Aug. 17, 1937. K. W. ROHLIN 2,090,073

METHOD AND APPARATUS FOR CONTROLLING HEATING SYSTEMS

Filed May 6, 1935 2 Sheets-Sheet 1

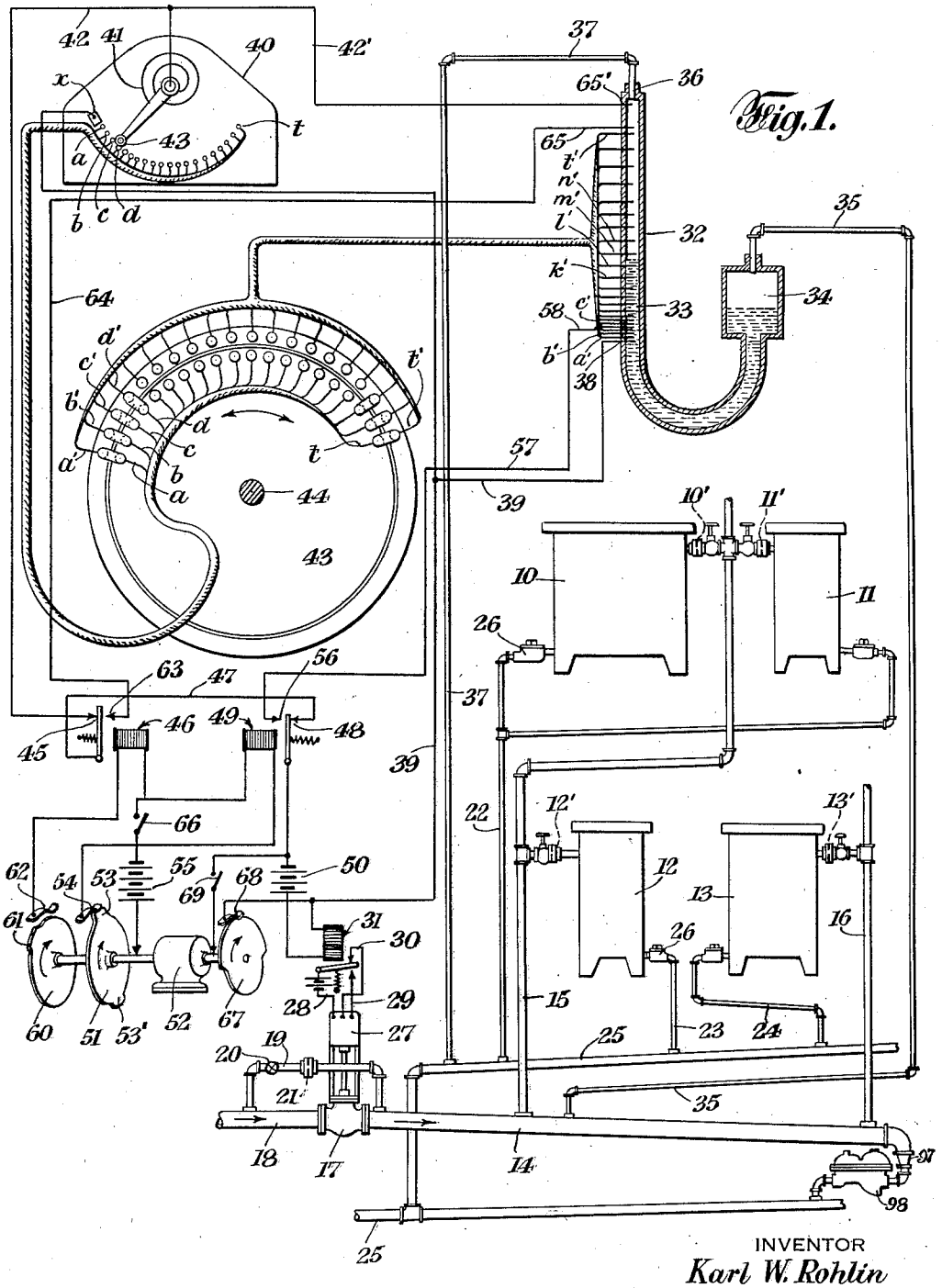


Fig. 1.

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Fig. 2.

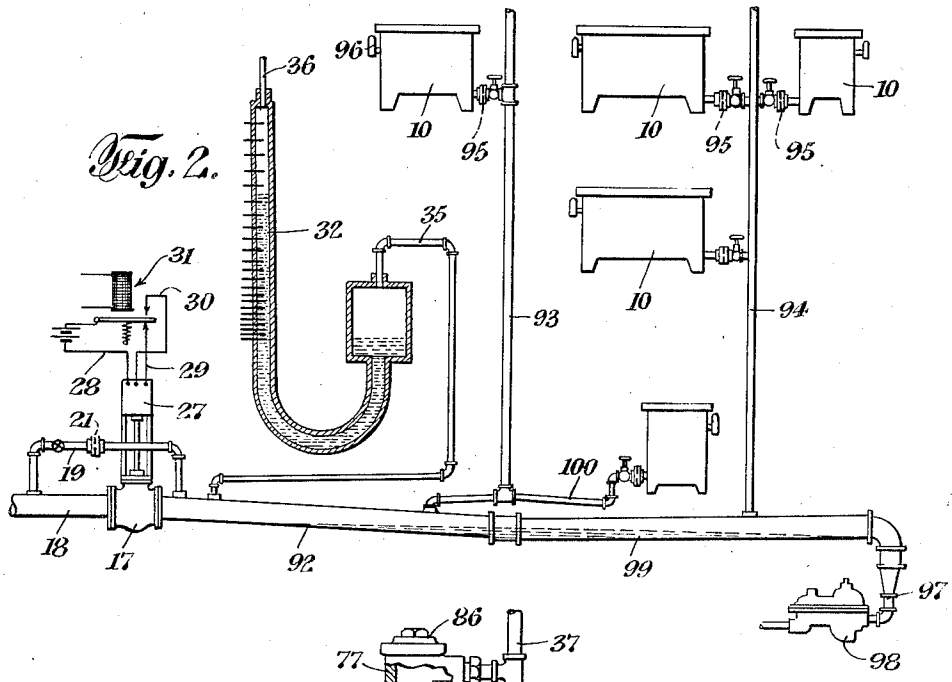


Fig. 3.

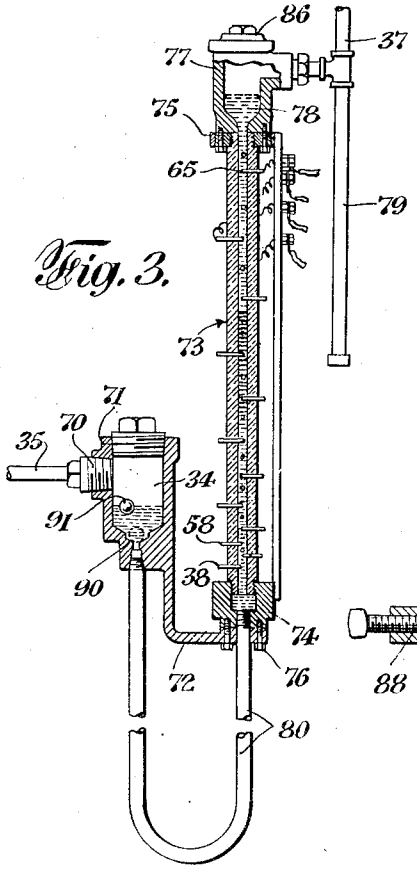


Fig. 4.

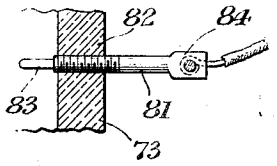
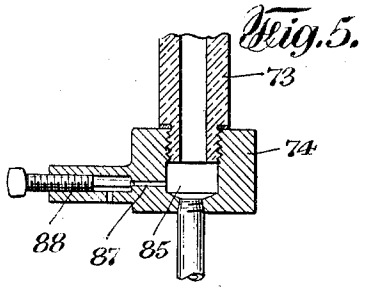


Fig. 5.



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2,090,073

METHOD AND APPARATUS FOR CONTROLLING HEATING SYSTEMS

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Application May 6, 1935, Serial No. 20,012

20 Claims. (Cl. 237—9)

This invention relates to apparatus and methods of providing a measured supply and distribution of steam or the like in heating systems.

The purposes of the invention include the provision of improved heating systems and methods of steam distribution which will in practice, economically eliminate the causes of unsatisfactory operation, discomforts and wastefulness existing in various systems heretofore used. The invention is adaptable not only to new installations but also may be quickly and economically applied to existing systems of inferior design, to correct the unbalanced and uncontrolled steam supply and distribution therein.

In overcoming the difficulties of controlling the distribution of steam in "one-pipe" systems, according to one phase of my invention, I provide a method of operation utilizing a timing device for causing steam to be applied to the system at regulated pressure, during each of a succession of relatively short and properly spaced periods, and utilizing the intervening intervals between such periods for the withdrawal of the condensate accumulated in the radiators during the previous period; and according to this method, the flow of steam may be accurately distributed to the various radiators by the use of restricting means in the steam connections to each radiator respectively, so that steam is applied to each, in amounts bearing substantially the same proportional relationship for each radiator to its heating capacity, and without interference with the condensate flowing through the conduits during the intervening intervals. Also according to my invention the pressure of steam intermittently supplied during each of the succession of short periods, may be accurately regulated in accordance with the prevailing outdoor temperature changes, so that the steam supplied to each radiator is varied in accordance with the system's heating requirements, whether moderate or maximum. In accordance with this system and method, the steam as supplied during each of the succession of spaced periods, may be of such substantial pressure even during mild weather, as to cause a decisive flow, so that its amount and pressure may be very accurately regulated, and such that the steam promptly reaches in the desired proportions, all the radiating units of the system, even though the piping system may be of an early design, poorly proportioned or having sections in which condensate tends to accumulate to an extent which would interfere with and restrict any gentle flow of steam such as available during mild weather with systems of the usual type.

This invention comprises in part an alternative embodiment of the invention of my copending application Ser. No. 19,397, filed May 2, 1935, entitled "Heat controlling systems". In that application apparatus and methods were disclosed for providing a measured supply and distribution of steam at a predetermined pressure, to a heating system intermittently, at periods of regulated or adjustable length, depending upon the heating requirements. With the embodiment of the invention hereinafter disclosed, a system may be provided wherein steam is supplied during each of a succession of periods, preferably with a normally fixed spacing between periods, and preferably with the periods normally fixed in length, and the quantity of steam provided during each such period may be adjusted or regulated by varying its pressure.

In accordance with this invention a relatively simple and inexpensive arrangement may be provided for thermostatically regulating, through the use of electrical circuits, the pressure during each "on" period of steam supply in accordance with the heating requirements, modified if desired at certain times of day by manually adjustable means.

Certain phases of the invention are adaptable for use with either "one-pipe" systems, or "two-pipe" systems of various types, which may have either open return mains wherein the condensate is returned from the radiators by gravity, or systems of the vacuum or closed return type. Where the invention is used with "two-pipe" systems, it is particularly adaptable for regulating the steam pressure during each "on" period in such manner that the pressure difference between the supply and return mains will be varied in accordance with the heating requirements of the system.

According to one feature of the invention, provision may be made for periodically supplying to the heating system during short periods, steam at a pressure substantially above the pressure normally supplied, for forcibly dislodging from the piping any accumulations of condensate which would otherwise tend to obstruct the desired proportional distribution of steam to various parts of the system.

Various further and more specific objects, features and advantages will clearly appear from the detailed description given below taken in connection with the accompanying drawings forming a part of this specification and illustrating by way of example various preferred embodiments of the invention. The invention consists in such novel features, arrangements, combinations of parts and

methods as are described in connection with the apparatus herein disclosed, by way of example only.

In the drawings, Fig. 1 comprises a schematic diagram of a "two-pipe" heating system embodying certain features of my invention;

Fig. 2 is a similar diagram illustrating a "one-pipe" steam heating system;

Fig. 3 is an elevational view partly in section of one of the pressure controlling devices of the system; and

Figs. 4 and 5 are sectional views of certain details of construction of the device of Fig. 3.

Referring now to Fig. 1, the system there schematically shown may comprise a plurality of radiators of conventional type as at 10, 11, 12 and 13, located in the various spaces or rooms of a structure to be heated. The piping system for these radiators may comprise a steam main 14 with risers to various parts of the structure as at 15, 16. The steam main 14 may be connected through a pressure controlling valve 17 to a supply conduit as at 18 connected to a boiler, a central heating plant or other source of steam supply at either a varying or more or less constant pressure, higher than the maximum pressure required in the main 14.

The valve 17 may be accompanied by a relatively small by-pass conduit as at 19. This by-pass is preferably provided with a valve as at 20 which may be used either for shutting off the steam or for adjusting the flow through the by-pass. The by-pass may also be provided with a normally fixed orifice member as at 21 for restricting the flow of steam to a predetermined extent through the by-pass.

In the conduits to each of the radiators respectively, preferably substantially adjacent the inlets thereto, normally fixed orifice members may be provided as at 10', 11', 12' and 13'. These orifice members are preferably formed with apertures of a predetermined size for restricting the flow of steam to each radiator to an extent depending upon the normal heating capacity thereof and the access of the steam source to each radiator. That is, for example, the steam source has access to each of the orifices 10' and 11' to substantially the same extent, these two particular orifices communicating with the steam source through piping of the same size and amount. However, the radiator connected at orifice 10' is larger than that at prifice 11' and accordingly the orifice 10' will in proportion, be larger than the orifice 11'. On the other hand, the radiators connected at orifices 11' and 12' are of equal size, but the steam source has more direct and immediate access to the orifice 12' and hence the orifice at 11' is made larger than that at 12'. In general these various orifices at the radiator inlets are so proportioned, by calculation or trial, that steam is supplied to each radiator respectively in amounts bearing substantially the same proportional relationship for each radiator, to its heating capacity. The methods of designing the orifices of predetermined size at the various radiator inlets, as well as the normally fixed orifice members which may be placed at various other parts of the piping system to aid proper steam distribution, are further set forth in the patent to Donnelly, No. 1,681,725, granted August 21, 1928.

The various radiators may be connected with condensate return pipes as at 22, 23 and 24, extending to a return main 25 which may be of the "open return" type for the gravity return flow of the condensate, or preferably with the particular arrangement as shown in Fig. 1, of the "closed return" type where the return main 25 communicates with any suitable well-known type of apparatus for maintaining a partial vacuum therein.

The outlets of each of the radiators to the return piping may preferably be provided with steam traps as at 26 of a suitable well-known type adapted to normally permit condensate to flow therethrough, but closing against the exit of steam when the radiators are filled to an extent such that the heat of the steam reaches the traps.

The valve 17 may be operated by a reversible electric motor 27 provided with circuit connections 28 and 29 for operating the motor in a direction to open the valve, and connections 28 and 30 for operating the motor in the opposite direction to close the valve. A relay 31 may be provided for controlling these connections, this relay having a "break" contact for the connection 29 and a "make" contact for the connection 30, so that when the relay magnet is de-energized, the motor 27 is so connected as to normally turn the valve 17 toward open position, or apply turning force tending to move the valve to such position. Then when the relay 31 is energized, power is applied to the motor to operate it in the opposite direction for closing or tending to close the valve.

A U-tube 32 may be provided for a mercury column 33. One end of this mercury column may open into a small mercury reservoir as at 34 having a pressure connection as at 35 communicating with the steam main 14. The other end of the U-tube as at 36 may be provided with a pressure connection as at 37 communicating with the return main 25. Thus the position of the mercury column within the U-tube may be varied in proportion to the difference in pressure between the steam and return mains.

A plurality of contacts as at a' to t' inclusive may be provided at the spaced positions for protruding into the mercury column 33. As hereinafter explained, means may be provided for thermostatically selecting one of these contacts for energizing the valve controlling relay 31 whenever the mercury column rises to or above such selected contact, whereby a circuit is made from such contact through the mercury column 33 to a lower contact 38 and connection 39 to the magnet of relay 31. The means for thermostatically selecting one of the contacts as at a' to t' may comprise a thermostat 40 located preferably out of doors or at some location where the temperature varies substantially in accordance with outdoor temperature changes, independently of the temperature in the spaces heated. According to some phases of the invention, however, this thermostat may be located in a room wherein the temperature is intended to be typical or representative of the spaces heated by the system or where the temperature changes are in proportion to such temperature. This thermostat may comprise a movable bi-metallic member 41 having a fixed electrical connection 42. The movable end of the member 41 may be provided with a suitable contact such as a roller 43 for variably engaging, in accordance with temperature changes, a series of fixed contacts a to t as indicated. The contacts a to t inclusive on the thermostat may normally correspond respectively and be connected to the contacts a' to t' at the mercury column. However, each of these contacts at the thermo-

stat respectively may not always correspond to a particular one of the contacts at the mercury column, since it may be desirable to shift the relative relationship of these two groups of contacts from time to time to provide for varying heating requirements. For shifting such relative relationship of the contacts, a manually operable switch as at **43** may be provided. This switch may be provided with a plurality of movable contacts as at *a* to *t*, all fixed to a pivoted support adapted for turning adjustment about a shaft **44**. Each of these movable contacts respectively corresponds to and is connected to one of the thermostat contacts *a* to *t*. The switch **43** may also be provided with a corresponding number of fixed contacts *a'* to *t'* connected respectively to the contacts *a'* to *t'* at the mercury column. Thus by adjusting the position of the switch **43**, the relationship of the whole group of connections from the thermostat contacts *a* to *t* may be shifted in respect to the connections to the mercury column contacts *a'* to *t'*. Hence while the thermostat may normally be used to select the particular contact to be energized at the mercury column, the attendant may at certain times of the day, for example when more heat is desired in the early morning hours, shift the relationship of these connections so that the apparatus will be thermostatically regulated at a higher temperature level. Then for normal operation of the equipment during the day, the switch **43** may be returned to a normal position as shown, and at night time, for example, the switch **43** may be adjusted to shift the connections for thermostatic regulation of the system at a sub-normal temperature level.

The fixed thermostat connection **42** may lead to a "break" contact as at **45** of a relay **46**, thence through a connection **47** to a "break" contact **48** of a relay **49**, thence to a source of power **50** to the magnet of relay **31**, connection **39**, to the lower mercury column contact **38**, through the mercury column **33** to the selected contact, for example *d'*, through the contacts *d'* and *d* of switch **43**, back to contact *d* of the thermostat.

The purposes of relays **46** and **49** will be explained hereinafter.

When a typical circuit as above traced, is in the condition as shown in Fig. 1, the valve control relay **31** will cause the valve motor **27** to operate in a direction for moving the valve toward closed position. After the valve has been partially closed, however, there will be a resulting drop in pressure in the steam main **14** as compared with the return main pressure, with the result that the mercury will rise in the reservoir **34**, with a consequent lowering of the mercury column at **33**. However, as soon as the mercury column thus falls sufficiently to interrupt a circuit connection with the thermostat, the relay **31** will be de-energized whereby the valve motor will reverse and then move the valve **17** toward open position. This will cause the pressure to be increased again in the steam main **14** as compared with the pressure in the return main, and the position of the mercury column will be restored or partially restored, depending upon the temperature conditions.

In order that a circuit may be completed through thermostat **40**, notwithstanding the movement of the contact wheel **43** from time to time, from one contact as at *a* to *t*, to another, this wheel may preferably be made of such dimensions as to continue in contact with one of these contacts until it is firmly in engagement with the next adjacent contact. Accordingly a circuit may sometimes be completed through two of the thermostat contacts, with a consequent energization of two of the mercury column contacts, as for example *c'* and *d'*. This, however, will not interfere with the proper operation of the equipment since at such times the relay **31** will be controlled by the lowermost of the two contacts energized.

The relay **49** is for the purpose of periodically interrupting the above described circuits during intervals of predetermined length whereby during such intervals the valve **17** may be promptly moved either nearly or completely to its closed position. The relay **49** may be controlled by a cam **51** rotated at constant but adjustable speed as by motor or clock works **52**. This cam may be provided with raised portions as at **53** and **53'** for periodically engaging a contact **54** for closing a circuit through the magnet of relay **49** through a source of power **55**. When the relay **49** is thus operated, the circuit of the thermostat is interrupted at the "break" contact **48** and instead, a circuit is completed from source of power **50** through a "make" contact **56**, connection **57**, to a contact **58** at the mercury column. The contact **58** is positioned at an elevation for engaging the mercury column at a lower level than all or most of the contacts *a'* to *t'*. Accordingly, when the relay **49** is energized, a circuit will be formed through the mercury column which may control the valve motor **27** in a manner similar to its control by the contacts *a'* to *t'* except that the motor will maintain the valve **17** either fully closed or near its closed position.

The relay **46** is for the purpose of interrupting the control by the thermostat during a short interval by substituting another control circuit for maintaining the valve **17** in fully open or nearly its open condition for a short period, so that an abnormally high pressure of steam will be admitted to the piping for assisting in dislodging any troublesome bodies of condensate and forcing the same into positions where they will be fully drained out of the piping. The relay **46** may be controlled by a cam **60** also rotated by the motor or clock works **52** and having a raised portion **61** for periodically engaging a contact **62** during short periods interspaced, for example, with the operation of relay **49**. The operating circuit for the magnet of relay **46** may include the source of power **55** connected as shown to the cam shaft. When the relay **46** is energized, the thermostat circuit is interrupted at "break" contact **45** and instead, a circuit is established from relay **31**, through source of power **50**, "break" contact **48**, connection **47**, "make" contact **63** of relay **46**, connection **64** to a mercury column contact **65**, through the mercury column to contact **38**, connection **39**, back to the relay **31**. As soon as the thermostat circuit is thus interrupted, the connections to motor **27** will be such that the valve **17** is moved toward open position and such movement will continue until the mercury column rises to contact **65**. But by this time the valve **17** will be open or substantially fully open and thereafter so long as relay **46** is energized, the valve **17** will be maintained in such open condition.

The thermostat connection **42** may be extended as at **42'** to a contact **65'** located near the top of the mercury column tube. This contact and connection is for the purpose of establishing a circuit for relay **31** to cause the valve **17** to be moved to closed position whenever for any reason

the pressure in the steam main may be such as to cause the mercury column to extend up to an abnormally high point. That is, in case for example, the steam main pressure should be so high in respect to the return main pressure that there might be danger of abnormally displacing the mercury column, then the connection 42' will permit the top of the mercury column to cooperate with the contact 65' in so regulating the valve as to prevent any substantial further increases in steam pressure.

When the prevailing temperature at the thermostat 40 rises for example, to in the neighborhood of 70°, at which point the system will not require any normal steam supply, the contact 43 may engage a contact *x*, which contact may be connected as shown to connection 39 for establishing a circuit independently of the mercury column, for causing the valve 17 to be normally moved to its closed position.

If the weather is very moderate, as for example during the spring and fall seasons, difficulty may be encountered in some cases in securing satisfactory regulation of the small supply of steam required, and in properly distributing the steam during each "on" period, if an attempt is made to supply the steam for such moderate conditions, at relatively low pressure. However, with the systems here disclosed, an additional arrangement is available for satisfactorily overcoming this difficulty by providing "on" periods of steam flow at regulated pressure, but with such periods occupying a substantially smaller proportion of the elapsed time. Then the steam may be admitted during the "on" periods at a higher pressure sufficient to permit of its accurate measurement and accurate distribution by the system. Yet the relative duration of the "on" periods is diminished so that the over-all quantity of the steam supplied to the system will not be in excess of the requirements. When the attendant notes that the temperature conditions are such that the mercury column is cooperating with one of the lower contacts as at *a'* to *d'*, for example, he may shift the position of switch 43 so as to cause the mercury column to rise somewhat and perform its regulating operations in cooperation with contacts near the mid-portion of the mercury column tube. At the same time he may open a switch as at 66 for disconnecting the relays 46 and 49 from operation, and then close a switch 69 for bringing into operation a circuit including a cam 67, contact 68, magnet of relay 31, and source of power 50. The cam 67 may, if desired, be rotated by the motor or clock works 52. This cam may, for example, be shaped so as to engage the contact 68 during only one-half of each revolution. As a result, relay 31 will be intermittently energized during at least one-half of the elapsed time, and hence move the valve 17 to closed position or nearly closed position, and maintain it in such position during a corresponding part of the elapsed time. During the intervening "on" periods of steam flow, the pressure of the steam will be regulated by the thermostat cooperating with a group of mercury column contacts, such for example as contacts *k'*, *l'*, *m'*, and this regulation will be free of interruption by the relays 46 and 49. This operation of the system may be continued so long as the moderate temperature conditions persist, and with the result that during each "on" period, although such periods will not occupy such a large portion of the elapsed time as with the normal operation, yet the steam will be supplied at an adequate pressure to insure its proper distribution during each period through the various radiator orifices of the system.

Summary of circuit operation.—The thermostat 40 will serve to select and prepare a circuit through one of its contacts *a* to *t*, depending upon the prevailing temperature. Thus one of the mercury column contacts *a'* to *t'* will be selected for operation, although the relationship of the thermostat and mercury column contacts may be arbitrarily shifted by the attendant through adjustments of the switch 43. The attendant may, for example, operate the switch 43 in accordance with a predetermined daily time schedule arranged for sub-normal heating at night, abnormal heating for quickly bringing the temperature of the spaces heated up to normal in the morning, and with normal heating during the day time. Also various conditions of wind and sunlight affecting the spaces heated, may make it desirable for him to shift the switch 43 from time to time. As a result of the selection of one of the contacts *a'* to *t'*, the main steam valve stem will be moved back and forth slightly, alternately toward its closed and open positions so as to maintain a difference of pressure in the steam and return mains such as will maintain the top of the mercury column 33 at or adjacent the selected contact. This thermostatically controlled pressure regulating action, however, will be periodically interrupted during fixed "off" intervals of steam flow, under the control of cam 51, the steam supply being either cut off during such intervals or being so regulated as to provide only a very small quantity of steam to the system. During such "off" intervals, the top of the mercury column will remain at or adjacent the contact 58. Also, if desired, the thermostatic regulation may be interrupted by periods of relatively high pressure steam supply during which the main steam valve is maintained in open or substantially fully open condition, under control of cam 60, while the top of the mercury column 33 remains at or adjacent contact 65. During the periods when relays 46 and 49 are not energized, the steam may be supplied at a normally regulated pressure, depending upon prevailing weather conditions and controlled by the thermostat through the cooperation of the mercury column with a selected one of the contacts *a'* to *t'*.

And as above explained, if difficulty is encountered in obtaining proper distribution of steam in the system during moderate weather, the attendant may adjust the switch 43 for bringing the mercury column up to a mid position, and open the switch 66 for disconnecting relays 46 and 49 from operation, and close the switch 69 for bringing the cam 67 into operation, so that the aggregate duration of the "on" periods will be relatively diminished while the regulated pressure during each "on" period will be at an increased level insuring proper steam distribution.

Various details of construction of a preferred form of thermostat 40 are disclosed in my copending application above referred to. If desired, the system as shown in Fig. 1 may be adapted for the control of a plurality of main steam valves operating respectively to control the flow of steam for a plurality of heating zones supplied from a common source.

The details of construction of a preferred form of U-tube arrangement for containing the mercury column will now be described in connection with Fig. 3. The steam main pressure con-

nection 35 is shown communicating with the small reservoir 34. This reservoir may be formed in a casting having two or more plugged openings as at 70 and 71 through which access may be had to its interior. This casting may be integrally formed with an extension arm 72. The various mercury column contacts 38, 58, 65, 65' and contacts *a'* to *t'* may be mounted in a tube 73 having a bore of small cross section for containing the part of the mercury column which cooperates with the various contacts. This tube may be formed of any suitable insulation material, preferably of transparent or semi-transparent composition such as will enable an observer to watch the variations in position of the mercury column. Suitable well-known phenol-formaldehyde condensation products may be used for the material of this tube. The lower end of the tube may be formed for threaded engagement with a flange 74 and the upper end of the tube may similarly be formed for threaded engagement with a flange 75, these flanges being cemented or otherwise sealed in respect to the tube. The assembly of the tube with its flanges may be bolted at its lower end as at 76 to the arm 72, and the upper flange may be similarly bolted to a member 77 at the top of the device. The member 77 may have a passage 78 communicating with the pressure connection 37 running to the return main of the heating system. The connection 37 may be continued downward as at 79 past the point of communication with the device in order to provide a pocket for dirt and any small amounts of condensate which may accumulate in the connection 37. This pocket may be opened and emptied from time to time. A conduit 80 forming the bottom of the U-tube may extend from the small reservoir 34 into the base of the flange 74 as shown.

The various contacts mounted in the tube 73 may be constructed as indicated in Fig. 4, and each may comprise a pin as at 81 formed, for example, of stainless steel and provided with an area as at 82 for threaded engagement with the insulation tube 73 and having a small contact portion as at 83 protruding within the bore of the tube for engagement with the mercury. The threaded area 82 may be sealed within the tube by cement. Suitable circuit wire connecting means may be provided as at 84.

The flange 74 may be provided with a cavity as at 85 (Fig. 5) for bringing the conduit 80 and the bore of the tube 73 into communication. The mercury may be introduced into the U-tube, for example, through the plugged opening 71 or a similar plugged opening at 86 in the member 77. A quantity of mercury may thus be introduced in excess of that which will be required when the system is assembled and adjusted. Then this excess of mercury may be drawn off through a small opening as at 87 in the flange 74. The opening 87 may be controlled by a drain plug 88 having threaded engagement with an integral extension on the flange member 74, and having its inner end finely pointed to form a valve-like member cooperating with the outlet of the opening 87. With this arrangement small quantities of the mercury may be gradually drawn off until the mercury column is brought accurately to the desired height.

A valve seat 90 may be formed at the bottom of the small reservoir 34 at the point where this reservoir communicates with the conduit 80. A steel ball 91 comprising a valve member may be introduced into the reservoir 34 and this ball will normally float in the mercury as shown. However, if the space within the reservoir should be subjected for any reason to an abnormally high pressure such as to force all of the mercury out of the reservoir, then the ball 91 will fall to the valve seat 90, as shown in dotted lines, and thus close off the U-tube against access of such excess pressure thereto. Accordingly any such abnormal or relatively high pressures will be prevented from forcing the mercury out of the U-tube into the connection 37. Thus, if for example the main steam valve 17 should become inoperative at a time when it is in open condition and subjected to a relatively high pressure, the mercury in the U-tube will be protected against any excessive abnormal displacement.

If desired, a quantity of oil may be introduced into the tube 73 and into the cavity within member 77, above the mercury column for aiding in the suppression of arcs at the contacts. The cavity in the member 77 may serve as a reservoir for receiving variable amounts of this oil, depending upon the position of the mercury column. The space within the pressure connections 35 and 37 and within the member 77 above the oil, may be filled with air or steam and some water.

Reference will now be had to the embodiment of the invention schematically illustrated in Fig. 2 in connection with a "one-pipe" steam heating system. In this system the valve 17 may be provided with the same type of motor and circuit connections and controlling means as above described in connection with Fig. 1. A mercury U-tube 32 may also be provided in the same manner as in Fig. 1, except that its upper end 36 may communicate directly with the atmosphere and its pressure connection 35 may be applied to the "one-pipe" steam main 92. The system may be provided with a plurality of radiators as at 10, connected to the steam main 92 by risers 93 and 94. Orifice means 95 may be provided in each of the radiator connections preferably at or adjacent the radiator inlets. Each of the radiators may be provided with air valves as at 96.

In the systems of both Figs. 1 and 2, such condensate as collects in the steam mains may be withdrawn through a suitable drip connection as at 97, from which such condensate may pass out through a steam trap as at 98 and thence to means for its disposal either in sewers or by apparatus returning the water to the steam generator. With the "two-pipe" system of Fig. 1, the condensate from the trap 98 may be conducted to the return main 25 as indicated.

In Fig. 2 the steam main 92 is shown with a sagging portion 99 to illustrate a condition which may be encountered in some existing piping installations of inferior design and from which the condensate will not ordinarily properly drain away to afford opportunity for the proper proportional distribution of steam through the various radiator orifices during each of the spaced "on" periods of regulated steam flow to the system. That is, accumulations of condensate may occur as indicated in dotted lines at 99, which would ordinarily tend to restrict the flow of steam and prevent a part of the system from receiving its intended quantity of heating medium. With the control system as above described, this difficulty may be promptly eliminated. That is, through the action of the cam 60, relay 46 and its associated circuit connections (Fig. 1), the steam valve 17 is periodically opened sufficiently

to supply steam to the steam main at a relatively high pressure so as to dislodge the body of condensate at 99 and cause it to flow out through the drip connection whereby during the succeeding "on" interval, the steam at the desired normal or thermostatically regulated pressure will be distributed to various parts of the system in the proper manner. Also, if various of the radiator connections as at 100 should be installed at an improper or insufficient angle to permit satisfactory draining away of the condensate, then with the method above described, the periodic supplies of steam at relatively high pressures will serve to substantially clear such connections as at 100 of condensate, so that steam during the succeeding "on" interval is properly distributed. Similarly, difficulties with piping at improper angles of inclination in "two-pipe" systems may be readily overcome.

The number of contacts such as at *a* to *t* on the thermostat 40 and the corresponding number of mercury column contacts *a'* to *t'*, may of course be varied, depending upon the range of temperatures over which the system is designed to operate and the accuracy with which it is desired to have the system respond to slight temperature changes. If the contacts *a* to *t* on the thermostat 40 are uniformly spaced and if it is desired to have the system operate to vary the flow of steam to the various radiators directly in proportion to the temperature changes, then the contacts *a'* to *t'* at the mercury column should be arranged with the contacts nearest the bottom, quite closely spaced and the higher contacts more and more widely spaced. That is, the height of each mercury column contact (as at *a'* to *t'*) above the contact corresponding to 70°, should preferably be substantially directly proportional to the square of the difference between 70° and the temperature corresponding to the contact at such height. This rule is due to the fact that the quantity of the steam flowing through the fixed orifices will vary substantially as the square root of the pressure difference at opposite sides of the orifice.

The purpose of the by-pass 19 as shown in both of the systems of Figs. 1 and 2, is to supply a small amount of steam to the conduits of the system during intervals when the valve 17 is closed or substantially closed. That is, the orifice 21 of this by-pass may have an aperture of a predetermined size just sufficient to admit enough steam to keep the steam connections to the radiators substantially heated during the "off" intervals, but without causing any substantial amount of steam to pass through the radiator inlet orifices during such "off" intervals. The valve 20 enables the attendant to shut off the steam entirely through the by-pass when the system is not in operation, or this valve may be used in connection with the orifice 21 in adjusting the flow of steam through the by-pass to the required amount. In some cases it may be advisable to restrict the flow of steam through the by-pass to such an extent that during the greater part of the "off" intervals there will be a slight vacuum within the conduit system, particularly with a "one-pipe" system as of Fig. 2. As hereinafter explained in further detail, this will aid in the withdrawal of the accumulated condensate from the radiators during such intervals.

With the conduits thus kept filled or partially filled with steam during the "off" intervals, upon the beginning of each "on" period, an effective flow of steam will promptly start through all of the radiator inlet orifices at substantially the same time. Thus from the beginning of each of said "on" periods, steam is supplied through the restricting orifices to the various radiators respectively in amounts bearing substantially the same proportional relationship for each radiator, to its heating capacity. With some buildings with an unusually large amount of pipe surface, the use of the by-pass is preferable, although in some installations substantially the above results may be obtained without its use.

The intervals or periods of operation for a typical system, may for example be arranged as follows. Steam may be admitted to the system for a period of six minutes at a pressure regulated by the valve 17 as controlled by the thermostat and mercury column. Then the steam may be shut off for an interval of one minute through the action of the raised area 53 of cam 51. This interval may be immediately followed by a two minute period of steam supply at an abnormally high pressure obtained by fully or nearly fully opening the valve 17 under the control of the raised area 61 of cam 60. Then for a period of five or six minutes the steam may be again supplied at the normally regulated pressure, such period being followed by an "off" interval of one minute as controlled by the raised area 53' of cam 51, thus completing one cycle of operation. Such cycles may be repeated in succession. However, as above explained and if the weather is moderate, it may be preferable to intermittently supply the steam at regulated pressures higher than those which would occur with the above described cycle and to increase the portion of elapsed time devoted to "off" intervals, and in that event the cams 51 and 60 may be thrown out of circuit, and the circuit of cam 67 placed in operation, for maintaining the valve 17 in its closed position during intervals which occupy, for example, at least one-half of the elapsed time, and with the intervening "on" periods of steam supply at a higher regulated pressure.

The pressure of the steam supplied during the periods of abnormally high pressure supply, may be determined by the position of the mercury column contact 65. While this contact is shown in a position above the contact *t'*, with some installations it may be found merely necessary to place this contact just above the contacts which regulate the heating at medium temperatures.

The relative lengths of the above described intervals or periods and their relationship, may be altered by changing the positions and extent of the raised portions of the several cams. The frequency of the cycles of operation may be adjusted by adjusting the speed of rotation of the motor or clock works 52. For satisfactory operation of "one-pipe" systems, the equipment should preferably be so adjusted that during each cycle an "off" interval of at least a predetermined length will occur, sufficient to allow the greater part of the condensate accumulated in the radiators during the previous normal "on" period to drain out of the radiators through the restricting inlet orifices and through the risers, even when the system is subjected to its most severe heating requirements. In "two-pipe" installations of average type and size, such a predetermined minimum "off" interval in the neighborhood of one minute may be necessary to drain water from small piping when water is required to flow counter to the direction of steam flow.

The manner in which the steam is distributed to the radiators and the condensate is returned,

will now be briefly explained. If the installation is a "one-pipe" system where the radiators are provided with air valves or air line valves, then air will be expelled from the radiators during each "on" period of steam flow. If air valves are used, they may preferably be of a thermostatically operating type designed to promptly close when the radiators are heated to a point where the steam reaches the valves. However, when the heating requirements of the system are moderate or substantially less than maximum as is the case during the larger part of the time with most heating systems, the radiators will be only partially heated with steam during each of the "on" periods, yet each radiator respectively will be filled to substantially the same proportion of its maximum capacity during each of such periods.

At the beginning of each "off" interval, the condensation of steam in the radiators will soon tend to create a slight vacuum therein, but the air valves if not already open, will soon open, and permit substantial quantities of air to be drawn into each radiator and this air will aid in expelling the accumulated condensate from the radiator through the restricted inlet orifice, unhampered by any incoming steam. This action will, as above indicated, be further aided if the conduits are maintained at a slight vacuum during the greater part of the "off" interval. Thus all or the greater part of the condensate accumulated in the radiators during the previous "on" period may be very quickly withdrawn, and in fact substantially forced back into the conduit system quite promptly, notwithstanding the orifice restrictions. Thus the orifices at the various radiators may be used to full advantage in distributing the periodic supplies of steam in proper proportions to various parts of the system unhampered by any substantial accumulations of condensate, yet at the end of each "on" period the resulting small accumulations of condensate are promptly expelled unhampered by any countercurrent flow of steam. Instead, the removal of the condensate is in fact aided by the vacuum conditions resulting from condensation of steam of the previous period. Then if necessary or desired, some of the "off" intervals may be followed by the short period of steam supply at abnormally high pressure, which will force any remaining condensate from improperly designed portions of the piping where it might restrict the subsequent flow of steam, back into the radiators or to other points where it will not interfere with the proper steam distribution through the orifices during the subsequent "on" period. Since the quantity of steam admitted to the steam main during each "on" interval is accurately controlled by the thermostatic regulation of the main valve, the use of the orifices in the above described manner will insure also that the quantity of steam admitted during each "on" period to each part of the system will be accurately controlled, particularly as a result of the fact that at the beginning of and during each "on" interval the steam is distributed in the desired proportions without delay through each radiator inlet orifice without any irregular or unintended obstruction by the condensate.

With "two-pipe" systems the various radiators will be heated or partially heated in the same proportion for each radiator to its normal capacity. In the case of partial heating while the radiator outlet steam traps remain open, the condensate is free to flow out through the return piping, aided if desired by any vacuum maintained in the return main. Or if as in coldest weather, the radiators are filled and the outlet traps closed during each period, then during the succeeding "off" interval the radiator outlet traps will have opportunity to open and permit the condensate to be withdrawn to the return main. During the "on" periods the concentration of the flow of steam into spaced periods, insures that during such periods even in moderate weather, a sufficiently decisive flow of steam will occur to enable its accurately proportioned distribution through the various radiator orifices. With the "two-pipe" systems the frequent periods of steam supply at abnormally high pressure will serve to remove restricting accumulations of condensate both from the steam and return piping.

The use of the system with short fixed "off" periods is particularly adaptable for relatively small installations where the use of any very prolonged "off" interval with interspaced "on" periods might interfere with economical operation of the steam generating means. That is, since with this system the "off" interval may remain fixed and of a preferred minimum duration, the system will consume steam from the boiler more uniformly and return the condensate to the boiler more uniformly than would be the case if the quantity of steam flowing to the system were regulated by varying the length of the periods or intervals. Since, with the system above described, the quantity of steam supplied is regulated by varying the pressure during the "on" periods, the duration of the "off" intervals may be kept relatively short and may normally remain fixed after it has been determined how long a time should be provided for the proper return flow of the condensate. The possibility of using such relatively short "off" intervals, renders the above described system also particularly applicable for installations where the radiators are of a type made of sheet metal or are of other light weight construction which would not retain any substantial amount of heat during prolonged "off" intervals.

As above indicated, this system is particularly adaptable to remedying the difficulties of securing proper measured distribution of steam in "one-pipe" systems. The difficulties of "one-pipe" systems have largely arisen from the fact that a single pipe is used both to convey the steam to the heating units and to convey the condensate back to a point of disposal. Thus the steam was required to travel countercurrent to the condensate, with the consequence that even upon resort to the expense of oversized piping or relatively higher pressures, the condensate did not freely return and great difficulties also were experienced in supplying steam to the various radiating units in the desired proportions. Any attempt to distribute the steam in proper proportion to the various radiators by the use of normally fixed orifices in "one-pipe" systems of the usual type, would still more seriously interfere with the countercurrent travel of the steam and condensate.

However, with the above described method and apparatus, these difficulties may be readily overcome with a consequent large saving in making possible the use of "one-pipe" systems where "two-pipe" systems have heretofore been considered necessary and in the case of existing unsatisfactory installations, the features of the invention above described may be quickly applied at relatively small expense. Often it is merely necessary to install and adjust the pressure regu-

lating valve and its associated control apparatus and by-pass, and to install the properly proportioned orifice members at the radiator inlets. The resulting controlled supply and distribution of steam enables very substantial savings in expense for steam while providing fully satisfactory and uniform heating in lieu of the almost universally unsatisfactory heating conditions with the usual large "one-pipe" installation and the unsatisfactory heating conditions arising from improperly designed "two-pipe" systems.

While the invention has been described with respect to certain particular preferred examples which give satisfactory results, it will be understood by those skilled in the art, after understanding the invention, that various changes and modifications may be made without departing from the spirit and scope of the invention, and it is intended, therefore, in the appended claims to cover all such changes and modifications.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. In a heating system comprising a plurality of radiators, a steam supply main and a return main therefor, a valve in said supply main, a reversible electrical motor for moving said valve in directions to either open or close the same, connections to said motor for normally energizing the same to move the valve in one direction, circuit controlling means comprising a column of mercury, a plurality of contacts respectively for cooperating with said mercury column when at various different heights, pressure connections to said supply and return mains respectively for regulating the height of said mercury column substantially in accordance with the difference in pressure in said mains, and electrical circuits for said contacts respectively operative in response to variations in the height of said mercury column, for reversing the operation of said motor to move the valve in the other direction.

2. In a heating system comprising a plurality of radiators, a steam supply main and a return main therefor, a valve in said supply main, a reversible electrical motor for moving said valve in directions to either open or close the same, connections to said motor for normally energizing the same to move the valve in one direction, movable circuit controlling means, pressure connections to said supply and return mains respectively for regulating the position of said circuit controlling means substantially in accordance with the difference in pressure in said mains, electrical connections operative in response to variations in position of said circuit controlling means, for reversing the operation of said motor to move the valve in the other direction, and means for intermittently checking the steam supply through said main during relatively short intervals, the proportion of elapsed time occupied by said intervals being normally substantially fixed and the periods between said intervals being of sufficient frequency to enable substantially continuous maintenance of predetermined temperatures in the spaces heated by the radiators.

3. In a heating system comprising a plurality of radiators, a steam supply main and a return main therefor, a valve in said supply main, a reversible electrical motor for moving said valve in directions to either open or close the same, connections to said motor for normally energizing the same to move the valve in one direction, movable circuit controlling means, pressure connections to said supply and return mains respectively for regulating the position of said circuit controlling means substantially in accordance with the difference in pressure in said mains, electrical connections operative in response to variations in position of said circuit controlling means, for reversing the operation of said motor to move the valve in the other direction, and means for supplying steam to said main during short spaced intervals, at a pressure substantially higher than the normal pressure of steam flowing therethrough, to aid in dislodging accumulated condensate from the conduits of the heating system.

4. In a heating system comprising a plurality of radiators, a steam supply main and a return main therefor, a valve in said supply main, a reversible electrical motor for moving said valve in directions to either open or close the same, connections to said motor for normally energizing the same to move the valve in one direction, movable circuit controlling means, pressure connections to said supply and return mains respectively for regulating the position of said circuit controlling means substantially in accordance with the difference in pressure in said mains, a plurality of electrical circuits respectively operative in response to different positions of said circuit controlling means, for reversing the operation of said motor to move the valve in the other direction, and thermostatic means for selecting one of said circuits for operation.

5. In a heating system comprising a plurality of radiators, a steam supply main and a return main therefor, a valve in said supply main, a reversible electrical motor for moving said valve in directions to either open or close the same, connections to said motor for normally energizing the same to move the valve in one direction, a mercury column, pressure connections from the ends of said column to said supply and return mains respectively for regulating the position of said column substantially in accordance with the difference in pressure in said mains, a plurality of electrical circuits controlled by contacts positioned to be energized respectively by contact with said mercury column in response to different positions of the latter, for reversing the operation of said motor to move the valve in the other direction, and thermostatic means for selecting one of said circuits for operation.

6. In a heating system, a steam supply main having a valve therein, a reversible electrical motor for moving said valve in directions to either open or close the same, connections to said motor for normally energizing the same to move the valve in one direction, a mercury column, a pressure connection from said column to said steam main for regulating the position of said column substantially in accordance with the pressure in said steam main, a plurality of electrical circuits controlled by contacts positioned to be energized respectively by contact with said mercury column in response to different positions of the latter, for reversing the operation of said motor to move the valve in the other direction, and thermostatic means for selecting one of said circuits for operation.

7. In a heating system, a steam supply main having a valve therein, a reversible electrical motor for moving said valve in directions to either open or close the same, connections to said motor for normally energizing the same to move the valve in one direction, a mercury col-

umn, a pressure connection from said column to said steam main for regulating the position of said column substantially in accordance with the pressure in said steam main, a plurality of electrical circuits controlled by contacts positioned to be energized respectively by contact with said mercury column in response to different positions of the latter, for reversing the operation of said motor to move the valve in the other direction, thermostatic means for selecting one of said circuits for operation, and means for intermittently checking the steam supply through said main during relatively short intervals, the proportion of elapsed time occupied by said intervals being normally substantially fixed and said intervals being of sufficient frequency to enable substantially continuous maintenance of predetermined temperatures in the spaces heated by the radiators.

8. In a heating system, a steam supply main having a valve therein, a reversible electrical motor for moving said valve in directions to either open or close the same, connections to said motor for normally energizing the same to move the valve in one direction, a mercury column, a pressure connection from said column to said steam main for regulating the position of said column substantially in accordance with the pressure in said steam main, a plurality of electrical circuits controlled by contacts positioned to be energized respectively by contact with said mercury column in response to different positions of the latter, for reversing the operation of said motor to move the valve in the other direction, thermostatic means for selecting one of said circuits for operation, and means for supplying steam to said main during short spaced intervals, at a pressure substantially higher than the normal pressure of steam flowing therethrough, to aid in dislodging accumulated condensate from the conduits of the heating system.

9. A method of providing measured distribution of steam in heating systems having a plurality of radiators with a common supply main, which comprises supplying steam through the supply main during each of a succession of relatively short spaced periods, the proportion of elapsed time occupied by said periods being normally substantially fixed, varying the pressure of the steam thus supplied upon changes in the prevailing temperature outside the spaces heated by the steam, whereby the quantity of heat supplied to the radiators is varied substantially in accordance with the system's heating requirements, and also supplying steam through the steam main during short separated intervals at a pressure substantially above the pressure normally supplied during said periods, to aid in the dislodging of accumulated condensate from the conduits of the system.

10. Method of providing a measured supply of steam to a heating system having a plurality of radiators connected to a supply main, which comprises supplying steam through the supply main during each of a succession of relatively short spaced periods, the proportion of elapsed time occupied by said periods being normally substantially fixed, varying the pressure of the steam supplied during said periods whereby the quantity of heat supplied to the radiators of the system is varied substantially in accordance with the system's heating requirements, and during relatively warm weather reducing by a predetermined amount the proportion of elapsed time occupied by said periods and continuing to vary the steam supply within a substantially higher range of pressures substantially in accordance with the system's heating requirements.

11. Apparatus for controlling the supply of steam to a heating system having a plurality of radiators connected to a source of steam supply, comprising time controlled means for admitting steam from the source to the system during each of a succession of relatively short spaced periods with the proportion of elapsed time occupied by said periods normally substantially fixed, means for altering said time controlled means to reduce by a predetermined amount the proportion of elapsed time occupied by said periods during warm weather, and means for regulating the pressure of the steam thus applied during each of said periods with either condition of said time controlled means, whereby the quantity of heat supplied to the radiators of the system is varied substantially in accordance with the system's heating requirements.

12. Apparatus for controlling the flow of steam in a heating system, comprising a mercury column, means for controlling the elevation of said mercury column by pressure conditions in the heating system, a plurality of electrical contacts each normally corresponding to a different prevailing temperature and so located as to successively make or break circuits upon the rise or fall of said mercury column, thermostatic means for selecting and preparing a circuit through one or another of said contacts depending upon the prevailing temperature to which said thermostatic means is subjected, electrically controlled valve means for controlling the flow of steam to the system, and circuits including said contacts and mercury column for so regulating said valve means as to provide pressure conditions in the system for maintaining the top of said mercury column at or adjacent the one of said contacts which is selected by the thermostatic means.

13. Apparatus for controlling the flow of steam in a heating system, comprising a mercury column, means for controlling the elevation of said mercury column by pressure conditions in the heating system, a plurality of electrical contacts each normally corresponding to a different prevailing temperature and so located as to successively make or break circuits upon the rise or fall of said mercury column, thermostatic means for selecting and preparing a circuit through one or another of said contacts depending upon the prevailing temperature to which said thermostatic means is subjected, electrically controlled valve means for controlling the flow of steam to the system, circuits including said contacts and mercury column for so regulating said valve means as to provide pressure conditions in the system for maintaining the top of said mercury column at or adjacent the one of said contacts which is selected by the thermostatic means, and means for supplying steam to the system during short spaced intervals, at an abnormal pressure to aid in dislodging accumulated condensate from the conduits of the heating system.

14. Apparatus for controlling the flow of steam in a heating system, comprising a mercury column, means for controlling the elevation of said mercury column by pressure conditions in the heating system, a plurality of electrical contacts each normally corresponding to a different prevailing temperature and so located as to successively make or break circuits upon the rise or fall of said mercury column, thermostatic means for selecting and preparing a circuit through one or

another of said contacts depending upon the prevailing temperature to which said thermostatic means is subjected, electrically controlled valve means for controlling the flow of steam to the system, circuits including said contacts and mercury column for so regulating said valve means as to provide pressure conditions in the system for maintaining the top of said mercury column at or adjacent the one of said contacts which is selected by the thermostatic means, and time controlled means for checking the flow of steam to the system during each of a succession of relatively short spaced periods with the proportion of elapsed time occupied by said periods normally substantially fixed.

15. In combination with a heating system having a plurality of radiators each connected to a source of steam supply through restricting orifices, apparatus for regulating the supply of steam to the system, comprising a mercury column, means for controlling the elevation of said mercury column by pressure conditions in the heating system, a plurality of electrical contacts each normally corresponding to a different prevailing temperature and so located as to successively make or break circuits upon the rise or fall of said mercury column, thermostatic means for selecting and preparing a circuit through one or another of said contacts depending upon the prevailing temperature to which said thermostatic means is subjected, electrically controlled valve means for controlling the flow of steam to the system, and circuits including said contacts and mercury column for so regulating said valve means as to provide pressure conditions in the system for maintaining the top of said mercury column at or adjacent the one of said contacts which is selected by the thermostatic means, said contacts being so spaced that their effective elevations respectively are substantially directly proportional to the square of the differences between the temperatures to which the contacts respectively correspond.

16. Apparatus for controlling the flow of steam, comprising an element movable in response to pressure variations applied thereto, means for controlling the position of said element in accordance with pressure conditions in the heating system, a plurality of electrical contacts each normally corresponding to a different prevailing temperature and so located as to successively make or break circuits upon movement of said element, thermostatic means for selecting and preparing a circuit through one or another of said contacts depending upon the prevailing temperature to which said thermostatic means is subjected, electrically controlled and variably adjustable valve means for controlling the flow of steam to the system, and circuits including said contacts and said element for so variably adjusting said valve means as to provide pressure conditions in the system for maintaining said element at or adjacent contacting position with that one of said contacts which is selected by the thermostatic means.

17. Apparatus for controlling the flow of steam, comprising an element movable in response to pressure variations applied thereto, means for controlling the position of said element in accordance with pressure conditions in the heating system, a plurality of electrical contacts each normally corresponding to a different prevailing temperature and so located as to successively make or break circuits upon movement of said element, thermostatic means for selecting and preparing a circuit through one or another of said contacts depending upon the prevailing temperature to which said thermostatic means is subjected, electrically controlled and variably adjustable valve means for controlling the flow of steam to the system, and circuits including said contacts and said element for so variably adjusting said valve means as to provide pressure conditions in the system for maintaining said element at or adjacent contacting position with that one of said contacts which is selected by the thermostatic means, said contacts and said element being so related in controlling said valve means, as to vary the flow of steam substantially directly in proportion to the temperature changes affecting said thermostatic means.

18. A method of providing measured distribution of steam in heating systems having a plurality of radiators with a common supply main, which comprises supplying steam through the supply main during each of a succession of relatively short spaced periods, varying the pressure of the steam thus supplied upon changes in prevailing temperature outside the spaces heated by the system whereby the quantity of heat supplied at said spaced periods is varied substantially in accordance with the system's heating requirements, and also supplying steam through the steam main during short separated intervals at a pressure substantially above the pressure normally supplied during said periods, to aid in the dislodging of accumulated condensate from the conduits of the system.

19. In a heating system, a steam supply main having a valve therein, a reversible electrical motor for moving said valve in directions to either open or close the same, connections to said motor for normally energizing the same to move the valve in one direction, a mercury column, a pressure connection from said column to said steam main for regulating the position of said column substantially in accordance with pressure variations in the steam heating system, electrical circuit means variably controlled by said mercury column in response to different positions of the latter, for reversing the operation of said motor to move the valve in the other direction, and thermostatic means further varying the control of said circuit means whereby the position at which said mercury column is effective in reversing the motor is controlled by the temperature affecting said thermostatic means.

20. Apparatus for controlling the flow of steam to a heating system, comprising an element movable in response to pressure variations applied thereto, means for controlling the position of said element in accordance with pressure conditions in the heating system, electrical circuit means having a series of portions each normally corresponding to a different prevailing temperature and so located as to be successively placed in circuit upon movement of said element, electrical thermostatic means for effectively selecting one or another of said portions depending upon the temperature affecting said thermostatic means, electrically controlled and variably adjustable valve means for controlling the flow of steam to the system, and means including the above mentioned circuit means and said portions thereof for so variably adjusting said valve means as to provide pressure conditions in the system for maintaining said element at or adjacent its position for placing in circuit that one of said portions which is effectively selected by the thermostatic means.

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