

Oct. 13, 1942.

R. D. JUNKINS ET AL

2,298,700

SUPERHEATER AND REHEAT CONTROL

Filed July 18, 1940

5 Sheets-Sheet 1

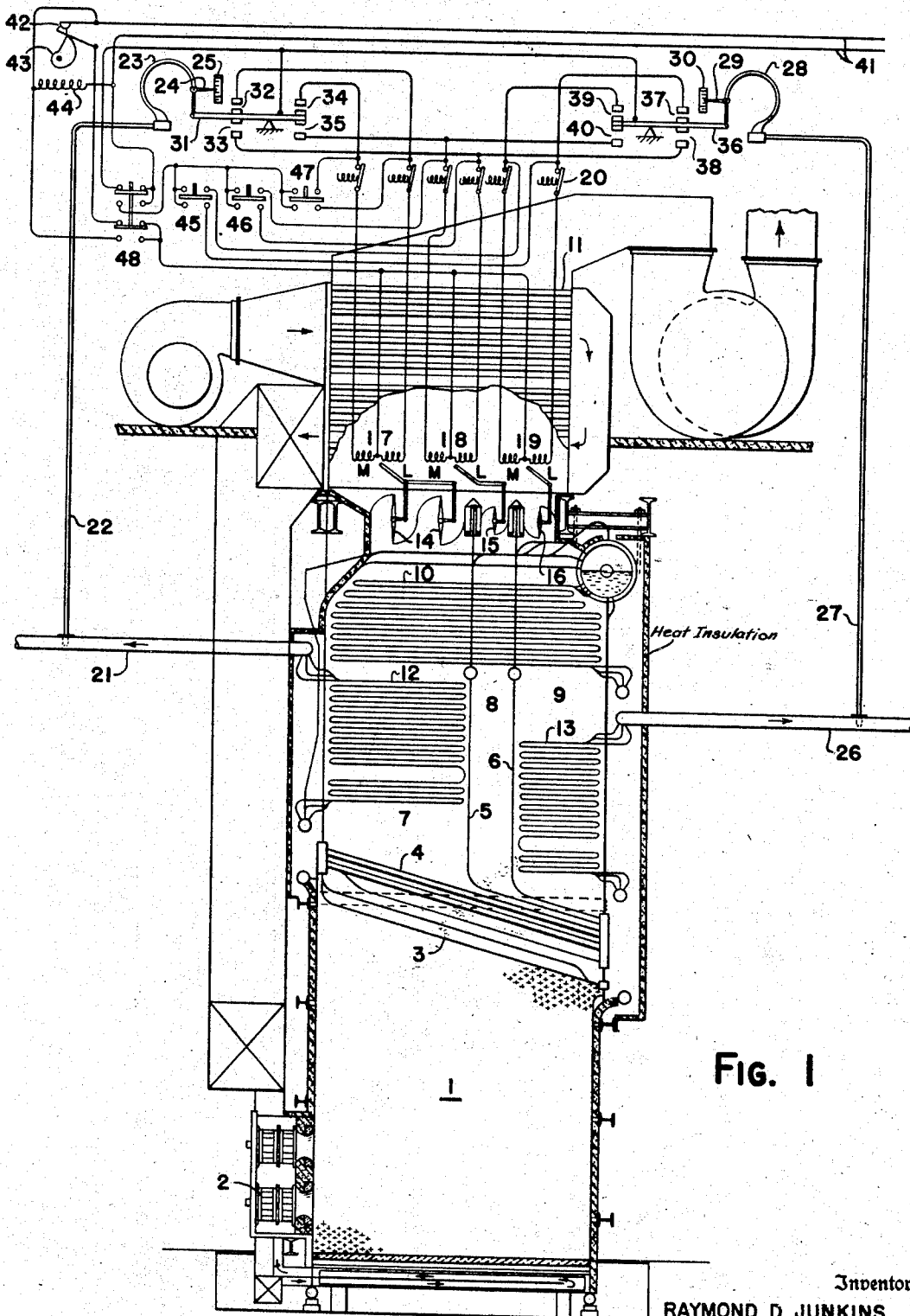


FIG. 1

Inventors

RAYMOND D. JUNKINS
THOMAS C. TOOMEY
CHARLES S. SMITH

AND

BY *Raymond D. Junkins*
ATTORNEY

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5 Sheets-Sheet 2

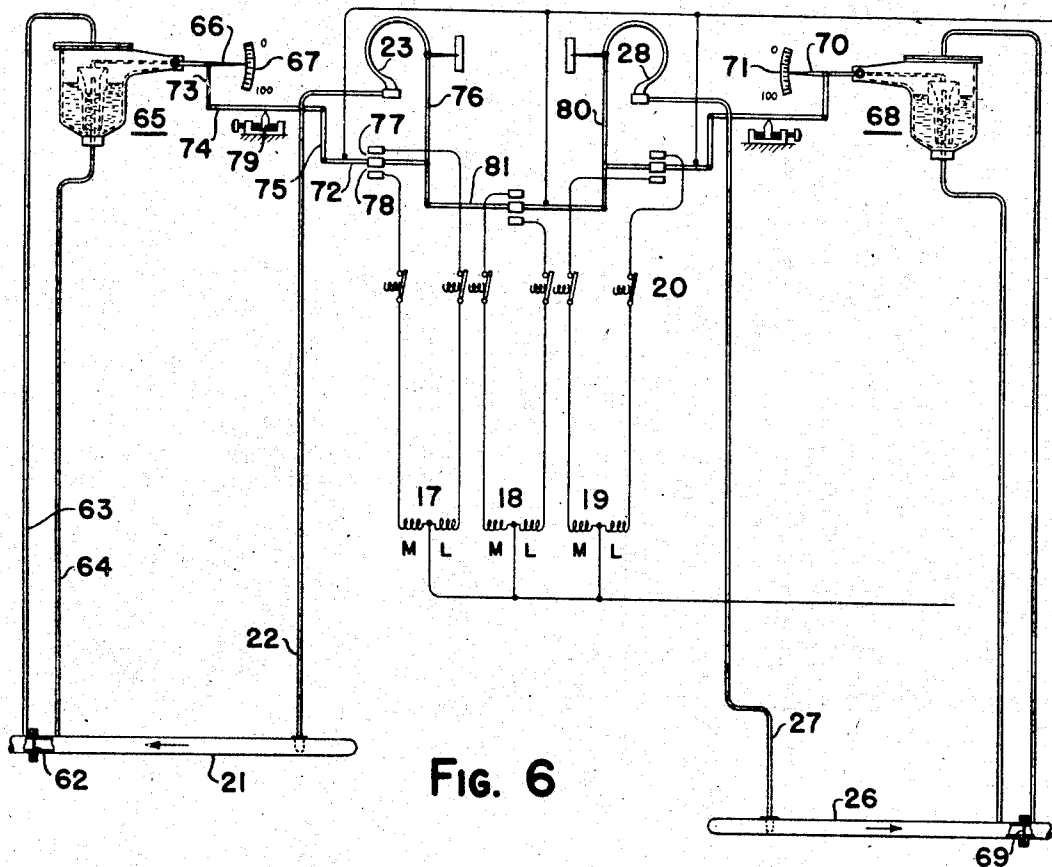


FIG. 6

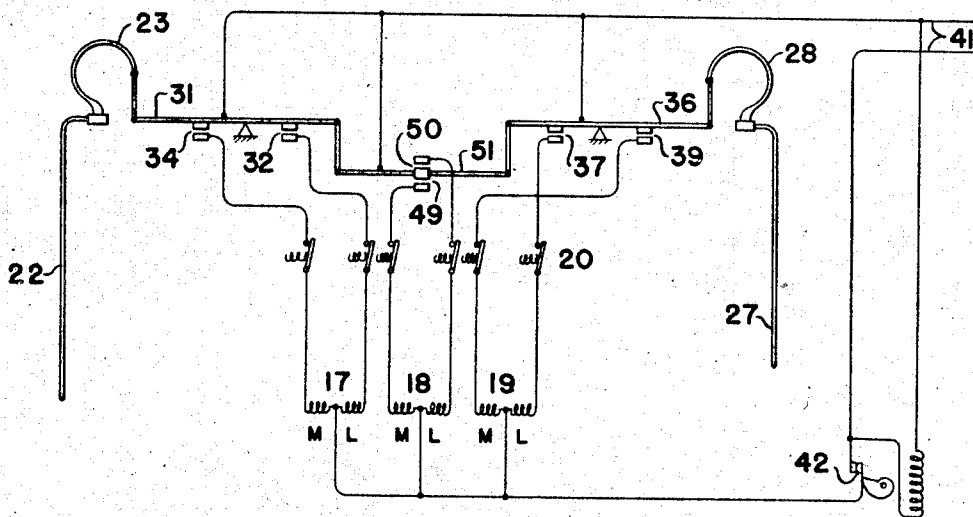


FIG. 2

Inventors
RAYMOND D. JUNKINS
AND THOMAS C. TOOMEY
CHARLES S. SMITH

BY *Raymond D. Junkins*
ATTORNEY

Oct. 13, 1942.

R. D. JUNKINS ET AL

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5 Sheets-Sheet 3

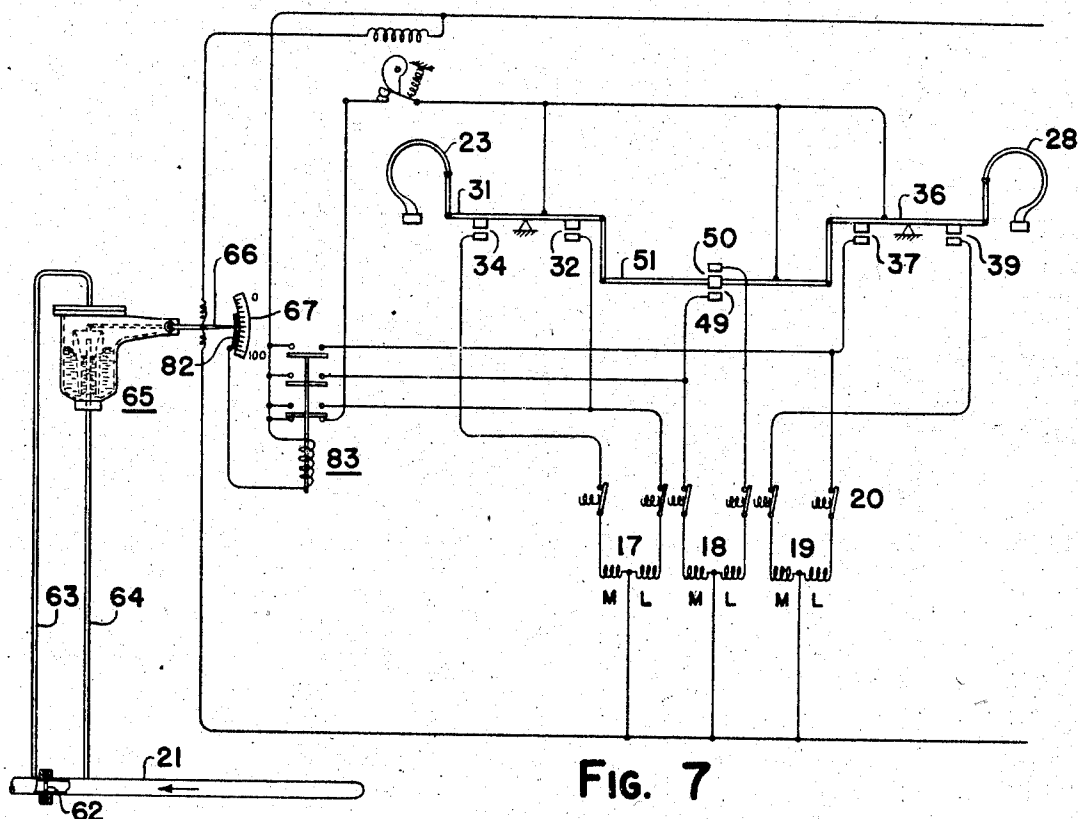


Fig. 7

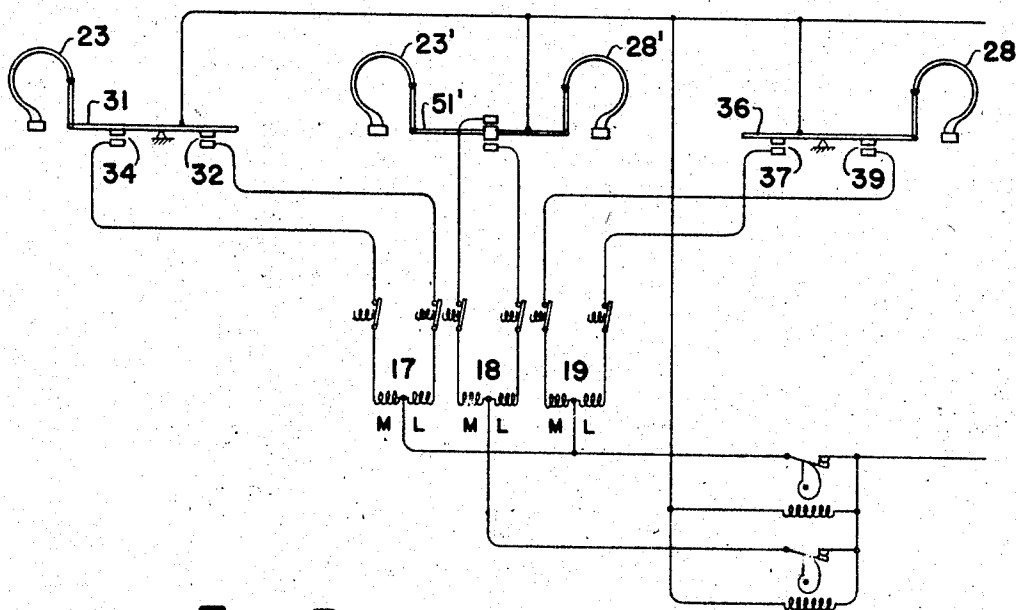


Fig. 3

Inventors
RAYMOND D. JUNKINS
AND THOMAS C. TOOMEY
CHARLES S. SMITH

BY *Raymond D. Junkins*
ATTORNEY

Oct. 13, 1942.

R. D. JUNKINS ET AL
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5 Sheets-Sheet 4

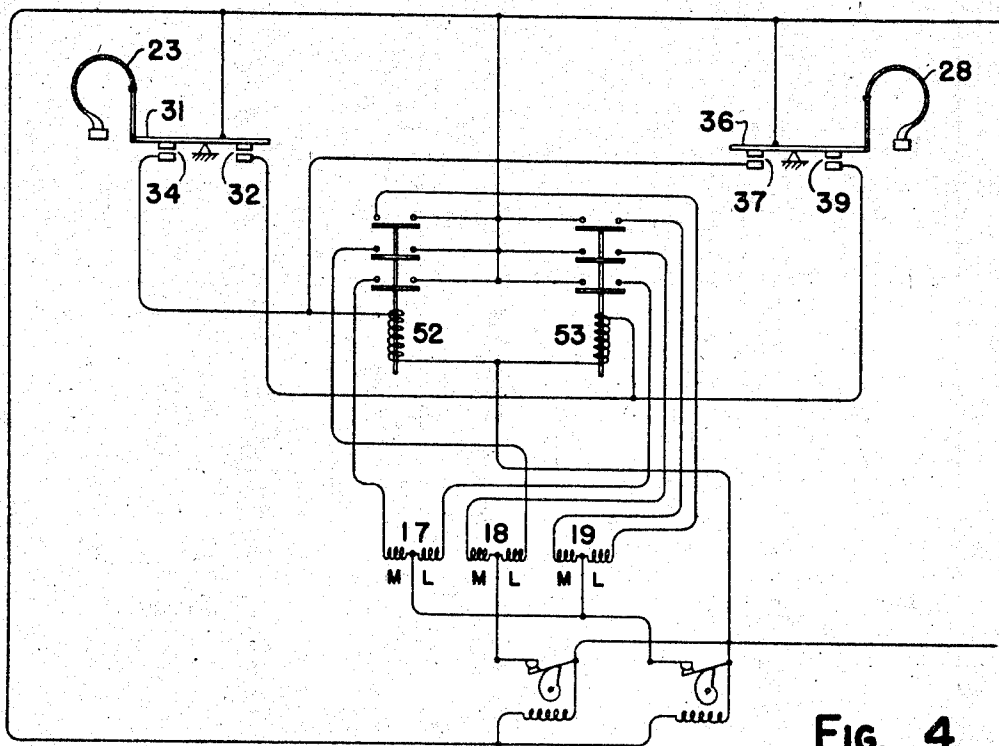


FIG. 4

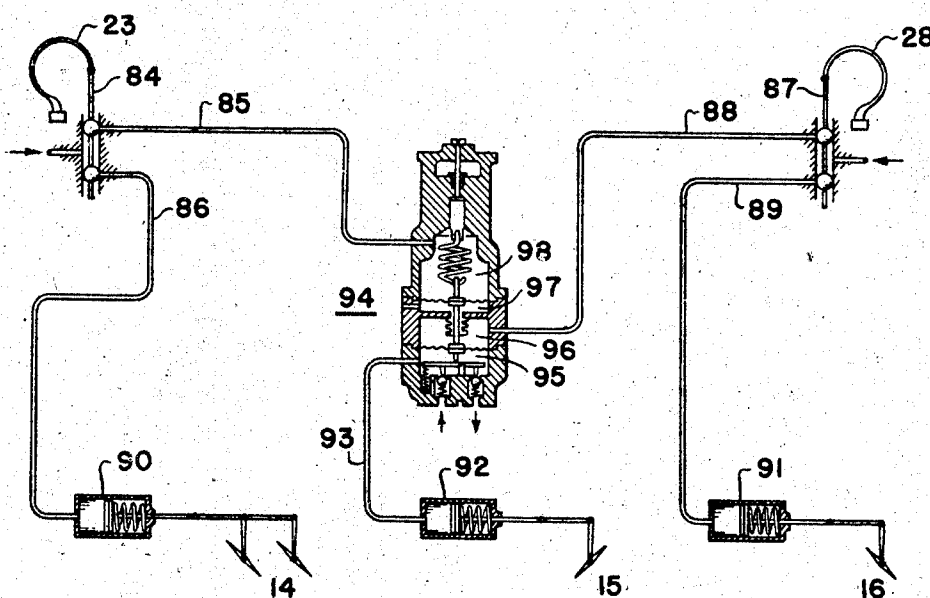


FIG. 8

Inventors
RAYMOND D. JUNKINS
THOMAS C. TOOMEY
AND
CHARLES S. SMITH

BY *Raymond D. Junkins*
ATTORNEY

Oct. 13, 1942.

R. D. JUNKINS ET AL

2,298,700

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5 Sheets-Sheet 5

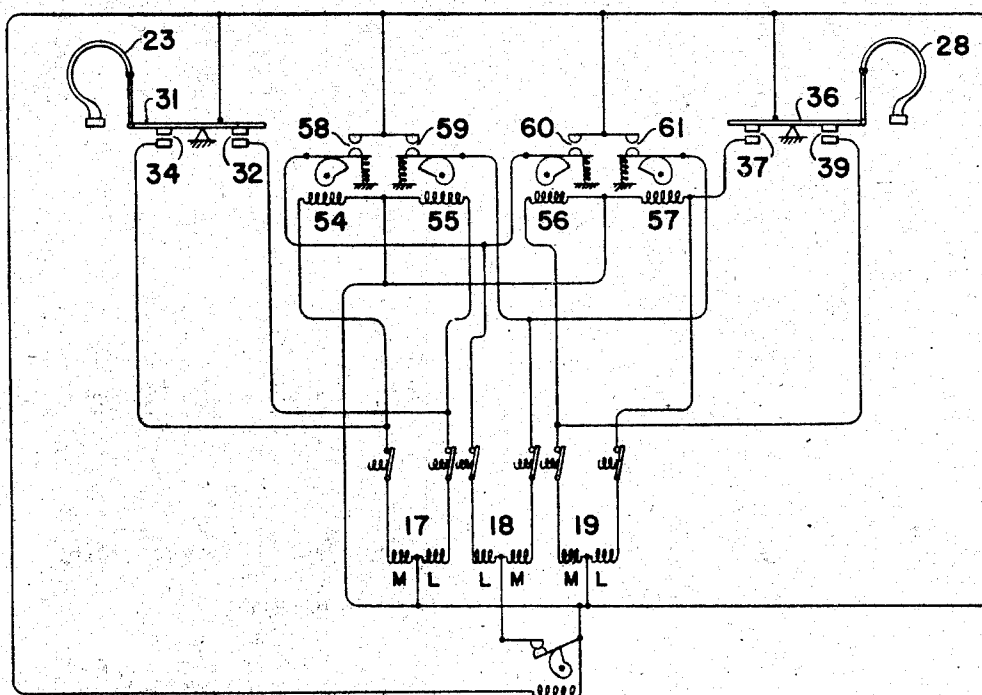


FIG. 5

Inventors
RAYMOND D. JUNKINS
THOMAS C. TOOMEY
AND
CHARLES S. SMITH

BY *Raymond D. Junkins*
ATTORNEY

UNITED STATES PATENT OFFICE

2,298,700

SUPERHEATER AND REHEAT CONTROL

Raymond D. Junkins, Cleveland Heights, Ohio,
Thomas C. Toomey, West New Brighton, N. Y.,
and Charles S. Smith, Westfield, N. J.; said
Junkins assignor to Bailey Meter Company, a
corporation of Delaware, and said Toomey and
Smith assignors to The Babcock & Wilcox
Company, Newark, N. J., a corporation of New
Jersey

Application July 18, 1940, Serial No. 346,120

5 Claims. (Cl. 122-480)

This invention relates to control systems and particularly to temperature control systems.

In steam power installations it is usual to superheat the steam above the temperature corresponding to its pressure. Superheated steam is used in practically all steam turbines, but in many turbine installations the steam is reheated between some of the expansion stages so that a reheater is employed as well as a superheater. This is particularly the case where high pressure turbines are used for it has not proven practical or economical to use high enough initial temperature to prevent excessive wetness of steam at the lower pressure end.

It is frequently desirable to have a unitary installation in which the steam generated and superheated by a single boiler furnace supplies a single turbine, and in which case the steam extracted from a preferred stage of the turbine may be reheated in a fluid path heated by the same furnace or by a separate furnace. For economic and operating reasons a single setting is most desirable. The arrangement in which our invention is particularly advantageous is one wherein the steam to be reheated is returned to the same furnace assembly, and in this case the control of the temperature of the superheat and of the reheat must be separately and collectively accurate and speedy.

A particular feature of our invention resides in the control of a vapor generating unit wherein three primary results are attained; namely, steam is generated, steam is superheated to desired degree, and steam is reheated to desired degree.

The rate of generation of steam, the temperature to which the steam is superheated, and the temperature to which steam is reheated in such a unit may be regulated or controlled manually under the guidance and by the aid of measuring instruments, or by automatic means positioned by measuring means; in either case by mechanisms operating dampers controlling the flow of hot gases over heat exchange surfaces. Automatic means are of course desirable in the interest of constant vigilance, promptness of action, etc. Naturally the arrangements disclosed and claimed herein are useful with vapor generators or furnaces other than the exact type used as an example in the description.

In regulating the temperature of either of the flows of vapor in such a combination unit, it is of course to be appreciated that the pressure of the steam may be different in one flow than in the other, consequently a different saturation tem-

perature, and that the temperature standard (usually superheat) of the flows may be the same or be different. Furthermore, that the temperature standard for either or both flows may be constant or variable with rating. These possibilities exist and are herein disclosed for either hand or automatic regulation.

While the particular embodiment illustrated and described herein is shown as having two steam heating gas passes and an idle pass, it is contemplated that any number of active and idle passes may be in combination, and that the passes may be horizontal or vertical. Furthermore, the fluid flow paths located in the gas passes need not contain steam or vapor. For example, one active pass may have a steam superheater, while another active pass may have an economizer section of either steaming or non-steaming type therein. Such an arrangement has particular advantage where the water entering the boiler drum should be near the saturation temperature at the drum to prevent leakage at the tube seats in the drum.

Inasmuch as a steam reheater may be considered as a form of superheater, the invention may broadly be considered as relating to the heating of a plurality of superheating surfaces in a single boiler setting, preferably where such superheating surfaces are not connected for series flow, but are independent parallel superheater paths.

In the drawings:

Fig. 1 illustrates in somewhat diagrammatic fashion a sectional elevation of a vapor generating unit to which the invention has been applied.

Figs. 2, 3, 4 and 5 diagrammatically illustrate different arrangements of electrical apparatus which may be substituted for the electrical arrangement of Fig. 1.

Figs. 6 and 7 illustrate in diagrammatic manner arrangements which may be applied to the boiler of Fig. 1 illustrating control of the heating conjointly from a measure of temperature and of flow.

Fig. 8 diagrammatically illustrates how the invention may be carried out by means of hydraulic or pneumatic control arrangements.

Referring now particularly to Fig. 1, a water-cooled furnace 1 is fired by burners 2 and the unit is arranged for vertical upward gas flow. A slag screen 3 is positioned across the furnace outlet and is backed by a bank of convection tubes 4. The gases in passing upward from the furnace 1, pass successively through the slag

screen 3 and convection bank 4, where after they are divided into three parallel gas flows confined by the closely fitted water walls 5, 6 forming three parallel passes 7, 8, 9 to the economizer 10 and air heater 11. In pass 7 is located the superheater 12, in pass 8 the reheater 13, while pass 9 is an idle pass.

In the three gas passes are arranged independent dampers, so that the division of gas flow over the two different superheating surfaces 12, 13 may be adjusted in accordance with the operating demands. This permits of the following combination of operating conditions:

(1) All gas up the idle pass, no superheating, and no reheating. This would probably be a starting condition with the economizer cooling the gases and thus protecting the damper.

(2) No gas up the idle pass, the whole gas flow being divided between superheating and reheating in any desired ratio as adjusted by the dampers of these two gas passes, from zero superheating and all reheating, to zero reheating and all superheating.

(3) Part of the gas up the idle pass with the rest divided between the other two passes, in any ratio as may be necessary to give the proper final steam temperatures, but with less total heat to be divided between the heaters in proportion as gas is by-passed through the idle pass.

Conditions 2 and 3 represent operating conditions to control both superheat and reheat through control of the quantity of gas for both and its division between them. Condition 1 represents a starting condition, or perhaps a condition after a sudden loss of a heavy load when there is little or no steam flow and before the unit is cooled off.

In Fig. 1 and throughout the description we refer to the damper or dampers at the outlet of the superheater pass 7 by the number 14; the damper or dampers at the outlet of the reheater pass 8 by the numeral 16; and the damper or dampers at the outlet of the idle pass 9 by the numeral 15. The number and type of dampers used at the various locations 14, 15, 16 is immaterial to the broad concept of our invention.

A preferred embodiment of the invention utilizes reversing electric motors for positioning the dampers, and to that end the motors are diagrammatically represented at 17, 18, 19 respectively, each shown with double windings representative of the possibility of rotation in either direction according as to which winding is energized. The motors are, of course, provided with the necessary gear reduction, linkage, etc. for connection to the respective dampers and for positioning the dampers at a speed relatively low compared to the speed of the motors. In order to readily follow the description in connection with the drawings, we have designated the windings of the motors 17, 18 and 19 by M and L, indicative of "more" and "less," by which we mean the winding of the motor which would be energized to rotate the motor in proper direction to position the related damper or dampers to allow the passage of "more" or "less" gas flow therethrough. It will be observed that in the M and L wires to each of the motors we have shown a spring closed limit switch 20 provided to limit the travel of the motor in either direction to thus protect the motor and gearing, as well as the damper, from travel beyond predetermined limits.

It will be apparent from an examination of Fig. 1 that through the control of motors 17,

18 and 19, and consequently of dampers 14, 15 and 16, we may proportion the flow of the hot gases through the passes 7, 8 and 9 in any desired manner, such as to attain the desired temperature of the steam leaving the superheater 12 and/or of the steam leaving the reheater 13.

In the steam header 21 is located the bulb of a gas filled temperature sensitive system connected through a capillary 22 with a Bourdon tube 23, adapted to position an indicator 24 relative to an index 25 for providing a visual indication of the temperature of the steam leaving the superheater 12. In the outlet conduit 26 from the reheater 13 is located the bulb of a gas filled temperature sensitive system connected through the capillary 27 with a Bourdon tube 28, adapted to position an indicator 29 relative to an index 30, for providing a visual indication of the temperature of the steam leaving the reheater 13. In general, the positioning of the dampers 14, 15 and 16, and correspondingly the proportioning of the gas flow through the passes 7, 8 and 9, is accomplished automatically responsive to the positioning of the Bourdon tubes 23, 28 and correspondingly responsive to the value of, and changes in the value of, the temperature of the superheated steam and of the reheated steam.

To this end the Bourdon tube 23 is arranged to angularly position a contact bar 31 around a pivot to cause engagement or disengagement with contacts 32, 33, 34, or 35. In like manner the Bourdon tube 28 is arranged to angularly position a pivoted contact arm 36 to open or close contacts 37, 38, 39, or 40. The contact bars 31 and 36 are connected to one side of a power source 41 through a normally closed finger of a switch 42 to be mentioned hereinafter. The neutral of the motors 17, 18 and 19 are all connected to the other side of the power source 41 through a normally closed finger of the switch 42 and an interrupting finger 43 which is periodically opened and closed through the agency of a cam 44 driven by a continuously running motor 45. Such periodic interruption of rotation, of any or all of the motors 17, 18 or 19 which may be energized, is to provide movement of the dampers 14, 15 and/or 16 by periodic increments rather than continuously, and thus precluding any possibility of over-correction or hunting. It will be evident that in one installation the speed or frequency of the opening and closing of the finger 42 may necessarily be different from that in another installation, and to that end the gearing between the motor 44 and the cam 43 may have to be different on one job from another, and at the same time the shape of the cam 43 may desirably be changed. In fact, on certain installations it may not be necessary to have the interrupter 42, 43, 44 at all.

In general, the arrangement of Fig. 1 is such that when the boiler is started from a cold condition the dampers 14 and 16 are preferably closed, and the damper 15 is wide open. This may be accomplished through the provision of manually actuated switches 45, 46 and 47 and the manually actuated selector switch 48. The latter is indicated on the drawings as having two positions representative of automatic and hand control. The three switches 45, 46 and 47 are preferably spring urged to the shown position wherein they are not closing any circuits. When it is desired to actuate the motors 17, 18 or 19 manually and entirely independently of the automatic control system, then the selector switch 48 is moved to the hand position (shown in auto-

matic position in Fig. 1), wherein the power line 41 is connected directly to the neutrals of the motors 17, 18 and 19 through the lowermost (shown open) contacts of switch 48, without passing through the interrupting finger 42. At the same time the switch 48 breaks the circuit between the power line 41 and the contact arms 31, 36 so that the contactors are without power and thus ineffective for the control of the motors; and energizes switches 45, 46, and 47.

After placing the switch 48 in the hand position, and thus connecting the neutrals of the motors 17, 18 and 19 directly to the power source 41, any or all of the switches 45, 46, 47 may be actuated to either a more or a less position for moving the dampers 14, 15 or 16 in the "more" or "less" direction separately or collectively. The moment a switch 45 or 46 or 47 is released by hand, it is spring urged to a neutral position as shown in Fig. 1. The switch 48 must be returned to automatic position before the contactors 31, 36 become effective to automatically control the dampers.

It will be seen that the manual control as well as the automatic control is subject to the limit switches 20, so that there is no danger of running the motors 17, 18 or 19 in one direction or the other past a predetermined extreme of travel; thus avoiding the possibility of damage to the motors or dampers.

A preferred method of placing the boiler unit in operation from a cold condition is to so manipulate the switches 48, 45, 46 and 47 that the dampers 14 and 16 are closed and that the damper 15 is wide open. All of the gases from the furnace 1 will then pass through the idle pass 8, be cooled by the economizer 10, and pass through the damper 15 at a temperature not high enough to damage the damper. The same condition may be encountered after a sudden loss of a heavy load when there is no appreciable steam flow, and before the unit has cooled off. More will be said about this operating condition hereinafter.

The arrangement of Fig. 1 provides for the automatic control of the dampers 14, 15 and 16 responsive to temperature of the steam passing through the conduit 21 and the temperature of the steam passing through the conduit 26. Assuming that the switch 48 is as shown in the automatic position, then the contact bars 31, 36 will control the position of the dampers 14, 15 and 16 responsive to temperature of the steam leaving the superheater and of the steam leaving the reheater.

Assume that the temperature of the steam leaving the superheater 12 decreases below the desired value. The Bourdon tube 23 will tend to contract, moving its free end in a clockwise direction, thus positioning the pointer 24 downward relative to the index 25 to give a visual indication of the change in temperature, and at the same time positioning the contact arm 31 in a counterclockwise direction around its pivot. If the said temperature deviates a predetermined number of degrees below the desired value, then the contacts 34 are close circuited, thus completing the circuit for energization of the M coil of the motor 17, whereby the dampers 14 are moved in an opening direction. The energization of the M coil of the motor 17 will be by increments (so long as the contacts 34 are closed), through the agency of the interrupter fingers 42. As the increased flow of hot gases through the superheater 12 is accomplished by a further opening of the

dampers 14, the increasing temperature of the steam leaving the superheater will be effective to position the Bourdon tube 23 and eventually open the contact 34. If, however, the temperature of the steam leaving the superheater continues to fall, or falls at a fast rate, so that the counterclockwise rotation of the contact bar 31 causes engagement of the contacts 33, this results in a positioning of the damper 15 in a less direction to further cause an increase in gas flow past the superheater 12.

Conversely, should the temperature of the steam leaving the superheater be higher than desired, then the Bourdon tube 23 will have positioned the contactor arm 31 in a clockwise direction, first closing the contacts 32 to energize the L coil of the motor 17, and for a continued increase in temperature to next close the contacts 35 effective to energize the M coil of the motor 18. It will be appreciated that when more gas is by-passed through the idle pass 8 it tends to decrease the amount of gas effective through the passes 7 and 9, and vice versa.

The Bourdon tube 23 is positioned representative of the temperature of the reheated steam leaving through the conduit 26, and as such temperature falls below a predetermined value, the contact 39 is first closed, causing an energization of the M coil of the motor 19, and if a continued decrease occurs then the contacts 38 are next closed, causing an energization of the L coil of the motor 18. The result, for a decrease in steam temperature leaving the reheater, is to first open the damper 16 in a "more" direction to allow a greater gas flow over the reheater, and if this does not satisfy the condition to then tend to close the damper 15 and decrease the amount of gas by-passed through the idle pass 8. Obviously the motor 18 must be of a type wherein no damage to the motor windings will occur if the M and L windings are simultaneously energized, the one from the contactor 31 and the other from the contactor 36, or vice versa; in such a case the motor being responsive to the algebraic sum of the contacts.

It will be appreciated that in the remaining illustrations of the present application we have avoided duplicating thereon those parts of Fig. 1 which are common to all of the drawings. For example, we have not duplicated the arrangement of boiler, superheater, reheater, etc., but in most instances have illustrated only those parts of the control arrangement which differ from that shown in Fig. 1. We intend that with any of the remaining figures of the drawings we may apply the limit switches, as well as the hand-automatic arrangement of switches, of Fig. 1, without the necessity of duplicating the showing in each of the other figures of the drawings.

Fig. 2 illustrates a somewhat similar arrangement of the control to that illustrated in Fig. 1, except that herein the free end of the contact bar 31 and that of the contact bar 36 are pivotally connected to position a floating contact bar 51 adapted under certain conditions to close the contacts 49 or the contacts 50. The arrangement is such that if the superheat temperature should decrease, and the reheat temperature should increase, each by a certain amount, the contact member 51 would be relatively moved in one direction or the other, but the center thereof would remain substantially undisplaced and neither the contacts 49 or 50 would be closed. Such a condition would be indicative that the proper total amount of heat, as represented by

hot gases, was being applied through the passes 7 and 9, but not properly distributed there-through. It would indicate that no change should be made in the amount of hot gases bypassed through the idle pass 8. If, however, both the superheat temperature and the reheat temperature were to fall and in substantially the same amount, as for example upon a sudden change in load, then the contacts 50 would be closed, energizing the less coil of the motor 18 for positioning the damper 15 in a closing direction whereby the flow of hot gases through the idle pass 8 would be decreased and additional gases would be sent over the passes 7 and 9 to bring both of the temperatures up toward predetermined normal. Conversely, if both temperatures increased in substantially the same amount, then the contact 49 would be closed, calling for an opening of the damper 15 to take some of the total heat away from the reheater and superheater. Thus in the arrangement of Fig. 2, the contact arms 31 and 36 will cause a distribution of heat relatively between the superheater and reheater, while the contact member 31 controls the total heat applied to both the reheater and superheater.

Fig. 3 shows an arrangement somewhat similar to that of Fig. 2, but herein a second Bourdon tube 23' is positioned responsive to temperature of the superheated steam along with the Bourdon tube 23; while a second Bourdon tube 28' is positioned along with the Bourdon tube 28 responsive to temperature of the reheated steam. The differential in temperature between that of the superheated steam and that of the reheated steam, as indicated by the position of the contact beam 51', controls the damper 15 of the idle pass 8. Fig. 3 provides over Fig. 2 many possibilities as to adjustment of the spacing between the contacts and otherwise to arrange for temperature value or differential to result in a movement of the damper 15, as well as in the sensitivity and speed of motion of said damper relative to the dampers 14, 16. In Fig. 3 we provide two interrupting fingers entirely independent of each other, the one in connection with the motor 18 and the other in connection with the motors 17, 19. Thus the motor 18 may be effective to open or close the damper 15 at a faster or slower rate than the other dampers and for longer or shorter increments of time and at desired frequency.

In Fig. 4 we show an arrangement wherein either the Bourdon tube 23 or the Bourdon tube 28 will simultaneously control all three of the motors 17, 18 and 19 in proper direction. For example, an increase in temperature of the superheated steam will result in a closing of the contacts 32, thus energizing the relay 53 and closing the proper circuits to energize the L coil of the motor 17, the M coil of the motor 18 and the M coil of the motor 19. Thus to take care of too high a superheat temperature the dampers 14 will be moved in a closing direction, while the dampers 15 and 16 will be moved in an opening direction. In similar manner the Bourdon tube 28 is adapted to position all three of the motors 17, 18 and 19. The neutral of the motors 17 and 19 is taken through one interrupting finger, while the neutral of the motor 18 is taken through another interrupting finger, so that by proper arrangement the speed of opening or closing of the damper 15 may be at a different rate than that of the dampers 14, 16.

It will be seen that the arrangement of Fig. 1

is one in which a predetermined substantially constant superheat temperature and reheat temperature is the desideratum and where each is controlled relatively independent of each other and of load. It may happen, however, the either the superheat temperature or the reheat temperature would tend to stabilize at a value other than the desired value, as for example if the superheat temperature falls enough to cause a closing of contacts 34 but not a closing of contacts 33. The energized M coil of motor 17 would cause an intermittent positioning of dampers 14 in an opening direction, which might continue until the dampers were wide open. Under this condition the only way to further increase the hot gas flow through the pass 7 would be to close down damper 15, but this is not accomplished because the superheat temperature has not fallen to low enough value to close the contacts 33. If the temperature of the superheat and reheat are below the desired standard and dampers 14 and 16 are wide open, then the superheat and reheat temperature might stay at the low point but not go any lower. If it did not go any lower it might not cause an actuation of damper 15. In the event the temperatures remained at the low point without starting to close the damper 15, then we provide a time element which would become effective after a certain length of time to make a slight closure of the damper 15 to get the system off from its stabilization point.

Referring to Fig. 5, the initial or primary control of the motors 17 and 19 is as previously described through the agency of the Bourdon tubes 23 and 28 and the related contactors 31 and 36. Additionally, however, we provide means to prevent stabilization at any other temperature than that desired. For example, the motors 54, 55, 56 and 57, when energized, are adapted to rotate in a predetermined direction and each angularly position a cam adapted to actuate the contacts 58, 59, 60 or 61 respectively. The necessary reduction gears are provided between the motors and their respective cams, as well as a friction clutch, maximum travel limit, and spring return. The arrangement is such, taking the motor 54 as an example, that when the motor 54 is energized for rotation in given direction it drives the cam associated therewith in predetermined direction and at a speed dependent upon the reduction gears therebetween. The drive is through a friction or slip clutch and the cam is arranged to slowly close the contacts 58 against the action of a spring. When the maximum limit of travel of the cam is reached, as determined by engagement of the contacts 58, a continued energization of the motor 54 will cause the friction clutch to slip, whereby the motor is not damaged and the contacts 58 are retained in closed position. Thus the time length of closure of the contacts 58 is dependent upon the time energization of the motor 54 after the contacts 58 engage. As soon as the motor 54 is deenergized the spring returns the movable half of contact 58 and the cam to their initial or starting position, thus breaking the circuit through the contact 58.

It will be observed that the contacts 58, 60 are connected in parallel to the L coil of the motor 18, while the contacts 59, 61 are connected in parallel to the M coil of the motor 18. Whenever the contact 34 is closed the motor 54 is energized. Likewise when the contacts 32, 37, 39 are each closed the respective motors 55, 57, 56 are energized. A momentary closure of any of the contacts such as 34 may not necessarily cause a

closure of the related contacts 58, since the time length of the closure is not sufficient to rotate the cam to a point where the contacts 58 engage. If however a sustained contact (as at 34) would persist, it would result in a closure of the contacts 58 and correspondingly an energization of the L coil of the motor 18.

It will thus be seen that the condition previously mentioned, of the possibility of stabilizing at some temperature other than that which is desired, is obviated through the arrangement as proposed in Fig. 5. If too much of the hot gases are passing through the idle pass 8 and the superheat temperature and reheat temperature are both low, regardless of the fact that the dampers 14 and 16 are wide open, then the Bourdon tubes 23, 28 responsive to the low temperatures would maintain the contacts 34, 39, or either of them, in a closed condition, and correspondingly the motors 54, 56 would be energized, resulting in a closure of the contacts 58, 60, either or both of which when closed are arranged to energize the L coil of the motor 18. Such an energization in a closing direction of the damper 15 will tend to increase the total heat available in the passes 7 and 9 over the superheater and reheater to bring the steam temperatures up.

Thus, in general, Fig. 5 provides that if the dampers 14 and 16 are wide open, and the temperatures are still too low, a timing device will come into play after a predetermined time interval and make a change in the position of the damper 15 to bring the system off from stabilization. It will be observed that an interrupting finger is arranged in the neutral connection of the motor 18 so that the positioning of the damper 15 is by increments whose frequency and duration may be properly adjusted to prevent over-correction.

It may be that in certain types of installations or under certain conditions of operation it will be desirable to have a somewhat different superheat temperature and/or reheat temperature at different loads. In Fig. 6 we illustrate an arrangement providing the establishment and maintenance of superheat temperature and reheat temperature varying with rating. To that end we provide in the superheated steam outlet conduit 21 an orifice 62 producing a pressure differential thereacross in known relation to rate of steam flow and effective through the pipes 63, 64 upon a flow meter generally indicated at 65. The flow meter 65 is of a type designed to move an indicator 66 relative to an index 67 directly in increments of rate of steam flow through the conduit 21. Thus we provide a visual indication of load as represented by rate of superheated steam flow leaving the superheater 12. A similar rate of flow meter 68 is responsive to the pressure differential existing across an orifice 69 in the reheat steam outflow conduit 26 and is adapted to position an indicator 70 relative to an index 71 directly in terms of rate of flow of reheated steam leaving the reheater 13.

A freely floating contact bar 72 is positioned at one end by the flow meter 65 through linkage 73, 74 and 75. From the Bourdon tube 23 is pivotally suspended a link 76 to which is pivotally connected the other end of the contact bar 72. A contact carried by the bar 72 is adapted to cooperate with either the contacts 77, 78 joining respectively to the L and M windings of the motor 17. The arrangement is such that in case the superheated steam temperature is lower than desired, the Bourdon tube 23 will move the link

76 downwardly, closing the contact 78 and energizing the M winding of the motor 17 to accomplish an opening of the dampers 14. Conversely, if the temperature of the superheated steam is too high, then the contacts 77 will be closed and the dampers 14 will be moved in a closing direction to decrease the flow of hot gases through the pass 7 over the superheater 12.

Through the agency of the flow meter 65 and the linkage 73, 74, 75 the left-hand end of the contact beam 72 is positioned upwardly or downwardly, thus decreasing the distance between the contacts 77 or 78, as the case may be, and resulting in the maintenance of a different superheated steam temperature at different rates of steam flow. An adjustment 79 is provided to vary the effect of the flow meter movement upon movement of the contact bar 72.

In like manner the flow meter 68 assists the Bourdon tube 28 in control of the motor 19 to the end that the superheat temperature maintained is in desirable relation, varying directly or inversely or in desired degree, with rate of reheat steam outflow through the conduit 26.

The motor 18 is under the control of a contact member 81 jointly positioned by the Bourdon tubes 23, 28 through the agency of links 76, 80 as have previously been described in connection with other figures of the drawings.

It will be evident that with the arrangement of Fig. 6 we may provide any desired functional relation between temperature of the superheated steam and its rate of flow, or between temperature of the reheated steam and its rate of flow. In other words, we may arrange to maintain superheated steam temperature varying directly or inversely and in any amount relative to rate of steam flow, or we may arrange that the relation between rate of flow and temperature of the flowing steam may be in any desired curved relation depending upon the design of the linkage interconnecting the flow meter and the Bourdon tube for jointly positioning the contact members.

In Fig. 7 we have provided an arrangement particularly adapted for emergency conditions, such as a sudden loss of load when the unit has been operating at a high rating. The flow meter 65 has its pointer 66 connected to one side of the power source and adapted to cooperate with a contact segment 82 extending over approximately three-quarters of the length of the index 67. Thus when rate of flow through the conduit 21 is above a predetermined minimum, as for example 25% of maximum rate, the contact pointer 66 will close circuit with contact segment 82 and energize the winding of a relay 83 shown in energized position in Fig. 7. In normal operation (as shown in Fig. 7) the neutral of the contact bars 31, 36, 51 is connected to one side of the power source through the lowermost and closed contact of the relay 83.

If there is a sudden loss of load to below 25% of maximum, the pointer 66 passes beyond the end of the contact segment 82 and the relay 83 is deenergized. Its consequent movement opens the circuit to the neutral, thus deenergizing contact arms 31, 36 and 51, and closes circuit through the L windings of the motors 17 and 19 and the M winding of the motor 18, whereby the dampers 14, 16 are immediately positioned in a closing direction and the damper 15 is positioned in an opening direction. This action serves to protect the reheater and superheater from excessive temperatures at a time when they are not cooled by

the flow of a material amount of steam there-through. The opening of the damper 15 allows a by-passing of a greater portion of the hot gases of combustion through the idle pass 8, and until the boiler operator or automatic equipment has made the necessary changes in firing rate, subsequent to the sudden decrease in output, whereby the total volume of heated gases is reduced below a dangerous value.

The arrangement of Fig. 7 further provides that upon starting up, and until a certain predetermined rate of steam flow is attained, the damper 15 will be in an open position and the dampers 14, 16 in a closed position. Thus the gases will pass through the idle pass 8, be cooled by the economizer 10, and pass through the damper 15 to the air heater 11. This obviates the possibility of damage to the superheater 12 or the reheater 13 by an excessive flow of hot gases when there is not a sufficient cooling of the reheater or superheater by steam flowing there-through in sufficient quantity.

Under such low load or emergency condition, upon starting up, the energization of motors 17, 18, and 19 is continuous and not through an interrupting finger, and motor travel will be limited by the limit switches 20.

It will be realized that we are not necessarily limited to electrical arrangements or electric motors for positioning the dampers. In Fig. 8 we have illustrated the embodiment of our invention in pneumatic means. Referring to Fig. 8, we show therein that the Bourdon tube 23, positioned responsive to the value of superheated steam temperature, is arranged to axially position a pilot stem 84 to vary an air loading pressure within the pipes 85, 86. In like manner the Bourdon tube 28 axially positions a pilot valve 87 to control an air loading pressure within the pipes 88 and 89. The pilot valves 84, 87 are of a type disclosed and claimed in the patent to Johnson No. 2,054,464 and of a general type wherein axial movement results in the establishment of an air loading pressure bearing a definite and predetermined relation to such axial movement. In the present arrangement, an upward movement of the pilot stems 86, 87 causes a proportionate increasing of pressure within the pipes 85, 88 and simultaneous decreasing in pressure within the pipes 86, 89.

Pipe 86 is connected to a pneumatic actuator 90 connected to position the dampers 14; while the pipe 89 leads to a pneumatic actuator 91 adapted to position the damper 16. The actuators 90, 91 are spring loaded so that the dampers 14, 16 assume positions representative of the air pressure applied to the actuators through the pipes 86, 89 respectively.

If the superheated steam temperature tends to rise above that desired, then the Bourdon tube 23 moves its free end in counterclockwise direction, raising the pilot stem 84 and decreasing pressure within the pipe 86. Such a decrease in pressure, opposed by the spring of the actuator 90, moves the dampers 14 in a closing direction to throttle the flow of heated gases past the superheater 12. Similarly, an increase in temperature of the reheated steam causes the Bourdon tube 28 to raise the pilot stem 87, thus resulting in a decreasing of pressure through the pipe 89 within the actuator 91, and a positioning of the damper 16 in a closing direction to decrease the heating effect upon the reheater 13.

For a control of the damper 15 we provide the air actuator 92 connected by a pipe 93 to an

averaging relay 94. Such an averaging relay is disclosed and claimed in the patent to Dickey 2,098,913 and is provided in general with four chambers 95, 96, 97 and 98. Chambers 95 and 96 are separated by a flexible diaphragm. The chambers 97 and 98 are likewise separated by a flexible diaphragm. Chambers 96 and 97 are separated by a rigid partition. The two diaphragms and an opposing spring are connected together with a stem adapted to position an air inlet and outlet valve in the chamber 95. It will be observed from a study of Fig. 8 that the pipe 85 connects with the chamber 98 while the pipe 88 connects with the chamber 96. Thus the pressures effective through the pipes 85 and 88 act in the same direction against the spring and for control of pressure within the chamber 95, which pressure is effective through the pipe 93 upon the pneumatic actuator 92. If the superheated steam temperature is too high, then the Bourdon tube 23, in positioning the pilot stem 84 upwardly, causes an increasing pressure effective through the pipe 85 within the chamber 98. Likewise an increase in temperature of the reheated steam results in an increasing pressure within the chamber 96. Such increased pressures acting against the opposition of the spring will cause an opening of the air inlet valve to the chamber 95, increasing the pressure within the chamber and within the pneumatic actuator 92, thus tending to position the damper 15 in an opening direction whereupon a larger percentage of the hot gases are passed through the idle pass 8 and away from the superheater and reheater. The action is somewhat different from those previously described in connection with the electrical embodiments, in that the relay 94 provides a resultant loading pressure through the pipe 93 which is in effect an algebraic summation of the pressures within the pipes 85, 88. Thus, if one of the temperatures is too high and the other is too low there will be very little, if any, change in the position of the damper 15, and this is correct, for the actual change should occur in the relative positions of the dampers 14 and 16. However, if both temperatures are too high, or both temperatures are too low, then in addition to any changes in the position of the dampers 14, 16, there should be and will be a readjustment of the position of the damper 15 to by-pass more or less of the gas by the superheater and reheater.

In general, while we have provided an arrangement and method of controlling the heating of a superheater and of a resuperheater in connection with a steam generating boiler, it will be understood that we are not to be limited thereby as the invention may equally as well be applicable to vapor generators in general, or to furnaces in general, or to combinations of superheaters or reheaters other than those specifically illustrated and described.

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

1. The combination with a vapor generator having a furnace, three parallel passes for the gases leaving the furnace, a superheater in one of the passes, a reheater in another of the passes, the third pass being an idle pass, means sensitive to temperature of vapor leaving the superheater adapted normally to vary the gas flow through the superheater pass in direction to maintain said temperature at optimum value, means sensitive to temperature of vapor leaving the reheater adapted normally to vary the gas

flow through the reheater pass in direction to maintain said temperature at optimum value, means so responsive to both said temperature sensitive means that that portion of the total gases flowing from the furnace which do not flow through the superheater and reheater passes will flow through the idle pass, and means responsive to a predetermined minimum rate of flow of one of the fluids being heated and arranged to render ineffective the said joint temperature sensitive means when there is no flow through the superheater and reheater passes and direct the total gas flow through said idle pass.

2. The combination with a vapor generator having three parallel gas passes leaving the furnace, one of the gas passes being an idle pass, a superheater in a second pass, a reheater in the third pass, temperature measuring means for the vapor leaving the superheater, temperature measuring means for the vapor leaving the reheater, dampers at the exit of each of the passes, and control mechanism so responsive to said measuring means as to so selectively position said dampers to maintain the temperatures each at a predetermined optimum value that the damper of said idle pass will be in open position and the dampers of said superheater and reheater pass will be in closed position when the vapor generator is under substantially no load, and the dampers of all three passes will be proportionally in open and closed position when said generator is under load.

3. The combination with a vapor generator having a furnace, a vapor generating tube portion at the gas exit of the furnace, three parallel gas passes leaving the generating tube portion, a vapor superheater in one of the passes, a vapor reheater in a second pass, the third pass being an idle pass, dampers at the exit of each of the passes, control means for each of the sets of dampers, means measuring temperature of the vapor leaving the vapor superheater, means measuring temperature of the vapor leaving the vapor reheater, means so responsive to the superheated vapor temperature measuring means as will so position the dampers in the pass at the exit of the superheater that the superheated vapor temperature will be maintained at an optimum value, means responsive to the reheated vapor temperature measuring means for positioning the dampers in the pass at the exit of the reheater to maintain the reheated vapor temperature at optimum value, and means so jointly responsive to both measuring means that the dampers in the idle pass are so positioned that

that portion of the total gases flowing from the furnace which do not flow through the heater passes will flow through the idle pass.

4. The combination with a vapor generator having a furnace, three parallel passes for the gases leaving the furnace, a superheater in one of the passes, a reheater in another of the passes, the third pass an idle pass, means responsive to temperature of the vapor leaving the superheater, means measuring flow of vapor from the superheater, control means for the heating of the superheater jointly controlled by said temperature responsive means and said flow means in such direction and amount as to maintain the temperature of the vapor leaving the superheater at optimum value, means responsive to temperature of the vapor leaving the reheater, means measuring flow of vapor from the reheater, control means for the heating of the reheater jointly controlled by said second temperature responsive means and said second flow means in such direction and amount as to maintain the temperature of the vapor leaving the reheater at optimum value, and means controlling the flow of gases through the idle pass responsive to both said temperature sensitive means, said last-mentioned means being so jointly responsive to both measuring means that the flow in the idle pass is that portion of the total gases flowing from the furnace which do not flow through the heater passes will flow through the idle pass.

5. In combination, a vapor generator having a plurality of parallel passes for the gases leaving the furnace, one of the passes being an idle pass, a vapor superheater in one pass, a vapor reheater in another pass, means so sensitive to the temperature of the vapor leaving the superheater as to so control the gas flow through its pass as to maintain said temperature at optimum value, means so sensitive to the temperature of the vapor leaving the reheater as to so control the gas flow through its pass as to maintain said temperature at optimum value, and time delay means coacting with both said temperature sensitive means in controlling the gas flow through the idle pass, said last-mentioned means being so jointly responsive to both measuring means that the flow in the idle pass is that portion of the total gases flowing from the furnace which do not flow through the heater pass will flow through the idle pass.

RAYMOND D. JUNKINS.
THOMAS C. TOOMEY.
CHARLES S. SMITH.