressure with the distance of travel and insure adequate delivery of steam in the proper quantity to the most remote radiator.

We control the supply of operating, heating or cooling medium, and consequently the heat exchange rate between the heat exchanger and the space to be heated or cooled, by causing the control device to operate whenever there is a variation from a predetermined relationship between the temperature of the space to be heated or cooled and the temperature of the heat exchangers or radiators. As one example of the application of the invention, we employ a thermostatically responsive control, indicated, generally, at 21, including a liquid containing thermostatic element 22 reflecting or responsive to the temperature of the operating fluid, and preferably located on the heat exchange element, such as a radiator 12, and a liquid containing thermostatic element 23 located in the space to be heated, such as in the room 11 containing the radiator 12, and reflecting or responsive to the temperature of said space.

The two elements 22 and 23 are coordinated to control the operation of the contacts 24 and 25 to open and close the electric circuit operating the steam valve 17, or other electrically operated control device for regulating the heating effect.

As shown at Figs. 1 to 3, one form of thermostatic control which may be employed includes a series of bulbs 26 constituting the radiator thermostat 22, said bulbs being connected communicatively together in series through the looped tubular portions 27 of reduced or capillary cross-sectional bore. The bulbs 26 are preferably clamped to the radiator 12, as shown in Fig. 1, and are preferably arranged more or less diagonally on a line extending from the entrance of the radiator to the outlet thereof. In the embodiment shown, three or more bulbs 26 are employed and arranged as shown in Fig. 1, in order to adequately reflect the average radiator temperature. With the bulbs 26 arranged vertically, as shown, and connected by the horizontally extending loops 27, the formation of convection currents is prevented, so that the bulbs can only become heated successively as the radiator fills, and the heating of the contents of one bulb cannot cause convection currents heating the contents of succeeding bulbs.

The several bulbs 26 are connected communicatively by a capillary tube 29 of reduced cross-section with the room thermostat bulbs 23, the tube 29 being connected to the innermost bulb 26 at the lower end thereof to prevent convection currents.

The room thermostat 23 comprises a casing 30 to which the bulbs 31 and 32 each filled with an expansible fluid or oil 31a are attached. The tube 29 communicates with the bulb 31 and the bulb 32 communicates with the bulb 31 through the tube 33 forming a branch of the tube 29, so that a continuous body of the expansible fluid 26a, 31a occupies all of the bulbs, completely filling the same and the tubular connections between the same. The pressure responsive device 28, in the form of a metallic bellows, is disposed within the bulb 31 and carries a plunger pin 34 adapted to engage a lever 35 pivoted at an intermediate point 36 upon a fixed bracket 37 disposed within the casing 30. The upper end of the lever 35 carries the contact 24. A lever 38 pivoted at 39 to a fixed bracket 40 within the upper end of the casing 30 carries the contact 25 which cooperates with the contact 24 to make and break a circuit controlling, for example, the valve 17. A spring 41 is interposed between the lever 35 and the wall of the casing 30 to oppose the pressure of the pin 34 when expansion of the fluid 26a—31a causes the metallic bellows 28 to contract and move the lever 35 to open the contacts 24 and 25. A retractile spring 42 connects the arm 38 with the back of the casing 30.

An arm 43 pivoted at 44 is provided at its upper end with a cam 45 riding against the back of the arm 38 for manually setting the contact 25 with relation to contact 24 to raise or lower the room temperature setting or range. The spring 42 tends to draw the arm 38 away from contact 24 and maintains the arm 38 in operative relation with the cam 45. The lower end of the arm 43 is provided with a finger piece 46 riding in the arcuate slot 47 for actuating the arm 43 in making the setting.

The bulb 32 has a safety bellows 48 therein containing a spring 49 normally retaining the head of the bellows against a stop 50, this arrangement constituting a safety device to relieve excess pressures should any occur in the system due to abnormal expansion of the thermostatic fluid due to temperature rise. The interior of both bellows 28 and 48 are vented to the atmosphere.

In heating systems employing steam at 212° F. as the heating medium, we have found that the radiator bulbs 26 range in average temperature from about 72° F. to 172° F., while the range of room bulb temperature as established is from 72° F. to 69.8° F. To satisfy this relationship of the two temperature ranges, the volumetric ca-

pacity of the room bulbs **23** should be and is made about fifty times that of the volumetric capacity of the radiator bulbs **26**. The liquid employed in the bulb thermostats **22—23** is preferably kerosene, and completely fills the system. The thermoresponsive system **21** is charged and adjusted so that when the room bulb **23** is at 72° F., the temperature of the four bulbs **26** on the radiator will also be 72° F., and the actuator **28** opens the contacts **24** and **25** to close off the steam supply by valve **17**. The valve **17** is also closed when the room bulb temperature is 71° F. and the radiator bulb temperature 120° F. and when the room bulb temperature is 70° F. and the radiator bulb temperature 172° F.

The temperature of the room bulb **23**, of course, corresponds to and ultimately attains the temperature of the room or space to be heated, but because of the large volume of liquid employed in the bulb, it has considerable lag relative to the room temperature variations, and such lag may be beneficially enhanced by the use of suitable insulation about the bulb casing **23**. Because of the foregoing characteristic of the bulb device **23**, it becomes substantially immune to changes in room temperature which might occur as a result of the on and off operations of the valve **17** resulting from the swings in radiator temperature occurring when the system is balanced for operation under constant weather conditions. The device **23** being located in the space to be heated, becomes operative when it is necessary to attain or reestablish such balanced operation when the heating system is first started, or after it has been off for a considerable period of time. Assuming that the room and radiator are both at a sub-normal temperature of about 62° F. under constant weather conditions, when the heating system is started the radiator will supply heat to the space at maximum capacity continuously until the room bulb temperature attains or slightly exceeds a temperature of 70° F., whereupon the supply of operating fluid will be shut off. Due to said lag the heating period is increased to insure full heating up of the room to the desired temperature, or to a temperature even greater than that demanded by the weather conditions. In case the weather conditions prevailing demand operation of the radiator at part load, say, at a radiator bulb temperature of 120° F., after the foregoing cycle, the radiator cools down and the bulb temperature will continue to heat up to correspond with the temperature of the space attained by the previous heating cycle, and approach, say, the balancing value of 71° F. At the next cycle of operation when the radiator temperature drops below 120° F., the valve **17** opens to reestablish the desired relationship between the radiator and room temperatures demanded by the weather conditions.

In attaining balanced operation under part load demands, the heat supplying means will be shut off before the room thermostat is satisfied by the room air temperature. The room bulb temperature gradually increases to reduce the operating temperature of the radiator with the successive balancing cycles.

In hot water systems embodying our invention, the water is usually maintained at a temperature of 180° F., and the radiator bulbs such as **26** at 100% radiator output will be at a temperature of about 152° F., the bulb temperature reflecting the radiator temperature throughout the output range of the radiator. In such system, as one example, if the average radiator bulb temperature range is 80°, i. e., from 72° F. to 152° F., the room bulbs such as **23** are designed to have a volume forty times as great as the volume of the radiator bulbs **26**. Therefore, a change in temperature of 2 degrees in room bulbs **23** produces the same change in volume as a change in temperature of 80° of the bulbs **26**. The system is so designed that at a room temperature of 72° F. and a radiator temperature of 72° F. the means for controlling the supply of operating fluid to the particular system is closed, and will be closed when the relations between the room temperature and the radiator temperature correspond to the curve or graph of Fig. 4, as hereinafter described. Furthermore, the sensitivity of the thermostatic system **21** is such that the valve **17**, or a suitable mixing valve in the case of a hot water system, will operate if the room temperature falls one-fifth of a degree, or if the radiator temperature falls 8 degrees, and will operate at various relationships of room and radiator temperatures, illustrated in said graph or curve, as hereinafter described.

The graph or curve shown in Fig. 4 illustrates the temperature relationships obtained in controlling the operation of hot water systems in which the control means **17** takes the form of the usual "gradual acting" mixing valve. In said graph, the left-hand axis of coordinate represents the room temperature range from 72° F. to 69.8° F. The right-hand axis of coordinate represents the outside or outdoor temperature range, say, from 72° F. to 0° F., the room temperature varying directly with the outside temperature but over a lesser range. The axis of abscissas represents the average radiator bulb temperature range, say, from 72° F. to 152° F. With a radiator temperature of 72° and a room temperature of 72°, the volume of the thermostatic liquid is such as to cause the control valve to close, the forces acting then being equal and opposite. This point is represented on the graph at *a*. The same condition will exist when the opposite relation obtains, i. e., when the room temperature is at 70°, and the radiator temperature at 152°, the volume of the thermostatic liquid being equal to the volume obtaining under the temperature conditions at *a*. This point is indicated at *b*. The control means therefore will be closed at all points lying on the line *a—b*. Assume that the temperature relationships are as indicated by the line *a—b* and the control means is closed. Should the room temperature drop to 71.8°, indicated by the point *c*, the valve will open to increase the radiator temperature from 72° to some value slightly greater than 72°. The same holds true should the room temperature drop from 70° to 69.8°, indicated by the point *d*. The controlling valve therefore will be open at all relationships of room and radiator bulb temperatures, indicated by the line *c—d*. Should the radiator bulb temperature decrease 8 degrees, say, from 80° F., as indicated by the broken line *e*, the control valve will open to reestablish the original radiator bulb temperature or radiator output, the system then operating on the line *c—d*.

The capacity of the radiating or heat exchange elements should be sufficient to heat the space to about 69.8° F. when it is 0° F. outside. The room temperature varies through a range of 2.2 degrees while the radiator bulb temperature varies through a range of 80°. The room and radiator temperatures vary in response to and in

accordance with variations in outside temperature to balance at predetermined relationships. When it is 72° F. outside, the room and radiator will be 72°, and the control valve will be closed. When it is zero outside, the room temperature will be at 69.8°, the radiator temperature 152°, and the control valve will be wide open. For outside temperatures between 0° and 72°, when employing a "gradual acting" valve, which is made so that the rate of flow of heating medium through the heating system is directly proportional to the valve opening, it will assume an intermediate position, as indicated by the broken line *a—d*, such that the radiator output will just balance the heat loss from the building while keeping the room temperature at some point between 72° and 69.8°, depending on the outdoor temperature or heat loss from the building. The line *a—d* represents the predetermined relationships between the room temperature and the average radiator temperature which will be maintained by the system throughout the outside temperature range, the gradual acting valve being progressively opened as the room temperature falls from 72° to 69.8°. Hence, the vertical line *y—y'* between the lines *a—b* and *a—d* represents the extent of valve opening and indicates the rate of heat loss from the building, which becomes progressively greater as the outside temperature falls from 72° to zero.

We have thus established predetermined relationships between radiator temperature and room temperature for all rates of heat loss from the building, the radiator output being proportional to the temperature difference between the radiator and the space or room to be heated. By varying the radiator and room temperatures in accordance with the variations in load or outside temperature, and establishing for each rate of heat loss a temperature difference in accordance with the predetermined relationship, we are able to control the radiator output in accordance with the changes in load.

The graph of Fig. 4, modified for a radiator bulb temperature range of from 72° F. to 172° F., as in the case of the use of steam, is also illustrative of the operation of the intermittent system shown at Figs. 1 to 3, the thermostatic system then operating to maintain an average or mean room and radiator temperature relationship as represented by the line *a—d*. The fluctuations caused by intermittent operation, however, have no appreciable or sensible effect upon room temperature, because the fluctuations, say of 20 degrees in radiator temperature, are not of sufficient magnitude to cause the room temperature to fluctuate to an extent noticed by the room occupants.

In our system of control, the operation of the control maintains the output of the heat exchangers close to a required mean value determined by the weather conditions, or the rate of heat loss from the building, so that the desired effect of continuous or constant heat flow will be produced. A variation of about 10 per cent. in radiator output has been found permissible when employing the intermittent type of control, the variation being substantially nil when employing a "gradual acting" valve.

The invention possesses supplemental advantages when applied to steam systems. No traps are needed, because instead of sending more steam than necessary into the system and stopping it at the ends of the exchangers, we send only what is required, up to but not exceeding the capacity of the exchangers to condense the steam.

In our system or method of control of the radiator output, we are able to maintain substantially the same, or relatively the same, radiator outputs, i. e., the same or relatively the same percentages of outputs compared to the maximum for which the radiators are designed, for all the radiators of the system or zone by means of a single control radiator. Upon the setting of the control radiator for a given output, the other radiators, such as 13 and 14, are maintained at corresponding outputs, and correspondingly vary in output with variation in the output of the control radiator.

By our invention we are able not only to take cognizance of the rate of heat loss from the building but also of any change in such rate of heat loss. The temperature of the heat exchanger or exchangers varies in accordance with the variations in room temperature accompanying change in the rate of heat loss from the building. The radiator temperature varies over a substantial range for a slight range of variation in room temperature, and such result is accomplished under conditions productive of comfortable room temperatures, although the room temperatures vary with the outside weather conditions. We control the supply of operating fluid to the heat exchangers in response to change in rate of heat loss and maintain a substantially constant radiator output offsetting the heat loss as long as the weather conditions remain constant.

What we claim and desire to secure by Letters Patent of the United States is:

1. In apparatus for heating buildings, the combination of a heat exchanger for heating the building space; means for supplying a heating medium to said exchanger including an electric switch operable to supply the heating medium when in one position and to prevent supply of the medium when in a second position; a first thermostatic bulb responsive directly to changes in temperature of said heat exchanger; a second thermostatic bulb responsive to changes in temperature of the building space remote from said heat exchanger; said bulbs being of such relative sizes that the volumetric capacity of said first bulb bears the same relationship to the volumetric capacity of said second bulb as a predetermined relatively small range of building space temperatures comfortable to the occupants, bears to the range of temperatures of said heat exchanger which affects said first bulb and which is necessary to maintain the building space within said relatively small range of comfortable temperatures throughout the heating season; a relatively small diameter tube connecting said bulbs and providing therewith a closed system, and the bulbs and tube being completely filled with an expansible liquid; and means for transmitting the force resulting from changes in volume of said liquid, incident to temperature changes affecting either of said bulbs, to said switch and providing for movement of said switch to said one position when the volume of liquid falls below a predetermined value and for movement of said switch to said second position when the volume of liquid attains or exceeds such predetermined value.

2. In apparatus for heating a building space, the combination of a plurality of heat exchangers located in said space; means for supplying a heating medium to all of said exchangers and including an electric switch operable to supply

the heating medium when in one position and to prevent supply of the medium when in a second position; a first thermostatic bulb responsive directly to changes in temperature of one of said heat exchangers; a second thermostatic bulb responsive to changes in temperature of said space and being located therein at points remote from said heat exchangers; said bulbs being of such relative sizes that the volumetric capacity of said first bulb bears the same relationship to the volumetric capacity of said second bulb as a predetermined relatively small range of temperature in said space, which is comfortable to the occupants therein, bears to the range of temperatures of said one heat exchanger which affects said first bulb and which is necessary to maintain said space within said relatively small range of comfortable temperatures throughout the heating season; a relatively small diameter tube connecting said bulbs and providing therewith a closed system, and the bulbs and tube being completely filled with an expansible liquid; and means for transmitting the force resulting from changes in volume of said liquid, incident to temperature changes affecting either of said bulbs, to said switch and providing for movement of said switch to said one position when the volume of liquid falls below a predetermined value and for movement of said switch to said second position when the volume of liquid attains or exceeds such predetermined value.

WILLIAM WALTER TIMMIS.
WILLIAM K. WALKER.