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FORCED AIR HEATING APPARATUS

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My invention relates to an improvement in forced air heating apparatus, and more particularly to an improvement in the means for controlling a forced air heating apparatus of the class wherein cold fresh air is fan-supplied to an enclosed heating zone in which the air is first preheated to a selected temperature and then further heated to a higher distribution temperature by steam radiators. The improved control means of my invention has particular utility in connection with the forced air heating apparatus commonly used in public schools and the like.

The heating and ventilating of school buildings, factories employing large numbers of people, and similar structures presents special problems in that the air within the occupied portions of the building tends to become rapidly contaminated with carbon dioxide, etc. because of the relatively large number of people breathing the air. It has been found that buildings of this type require a system of forced ventilation in which the amount of fresh air supplied can be controlled independently of wind or weather in order that such buildings will be adequately ventilated. Such forced ventilation is generally carried out by the use of a plenum-type ventilation system in which the air is forced into the rooms to be ventilated under slight pressure, thus causing the foul air to be discharged from the rooms. Ventilation systems of this type are generally combined with a forced air heating system in which the air for ventilation also carries the heat required to maintain a comfortable temperature in the rooms. Indirect heating systems of this type are commonly found in school buildings and are generally referred to as forced air or hot blast heating systems.

In order to understand the nature of my invention, it will be necessary to briefly describe the general nature of these forced air heating systems with which my invention has its greatest utility and importance. In general, cold fresh air is fan-supplied through a fresh air shaft to a heating zone or chamber containing steam radiators. This chamber or zone may take the form of a room, tunnel, etc. but all of such heating zones are characterized by having both preheating or

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tempering radiators and secondary or reheating radiators. Thus, in operation the fresh air which may be combined with recirculated air from inside the building is first preheated to a selected temperature and then further heated to a higher disposition temperature. After passing through this heating zone the heated air is then carried to the rooms to be heated and introduced into them, and thereby causes the foul air in the rooms to be exhausted through ducts provided for this purpose, which are generally in communication with an opening in the roof of the building.

In the operation of forced air heating systems of this type, it has been found that it is desirable to preheat the air to temperatures ranging from 60 to 70° F. and then to further heat or reheat the air to temperatures ranging between 75 and 150° F. depending on variations in the heat requirements of the rooms because of differing outside temperatures, wind conditions, etc. For most buildings similar to public school buildings, it has been found that in order to maintain a room temperature of around 70° F., it is necessary to deliver heated air to the rooms at considerably higher temperatures. For example, in mild weather the heated air can be delivered to the rooms at around 74° F., while in cold weather it can be delivered as high as 150° F. It will readily be understood that in order to maintain the desired temperatures of the heated air that control means will be required for regulating the amount of heat transferred to the incoming air by the steam radiators within the heating chamber.

Hot blast heating systems of the plenum or tunnel type are usually operated so that a supply of fresh heated air is continually delivered to the rooms while foul air is continually exhausted therefrom. Thus, it is important that means be provided for preventing the air distributed to the rooms from carrying too much heat and thereby overheating the rooms. Heretofore the temperature control of the heated air has been attempted mainly by utilizing by-pass and/or mixing dampers. So far as is known all forced air heating systems of the type described above now utilize a damper located in a by-pass duct

around the preheating radiators which is opened and closed by a motor which is responsive to a thermostat actuated by the temperature of the preheated air. Thus, with this control device when the tempered air temperature becomes higher than a selected value, the by-pass damper begins to open and allow a portion of the fresh cold air to be passed around the preheating radiators and then recombined with the air passing through the preheating radiators to achieve a cooling of the preheated air. If the temperature of the preheated air continues to rise further above the selected temperature setting, the thermostat causes the by-pass damper to open further until a position is reached at which the proportion of by-passed air to preheated air is such as to hold the preheated air at the desired temperature. It has been found that such by-pass dampers provide a fairly effective means for preventing the temperature of the tempered air from becoming excessive, but such by-pass dampers suffer from other serious defects which will subsequently be discussed.

In addition to the by-pass damper around the preheaters just described, substantially all forced air heating systems of this type also utilize by-pass ducts around the secondary heaters and provide mixing dampers to vary the proportions of tempered by-passed air and reheated air. These dampers are generally constructed of two leaves and operate so that as one leaf leading to one duct opens the other one closes. This tends to admit a constant quantity of air to the room heating ducts, but controls the proportions of reheated and tempered air. These mixing dampers are generally controlled by thermostats in the rooms to be heated, which cause one leaf to be closed as the other opens in order to deliver air to the room at the temperature required to produce the desired room temperature. As can readily be seen, however, this secondary control means can do no more than cause all of the tempered air to be by-passed when the room becomes overheated.

Moreover, it has been found advisable to further heat the tempered air by the reheating radiators even though it is not passed directly through these radiators. In other words, it is generally recommended that the tempered air temperature produced by the preheating radiators be considerably lower than the temperature at which such air could be delivered to the rooms without causing them to feel drafty, and therefore the reheating radiators are so positioned as to radiate substantial quantities of heat to the tempered air even when all of the tempered air is by-passed around these radiators. For example, in the tunnel type of forced air heating system there is provided a series of casings at spaced points along the tunnel within each of which is contained reheating radiators and a by-pass duct around these reheating radiators. Since these casings and ducts are constructed of metal and are not provided with insulation, the temperature of the tempered air continually rises as it is passed through the tunnel and around these casings because of the heat radiated through the casings by the reheating radiators. Also, the reheating radiators radiate considerable heat to the tempered air passing through the by-pass ducts within the casings. In fact, it is not uncommon to find in tunnel systems containing three of such casing structures that the tempered air temperature is increased from eight to twelve degrees as it is passed along the tunnel after passing through the reheating radiators which are positioned at the

mouth of the tunnel. Of course, the temperature increase will depend primarily on the steam pressure maintained within the reheating radiators.

Forced air heating systems of the type described generally use two preheating radiators in order that one of the preheating radiators can be manually cut in and out of the heating circuit as the outside air temperature requires. Also, these heating systems generally provide a plurality of reheating radiators, which may be arranged in series or in parallel, that is, the reheating radiators can be located so as to heat divided portions of the tempered air to the temperature desired for particular rooms. Although such systems can be operated in a low pressure steam supply, it is common practice to utilize a high pressure steam supply at from 100 to 125 pounds per square inch gauge (p.s.i.g.). When a high pressure steam supply is utilized, the steam is passed through a pressure regulating valve or device before being supplied to the radiation units. On the radiation side of the system a pressure is generally maintained of between one to three pounds, which can be varied according to heating requirements by varying the setting of the pressure regulator. The radiation units are connected in parallel to the steam supply and condensate return pipes are attached thereto. Both gravity and vacuum returns can be utilized, although the vacuum-type of return is preferable. The radiators (both preheating and reheating) are equipped with manually-controlled gate valves by means of which the individual radiators can be cut in or out of the system. Thus, by manual adjustment it is possible to vary the radiation capacity of the system and the pressure of the steam supplied to the radiation units. However, since both the preheating and reheating radiators are connected in parallel at any given time or setting the steam pressure tends to be substantially the same in all the radiation units. This has a serious disadvantage in producing overheating or underheating as will subsequently be discussed. Also, it is common practice to introduce exhaust steam from engines, etc. into the radiation side of the system.

Forced air heating systems of the type described require the constant attention of a heating engineer to adjust the manual controls in order to prevent underheating or overheating of the air delivered to the rooms. Even with constant attention the present control system for this type of heating apparatus is frequently inadequate to prevent overheating or underheating of the air delivered to the rooms. The overheating tends to primarily occur in cold weather while the underheating tends to occur in warm weather. This is true because the steam pressure required in the preheating radiators is determined by the outside temperature which varies widely. As pointed out above, this same pressure is applied to the reheating radiators which are positioned to heat the tempered air even though most of it is by-passed around the reheating radiators. Thus, when the preheating radiators contain sufficient steam pressure to warm the incoming air from say 10° F. to 70° F., the steam pressure in the reheating radiators will be such as to overheat the air distributed to the rooms. A further complication is that the individual rooms have varying heating requirements because of differences in wind direction, radiation loss, etc. This means that frequently in order to sufficiently heat some rooms where the heat requirement is relatively great on the particular day, it will be necessary to overheat other rooms. A further dis-

advantage of the present system is at high steam pressure it is frequently necessary to spray water on the condensate return line above the condensate pump in order to condense the steam or further cool the condensate. This is caused primarily in cold weather by the steam being forced through the reheating radiators without having all of the heat value utilized because of the excess steam pressure maintained on these units.

In warm weather the opposite condition tends to prevail in that the air delivered to the rooms will frequently be underheated. This is true because the steam pressure required in the preheating radiators to meet the requirements of the incoming air is insufficient at times for the reheating radiators. Thus, except for a relatively narrow range of incoming air temperatures, the present systems tend to either over-radiate or under-radiate the air distributed to the rooms and are not effective in spite of constant manual adjustment in regulating the distribution of steam by the reheating and preheating radiators.

A further serious defect of the present system is found in the use of a by-pass damper around the preheating radiators to control the tempered air temperature. In cold weather, when the tempered air temperature advances sufficiently to cause the by-pass damper to open the rooms are caused to feel cold and drafty even though the temperature of the air within the room remains relatively high. This effect is produced because the opening of the by-pass damper greatly reduces the air friction, and thereby increases the velocity of the air moving upwardly into the rooms. Immediately after the opening of the by-pass damper air at increased velocity is passed rapidly into the rooms at a considerably lower temperature than the air within the rooms, and thus causes the rooms to feel drafty and uncomfortable. When it is realized that in order to maintain an equilibrium temperature of the tempered air, the by-pass damper will continually be opening and closing throughout the heating period, it can be seen that the effect described is a rather serious disadvantage to the use of such a damper. Furthermore, in warm weather the by-pass damper tends to open even though the reheating radiators have insufficient steam pressure to meet the room requirements. In spite of these disadvantages, until the present invention no one has suggested a satisfactory means for eliminating the mixing damper around the preheaters while maintaining an effective control of the tempered air temperature.

It is therefore an object of my invention to provide an entirely new means for controlling forced air heating systems of the type described in which overheating and underheating of the air is substantially prevented, and the undesirable by-pass damper around the preheaters is eliminated. It is a further object of my invention to devise a control means for use in forced air heating apparatus which will substantially decrease the manual adjustments required to deliver the air to the rooms at proper temperatures, and to allow the system to operate automatically after equilibrium conditions are established on a particular day. More specifically, it is an object of my invention to provide a control means of the type indicated which will decrease the amount of fuel required to satisfactorily heat a building, and which will prevent the rooms from periodically feeling drafty because of the introduction of cold air at increased velocity. In this connection, it is an object of my invention to eliminate the by-

pass mixing damper around the preheating radiators. It is a still further object of my invention to provide a new control means to accomplish the results indicated which can be installed in the forced air heating systems now in use with relatively little cost.

In place of the by-pass mixing damper and continual manual adjustments as heretofore required, it is an object of my invention to provide control means which will automatically supply steam to the radiation units at the pressure required to meet the heating requirements of the incoming air in spite of substantial variations in the outside air temperature. Furthermore, it is an object of my invention to provide control means for distributing the steam supplied between the preheating and reheating radiators as required, while allowing differing pressures to be maintained within the preheating and reheating radiators as needed to balance the heating carried out by the two types of units. More specifically, it is an object of my invention to provide control means by which steam can be incrementally supplied at the pressure required to meet the needs of the whole system and then redistributed within the system to meet the varying needs of the reheating and preheating radiators. Also, it is an object of my invention to provide means for the more efficient utilization of exhaust steam by the radiation units. Further objects and advantages will appear as the specification proceeds.

My invention is shown in an illustrative embodiment in the accompanying drawing in which is shown a typical forced air heating system of the tunnel-type in diagrammatic side view employing the control means of my invention.

For purposes of simplified explanation, my new control means will be described primarily in connection with the tunnel-type of forced air heating apparatus. However, I wish it clearly understood that I do not limit the applicability of my control means to this specific type of forced air heating apparatus. From the following discussion, it will be clear that my control means is generally applicable for use in connection with any forced heating apparatus of the class wherein cold air is fan-supplied to an enclosed heating zone in which the air is first preheated to a selected temperature and then further reheated to a higher distribution temperature by steam radiators.

In the illustration given, 10 designates a heating zone in the form of a tunnel. At one end, tunnel 10 is in direct communication with a fresh air shaft 11 through which cold fresh air is supplied from the outdoors. In the illustration given, and preferably, a corridor air return 12 is provided to supply recirculated air to combine with the fresh air introduced at the mouth of tunnel 10. It will be understood that the proportion of fresh air to recirculated air can be varied as desired by mixing dampers, etc. (not shown). In actual operation, in buildings such as schools, the volume ratio is frequently maintained at about one to one between fresh and recirculated air.

At the mouth of tunnel 10 there is provided two preheating radiators, the first preheater being designated as 13 and the second preheater as 14. It will be understood that preheaters 13 and 14 are provided with openings or apertures there-through for the passage of air through these heating units into tunnel 10. Also, two preheaters are generally used in forced air systems

of this class, and it is apparent that this number can be changed as desired so long as at least one preheater is utilized which has sufficient heating capacity to meet the heating requirements of the incoming air.

In the illustration given, a fan or blower 15 is mounted in tunnel 10 in front of preheaters 13 and 14 in order to move such air therethrough. Thus, all of the incoming air at all times passes through preheating radiators 13 and 14 in entering tunnel 10. Heretofore, a by-pass damper (not shown) has been provided in a duct by-passing the preheaters. For example, such a by-pass damper could be located in place of imperforate plate 16 in the system shown. However, with my new control means the need for a by-pass damper in this position is completely eliminated. In installing my heating apparatus of this type having my control means incorporated therein the conventional mixing damper would simply be omitted. In converting the systems now in use to my control means, the mixing damper can simply be disconnected from its thermostatic control so that it will permanently remain closed.

In the tunnel-type of system a plurality of spaced compartments or casings 17 are provided within tunnel 10. In the illustration given, three casings 17 are shown. Casings 17 are so placed in tunnel 10 that the forced air from fan 15 travels around and below and a portion thereof into casings 17. In the illustration given, and generally, casings 17 are composed of metal and are not insulated in any way.

Within each casing 17 there is provided a dividing partition 18 which separates the interior of the casing 17 into two passages or ducts 19 and 20. In duct 19 in the illustration given there is located two reheating radiators 21. It will be understood that reheating radiators 21 are provided with suitable openings or apertures therethrough so that the portion of air passing through ducts 19 passes entirely through reheating radiators 21. Duct 20 is intended to be a by-pass around reheating radiators 21 by which air can be passed upwardly from tunnel 10 through room ducts 22 without passing directly through reheating radiators 21. In the upper portion of casings 17 ducts 19 and 20 communicate with room duct 22. However, a mixing damper 23 is provided to regulate the proportion of reheating and by passed air introduced into room ducts 22. In the illustration given mixing dampers 23 consist of two leaves 23a and 23b linked by member 23c so that when leaf 23a is moved towards closed position leaf 23b moves towards open position. By this arrangement, the volume of heated air delivered to room ducts 22 is maintained substantially constant while allowing for the variation in the proportion of reheating air to by-passed tempered air. Mixing damper 23 can be operated by any convenient motor means. In the illustration given, and generally, damper 23 is operated by suitable linkage to an air motor 23, which is actuated by an air supply pipe 25 which communicates with thermostats (not shown) located in the rooms to be heated to which air is conveyed by room ducts 22.

In the illustration given for purpose of clarity, the steam supply pipe, condensate return pipes and other piping is shown below tunnel 10. However, it will be understood that in actual installations such piping is usually installed within tunnel 10.

In the illustration given, a steam supply pipe

26 is shown. It will be understood that the steam within pipe 26 can be supplied from any convenient source such as a steam boiler and that it can be at either high or low pressures, that is, from one to three to one-hundred and twenty-five pounds per square inch gauge. I prefer, however, to utilize steam at relatively high pressures of around one-hundred p. s. i. g. or somewhat in excess thereof. Steam supply main 26 is connected to the preheating radiators by pipes 27 and to the reheating radiators by pipes 28. It will be noted as is generally the case, that preheating radiators 13 and 14 and reheating radiators 21 are all connected in parallel to steam supply main 26.

A condensate return pipe 29 is provided, which is connected to the opposite end of preheating radiators 13 and 14 by pipe 30 and to the opposite end of reheating radiators 21 and pipes 31. A condensate return pipe 29 is preferably equipped with a condensate pump (not shown) to maintain a vacuum suction on the condensate line, although a gravity return can be utilized.

The apparatus shown is designed for best operation with a steam supply in steam supply main 26 at from about ten to one-hundred and twenty-five p. s. i. g., and a steam pressure within the radiation units at from one to three pounds p. s. i. g. Therefore, a pressure regulating valve 32 is positioned in line 26 between the steam supply source and the juncture of pipes 27 and 28 to the preheating and reheating radiation units. Pressure regulating valve 32 can be any sort of a pressure regulating valve which can be used to reduce the pressure from about ten to one-hundred and twenty-five p. s. i. g. on the boiler side to from one to three pounds on the radiation side of the system. In the illustration given, pressure regulating valve 32 is a gate valve equipped with a diaphragm 33 which is connected by pipe 34 to the radiation side of pipe 26. Since the construction of such diaphragm-controlled pressure regulating valve is well-known, it is believed that it will not be necessary to further describe it herein. I prefer to utilize a pressure regulating valve which can be set for varying pressures as desired, such as by weight loading in valves of the pressure-diaphragm type.

The supply of steam is further controlled by a motor-operated gate valve 35. Gate valve 35 can be any type of motor-operated valve which is capable of being controlled by a thermostat and moved over a range of positions from closed to fully open. In the illustration given, valve 35 is actuated by a diaphragm member 36 which is connected by an air supply line 37 to thermostat 38.

Thermostat 38 can be located at any point at which it can measure the tempered air temperatures and be responsive thereto. Preferably, thermostat 38 is located close to the output side of fan 15 so that it can be immediately responsive to changes in the temperature of the tempered air produced by preheaters 13 and 14 and passed into tunnel 10 by fan 15. It will be understood from what has been said in connection with the structure of valve 35, that thermostat 38 is to be selected so that it can actuate valve 35. Thus, if valve 35 were to be electrically-operated thermostat 38 should be an electrical-type thermostat. In the illustration given, thermostat 38 is of the air pressure type having a leak port 39 through which air supplied by line 40 can escape when the leak port begins to open. Since the structure of thermostats of this character is well-

known it is not believed that it will be necessary to further set out such structure herein. The method of operation of such thermostats is that a selected pressure, say 15 p. s. i. g. is normally maintained within pipes 37 and 40. However, when the temperature of thermostat 33 drops below a selected value, say 70° F., the leak port 39 begins to open and thus reduce the pressure within line 37. Leak port 39 generally continues to open over a temperature interval, which generally is around two degrees until fully open when the pressure in lines 37 and 40 is reduced to zero p. s. i. g. Diaphragm 36 has a spring exerting force on one side thereof which would be effective in opening valve 35 if it were not for the air pressure within pipe 37. This spring can be of any selected strength less than the pressure of the air supply. Thus, if the spring pressing against diaphragm member 36 is of ten pounds strength, valve 35 will not begin to open until the pressure within line 37 is reduced to ten pounds by the leaking of air through leak port 39.

Motor-controlled gate valve 36 can be located either above or below pressure regulating valve 32. Also, gate valve 35 and pressure regulating valve 32 can be combined through one valve which is adapted to perform both functions. The structure of such valves is well-known to those skilled in the art, and they are readily available from valve manufacturers. I prefer, however, to either use a single valve to accomplish the functions of valve 35 and pressure regulator 32 or to locate valve 35 above pressure regulator 32, as shown in the drawing. This arrangement of valve 35 is preferable because the full boiler steam pressure is available to incrementally inject steam into the radiation system. This method of operation will subsequently be more fully described.

In pipes 27 I provide motor-operated gate valves 41, which are preferably of the same type as gate valve 35 in order that gate valves 41 can also be controlled by thermostat 38. If desired, however, separate thermostats located near thermostat 38 can be used to control valves 41. In the illustration given, gate valves 31 are controlled by diaphragm members 42 which are connected by air pipes 43 to line 37. It will be understood that diaphragm structures 42 can be made to operate in the same way as diaphragm member 36, which method of operation has been fully covered above. It will also be understood that the springs within diaphragm members 42 can be of different strengths and therefore opening or beginning to open valves 41 at different pressures from each other or from valve 35.

I also prefer to equip the steam supply lines to the radiation units with manually operated gate valves which can be used to allow steam to bypass the motor-operated valves and to cut in or out a particular radiation unit. In the illustration given, these functions are performed by by-pass gate valve 44 located in by-pass line 45 around motor-controlled valve 35. Similarly manually-operated gate valves 46 are located in by-pass lines 47 around motor-controlled valves 41. Adjacent to preheaters 13 and 14, pipes 27 are also equipped with manually operated gate valves 48 by means of which preheaters 13 and 14 can cut in and out of the steam circuit. Likewise, preheating radiators 21 are individually equipped with manually operated gate valves 49 which can be used to cut them in or out as desired.

I also prefer to provide a pipe 50 communicat-

ing with the radiation side of pipe 26 so that exhaust steam from engines, etc. can be introduced into the radiation units without passing through valve 35 or pressure regulator 32. It will be understood that pipe 50 can be equipped with a suitable butterfly valve to prevent the backflow of steam within pipe 50.

The operation of my control means which consists essentially of motor-controlled valves 35 and 41 and thermostat 39 can best be appreciated by reference to a specific example. However, I wish it clearly understood that this example is merely set out by way of illustration and not limitation, since my control means can be adapted for use with other types of forced air heating apparatus in which it is desired to effect a distribution of steam by the preheating and reheating radiators within the plenum chamber.

EXAMPLE

The general operation of the control system of my invention is to arrange the valves and to provide for their automatic operation so that any excess steam within reheating radiators 21 which is not required to meet the secondary heating needs can be redistributed to preheating radiators 13 or 14 before additional steam is supplied to both the preheating and reheating radiators from the steam supply main. Whenever additional steam is required, it is intended that my control means be operative to supply such steam requirements incrementally at pressures corresponding with those required to maintain the selected preheated air temperature. Furthermore, it is intended to provide a structure in which exhaust steam can be introduced into the radiation units to supply their heat requirements such as by pipe 50.

It will be assumed that the forced air heating apparatus shown in the drawing is to be used to heat the rooms of a school building in which room ducts 22 supply at least one room with heated air. It will be further assumed that thermostatic controls are located within these rooms to actuate mixing dampers 23. While this control system can be of any suitable type, the illustration given shows an air pressure control system, since this type of control system is usually found already installed in school buildings at the present time.

Generally, it is desired to maintain room temperatures of about 70° F., which requires that air be delivered to the room at from 74 to 150° F. depending on the weather conditions and outdoor temperatures. It will here be assumed that the outdoor temperatures are around 40° F. and that to maintain the desired room temperatures of 70° F. that the air must be delivered to the rooms at about 90° F.

To achieve this result, thermostat 38 is set to begin to open leak port 39 when the temperature of the tempered air falls below 70° F. and to continue to reduce the pressure in air lines 37 and 40 until a zero pressure is attained at about 68° F. Air is supplied into lines 37 and 40 at approximately 15 p. s. i. g. Diaphragm motor 36 is set to begin to open main valve 35 at about 69° F. or 8 p. s. i. g., while diaphragm motor 42 is set to open the first preheater 13 valve 41 at about 69¾° F. or 10 p. s. i. g. and the other diaphragm motor 42 is set to begin to open valve 41 for the second preheater 14 at about 68¾° or 6 p. s. i. g.

The effect of setting the valves in this manner can best be seen by looking at the Typical Operational Chart set out on the following page.

Typical operational chart

Thermostat setting	Operation Thermostat Controlled Valves		
	Main Line Supply	First Preheater	Second Preheater
70° F. (15 p. s. i. g.)	Fully Closed	Fully Closed	Fully Closed
69 3/4° F. (10 p. s. i. g.)	↓	↓	↓
69° F. (8 p. s. i. g.)	Begins to Open	Begins to Open	↓
68 3/4° F. (6 p. s. i. g.)	↓	↓	Begins to Open
68° F. (0 p. s. i. g.)	Fully Open	Fully Open	Fully Open

In addition to the settings mentioned above and set out in the chart, pressure regulating valve 32 is set at the maximum pressure which will be required within the radiation units to meet the heating requirements of the incoming air at its lowest probable temperature. For example, in the illustration given this pressure regulator 32 is set at 3 p. s. i. g. Thus, pressure regulator 32 will remain open until a pressure is built up in excess of 3 pounds p. s. i. g. within the radiation units.

Referring now to the operational chart set out above, a typical cycle of operations at the indicated settings will be explained. At tempered air temperatures above 70° F., leak port 39 is fully closed. However, as the temperature of the tempered air drops below 70° F. leak port 39 begins to open and reduce the pressure of the air within pipes 40 and 37. When the tempered air temperature reaches 69 3/4° F. the pressure within the air pipes will be around 10 p. s. i. g. At this point, as indicated in the chart, the valve 41 controlling the supply of steam to the first preheater 13 begins to open, while the other valve 41 controlling the supply of steam to the second preheater remains closed, as well as main supply valve 35. The opening of the first preheater valve 41 allows steam to be redistributed from the reheater radiators into the first preheater radiator 13, and also for exhaust steam introduced into pipe 50 to be admitted into preheater 13. This redistribution and/or the introduction of exhaust steam may be sufficient to cause the temperature of the tempered air to move temporarily upward.

Eventually, however, the tempered air temperature (except in very mild weather when the exhaust steam supply is alone adequate) drops below 69 3/4° F. and reaches about 69° F. at which point the air line pressure is about 8 p. s. i. g. and therefore main supply valve 35 begins to be opened by air diaphragm motor 36. It will be noted, however, that the second preheater valve 41 remains closed until the temperature drops further. Thus, the opening of valve 35 meters steam into first preheater 13 through its partially opened motor control valve and also supplies steam to reheater radiators 21. At some incoming air temperatures, this introduction of steam will be sufficient to cause the tempered air temperature to rise and thereby closing first the main supply valve and secondly the first preheating valve, whereupon the described cycle of operations commences again. This can happen in the apparatus shown at temperatures above about 40° F., but at temperatures around 40° F. and below, the tempered air temperature will probably continue to fall to 68 3/4° F. while further opening main supply

valve 35 and first preheater valve 41 until the second preheater valve 41 begins to open as indicated on the chart. Steam is then introduced into the second preheating unit which doubles the preheating capacity of the preheating units. At 68° F. pressure in the air lines is at zero and all motor-controlled valves are fully open. This condition, however, is attained only momentarily since the setting of pressure regulating valve 32 is such that when this condition is reached the tempered air temperature is caused to rise rapidly until it achieves 70° F. or above.

It will be understood that the cycle of operations just described is sequentially repeated as directed by the temperature requirements of the incoming tempered air. It has been found that in warm weather the temperature interval between the opening of the first preheater valve and the main valve can be increased to allow more time for redistribution of the steam from the reheating radiators and for the use of exhaust steam. In very mild weather for example the main valve might be set to open at around 68 3/4° F. However, in cold weather it would not be desirable to utilize this great an interval, since too great a cooling of the radiation units might result. In fact, in very cool weather it is generally desirable to decrease the temperature interval by setting the main supply valve to open closer to the first preheater valve. For example, the main supply valve in very cold weather can be set to open at about 69 1/4° F.

In the illustration given, manually operated valves 44, 46, 47, 48 and 49 are shown. If desired, these valves can be utilized as follows. When the building to be heated is cold, such as would be the case in school buildings after the weekend recess, it may be desired to admit steam at a constant pressure to the radiation units in order to rapidly heat up the air. This can be accomplished by opening by-pass valve 44 and by-pass valves 46. Also, depending on weather conditions, etc. it may be desired to cut in or out one of the preheating units or one or more of the reheating units. This can be accomplished by means of valves 48 and 49.

In the operation of a system substantially as described in this example, it has been found that a very exact control of the tempered air temperature can be attained while also preventing the reheating radiation units from overheating the air passing to the room ducts. Furthermore, since the use of a by-pass damper around the preheating units is eliminated, the periodic drafty feeling within the rooms is also avoided. Underheating is also prevented. However, from an economic standpoint the great advantage of my new control system is that fuel bills can be substantially

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decreased. Under comparable conditions, it has been found that fuel consumption can be cut from 15 to 20% or more.

While in the foregoing specification I have set forth specific structures and operating conditions for the purpose of illustrating an embodiment of my invention, it will be apparent to those skilled in the art that many of the details of the conditions specified can be widely varied without departing from the spirit of my invention.

I claim:

1. In a forced air heating apparatus of the class described wherein cold air is fan-supplied to an enclosed heating zone in which said air is first preheated to a selected temperature and then further heated to a higher distribution temperature by steam radiators, said apparatus including a preheating radiator and a reheating radiator connected in parallel by branch pipes to a steam supply main and having condensate return pipes attached thereto, the combination with said apparatus of a motor-controlled gate valve means in said supply line together with a pressure regulating means, both of said means being located above the juncture of said branch pipes so as to control the input quantity and pressure of steam to both of said radiators, a motor-controlled gate valve means in the branch pipe between said supply main and said preheating radiator to separately control the supply of steam to said preheating radiator, and a thermostat control means responsive to variations in the preheated air temperature actuating both of said motor-controlled valve means, said thermostat means being set to open and close both of said valve means over narrow overlapping temperature ranges and to begin to open said preheater valve means at a slightly higher temperature than said supply main valve means, whereby excess steam in said reheating radiator can be distributed to said preheater radiator before additional steam is supplied to both of said radiators by said supply main valve means and when additional steam is required said steam is supplied incrementally at pressures corresponding with those required to maintain the selected preheated air temperature.

2. In a forced air heating apparatus of the class described wherein cold air is fan-supplied to an enclosed heating zone containing steam radiators in which zone said air is first preheated to a selected temperature and then further heated to a higher distribution temperature, said apparatus including two preheating radiators and a plurality of reheating radiators being connected in parallel by branch pipes to a steam supply main and having condensate return pipes attached thereto, said apparatus also including a by-pass duct around said reheating radiators equipped with a mixing damper to control the temperature of the distributed air by varying the proportions of reheated and by-passed preheated air, the combination with said apparatus of a motor-controlled gate valve means in said supply line together with a pressure regulating means both of said means being located above the juncture of said branch pipes so as to control the input quantity and pressure of steam to all of said radiators, a motor-controlled gate valve means in each of the branch pipes between said supply main and said preheating radiators to separately control the supply of steam to each of said preheating radiators, and a thermostat control means responsive to variations in the preheated air temperature actuating all of said

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motor-controlled valve means, said thermostat means being set to open and close all of said valve means over narrow overlapping temperature ranges and to begin to open one of said preheater valve means at a slightly higher temperature than said supply valve means and the other of said preheater valve means at a slightly lower temperature than said supply valve means, whereby excess steam in said reheating radiators can be distributed to one of said preheating radiators before additional steam is supplied to all of said radiators by said supply main valve means and when additional steam is required said steam is supplied incrementally at pressures corresponding with those required to maintain the selected preheated air temperature, said additional steam being first introduced into one of said preheating radiators and later into the other of said preheating radiators according to the heat requirements of the incoming air.

3. In a forced air heating apparatus of the class described wherein cold air is fan-supplied to an enclosed heating zone containing steam radiators in which zone said air is first preheated to a selected temperature and then further heated to a higher distribution temperature, said apparatus including two preheating radiators and a plurality of reheating radiators being connected in parallel by branch pipes to a steam supply main and having condensate return pipes attached thereto, said apparatus also including a by-pass duct around said reheating radiators equipped with a mixing damper to control the temperature of the distributed air by varying the proportions of reheated and by-passed preheated air, the combination with said apparatus of an air motor-controlled gate valve means in said supply line together with a pressure regulating means both of said means being located above the juncture of said branch pipes so as to control the input quantity and pressure of steam to all of said radiators, an air motor-controlled gate valve means in each of the branch pipes between said supply main and said preheating radiators to separately control the supply of steam to each of said preheating radiators, and an air pressure thermostat control means responsive to variations in the preheated air temperature actuating all of said motor-controlled valve means, said thermostat means being set to open and close all of said valve means over narrow overlapping temperature ranges and to begin to open one of said preheater valve means at a slightly higher temperature than said supply valve means and the other of said preheater valve means at a slightly lower temperature than said supply valve means, whereby excess steam in said reheating radiators can be distributed to one of said preheating radiators before additional steam is supplied to all of said radiators by said supply main valve means and when additional steam is required said steam is supplied incrementally at pressures corresponding with those required to maintain the selected preheated air temperature, said additional steam being first introduced into one of said preheating radiators and later into the other of said preheating radiators according to the heat requirements of the incoming air.

4. In a forced air heating apparatus of the class described wherein cold fresh air is fan-supplied to a tunnel containing steam radiators in which tunnel said air is first preheated to a selected temperature and then further heated to a higher distribution temperature, said tunnel including a preheating radiator at the mouth

thereof and a reheating radiator at a spaced distance therefrom in said tunnel both of said radiators being connected in parallel by branch pipes to a steam supply main and having condensate return pipes attached thereto, the combination with said apparatus of a motor-controlled gate valve means in said supply line together with a pressure regulating means, both of said means being located above the juncture of said branch pipes so as to control the input quantity and pressure of steam to both of said radiators, a motor-controlled gate valve means in the branch pipe between said supply main and said preheating radiator to separately control the supply of steam to said preheating radiator, and a thermostat control means responsive to variations in the preheated air temperature actuating both of said motor-controlled valve means, said thermostat means being set to open and close both of said valve means over narrow overlapping temperature ranges and to begin to open said preheater valve means at a slightly higher temperature than said supply main valve means, whereby excess steam in said reheating radiator can be distributed to said preheater radiator before additional steam is supplied to both of said radiators by said supply main valve means and when additional steam is required said steam is supplied incrementally at pressures corresponding with those required to maintain the selected preheated air temperature.

5. In a forced air heating apparatus of the class described wherein cold fresh air together with recirculated air is fan-supplied to a heating tunnel containing two preheating radiators at the mouth thereof through which said air is caused to pass and a plurality of reheating radiators located in casings within said tunnel, said casings providing a by-pass duct therein around said reheating radiators equipped with a mixing damper to control the temperature of the distributed air by varying the proportion of reheated and by-passed preheated air, the combination with said apparatus of a motor-controlled gate valve means in said supply line together with a pressure regulating means both of said means being located above the juncture of said branch pipes so as to control the input quantity and pressure of steam to all of said radiators, a motor-controlled gate valve means in each of the branch pipes between said supply main and said preheating radiators to separately control the supply of steam to each of said preheating radiators, and a thermostat control means responsive to variations in the preheated air temperature actuating all of said motor-controlled valve means, said thermostat means being set to open and close all of said valve means over narrow overlapping temperature ranges and to begin to open one of said preheater valve means at a slightly higher temperature than said supply valve means and the other of said preheater valve means at a slightly lower temperature than said supply valve means, whereby excess steam in said reheating radiators can be

distributed to one of said preheating radiators before additional steam is supplied to all of said radiators by said supply main valve means and when additional steam is required said steam is supplied incrementally at pressures corresponding with those required to maintain the selected preheated air temperature, said additional steam being first introduced into one of said preheating radiators according to the heat requirements of the incoming air.

6. In a forced air heating apparatus of the class described wherein cold fresh air together with recirculated air is fan-supplied to a heating tunnel containing two preheating radiators at the mouth thereof through which said air is caused to pass and a plurality of reheating radiators located in casings within said tunnel, said casings providing a by-pass duct therein around said reheating radiators equipped with a mixing damper to control the temperature of the distributed air by varying the proportion of reheated and by-passed preheated air, the combination with said apparatus of an air motor-controlled gate valve means in said supply line together with a pressure regulating means both of said means being located above the juncture of said branch pipes so as to control the input quantity and pressure of steam to all of said radiators, an air motor-controlled gate valve means in each of the branch pipes between said supply main and said preheating radiators to separately control the supply of steam to each of said preheating radiators, and an air pressure thermostat control means responsive to variations in the preheated air temperature actuating all of said air motor-controlled valve means, said thermostat means being set to open and close all of said valve means over narrow overlapping temperature ranges and to begin to open one of said preheater valve means at a slightly higher temperature than said supply valve means and the other of said preheater valve means at a slightly lower temperature than said supply valve means, whereby excess steam in said reheating radiators can be distributed to one of said preheating radiators before additional steam is supplied to all of said radiators by said supply main valve means and when additional steam is required said steam is supplied incrementally at pressures corresponding with those required to maintain the selected preheated air temperature, said additional steam being first introduced into one of said preheating radiators according to the heat requirements of the incoming air.

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