

April 9, 1940.

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2,196,377

FLUID-HEATING METHOD AND APPARATUS

Filed June 23, 1936

4 Sheets-Sheet 1

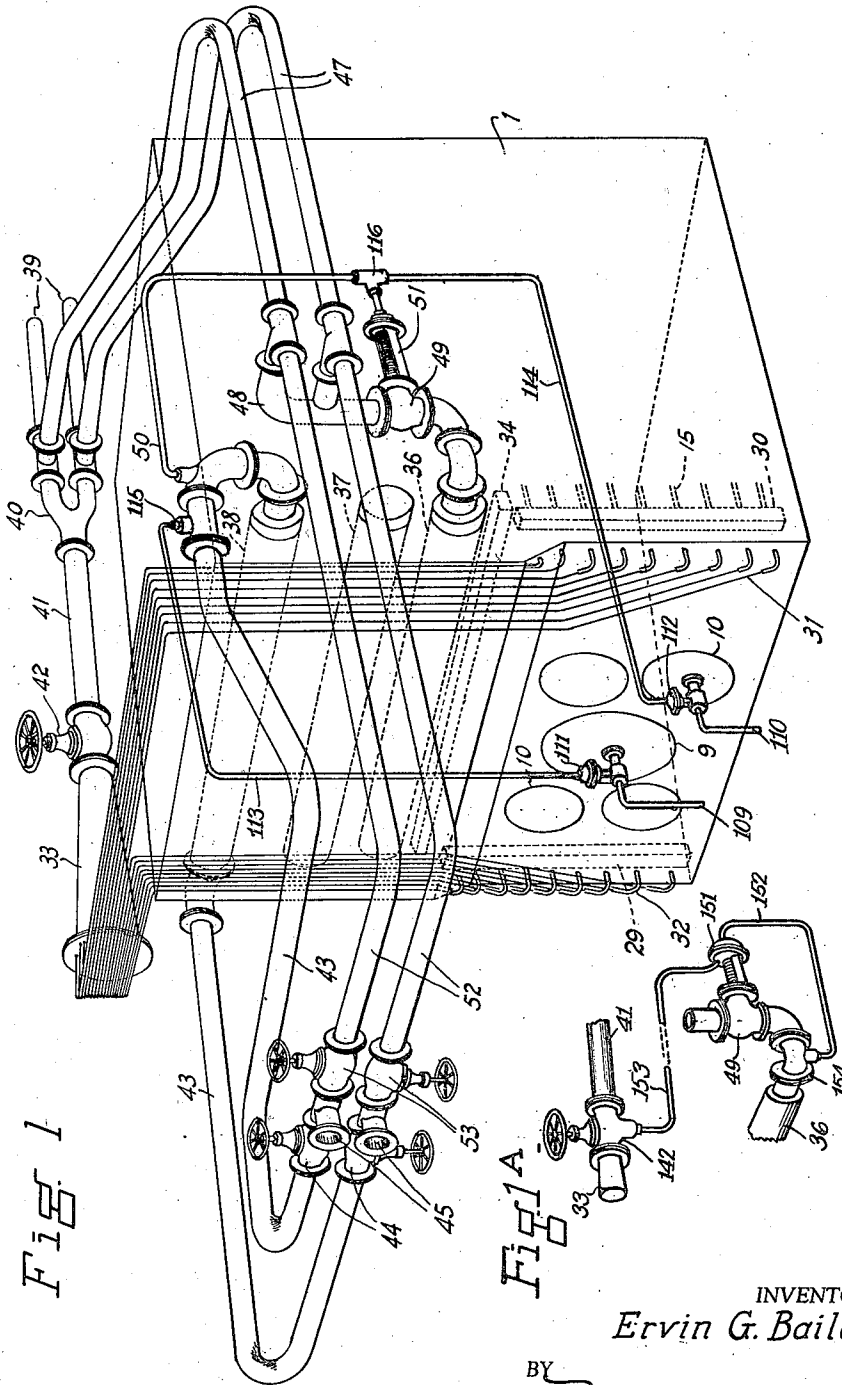


Fig. 1

Fig. 1A

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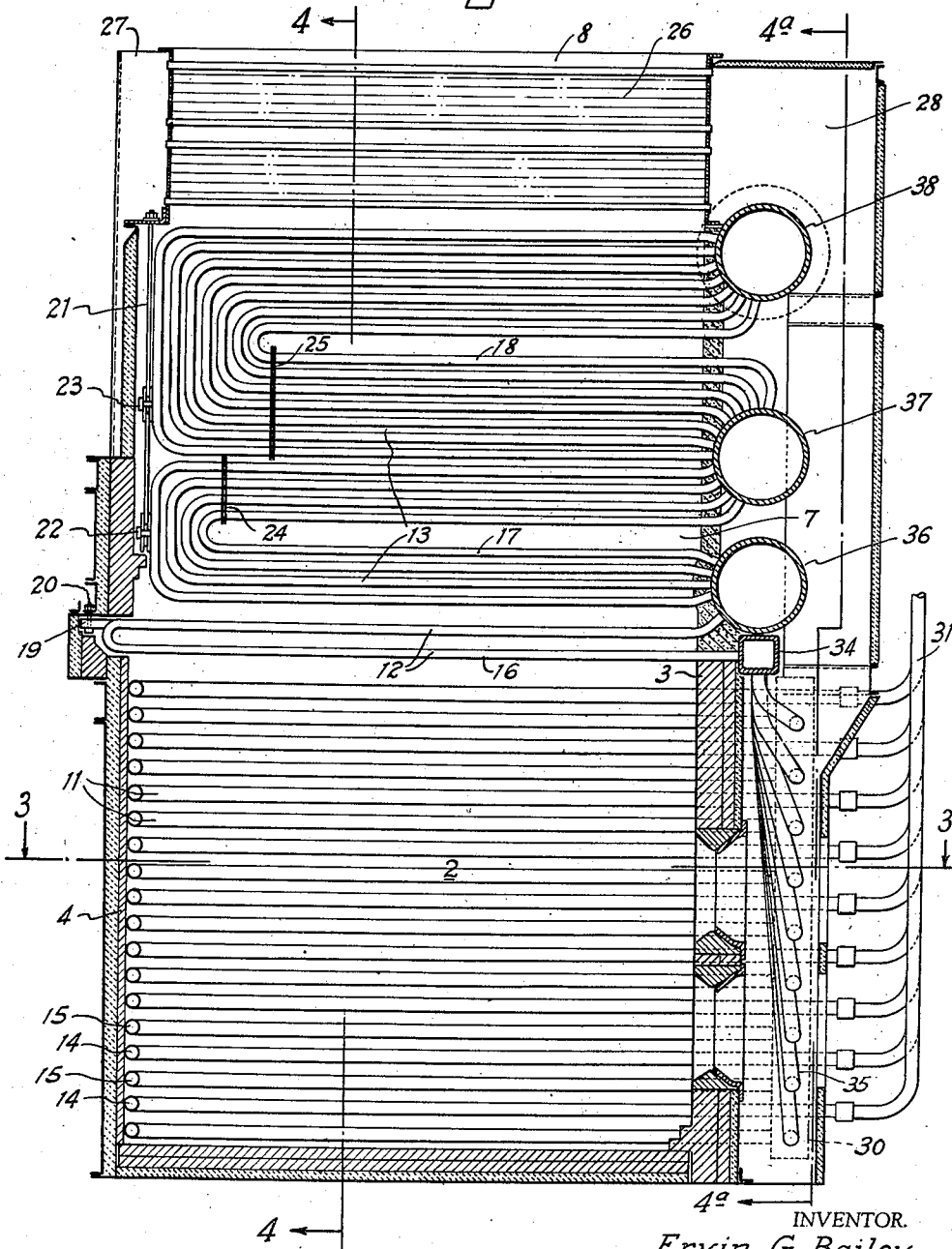
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Fig. 2



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4 Sheets-Sheet 3

Fig. 3

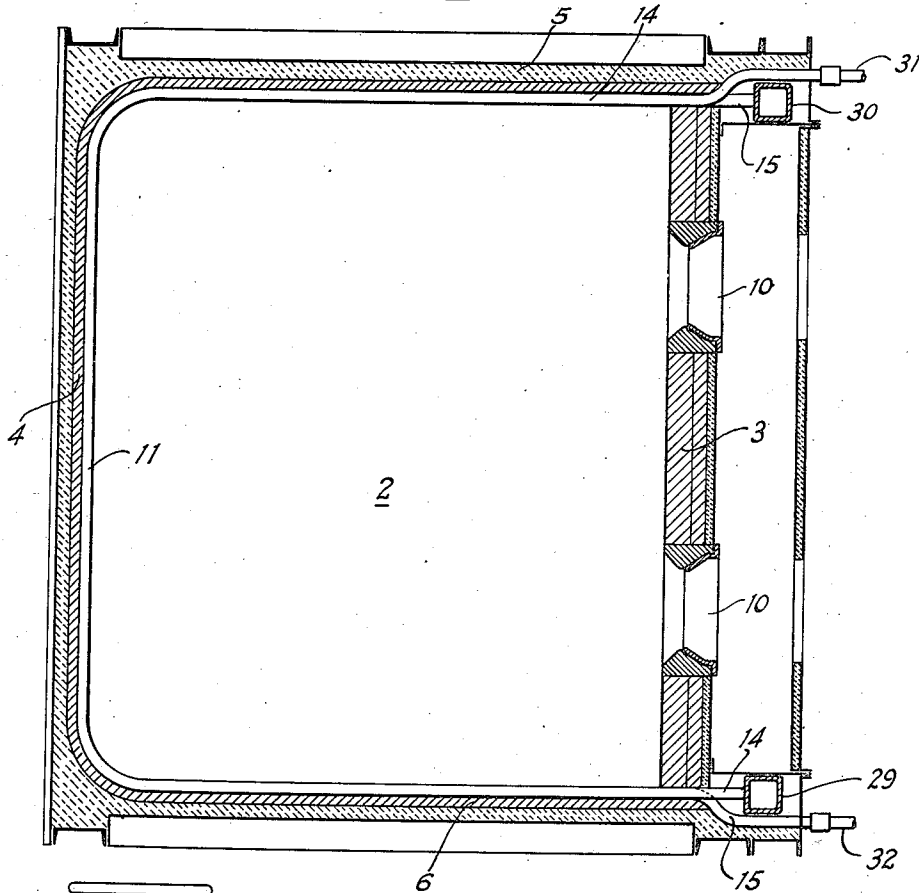


Fig. 5

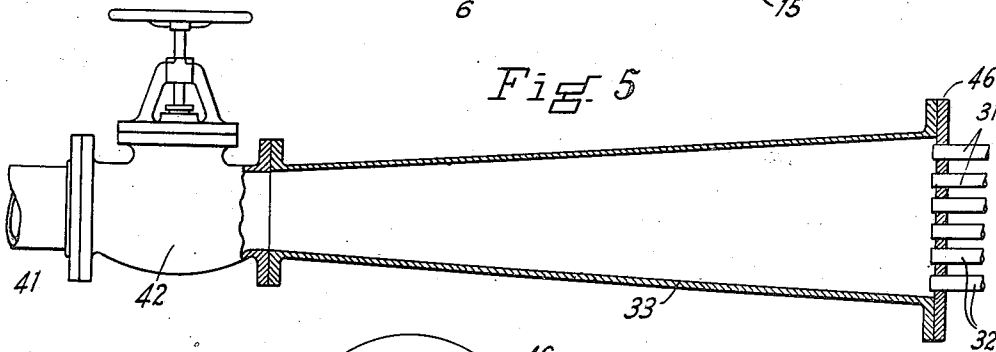
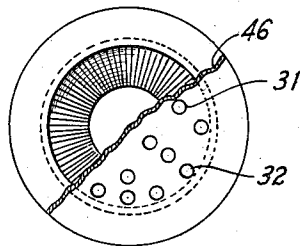


Fig. 6



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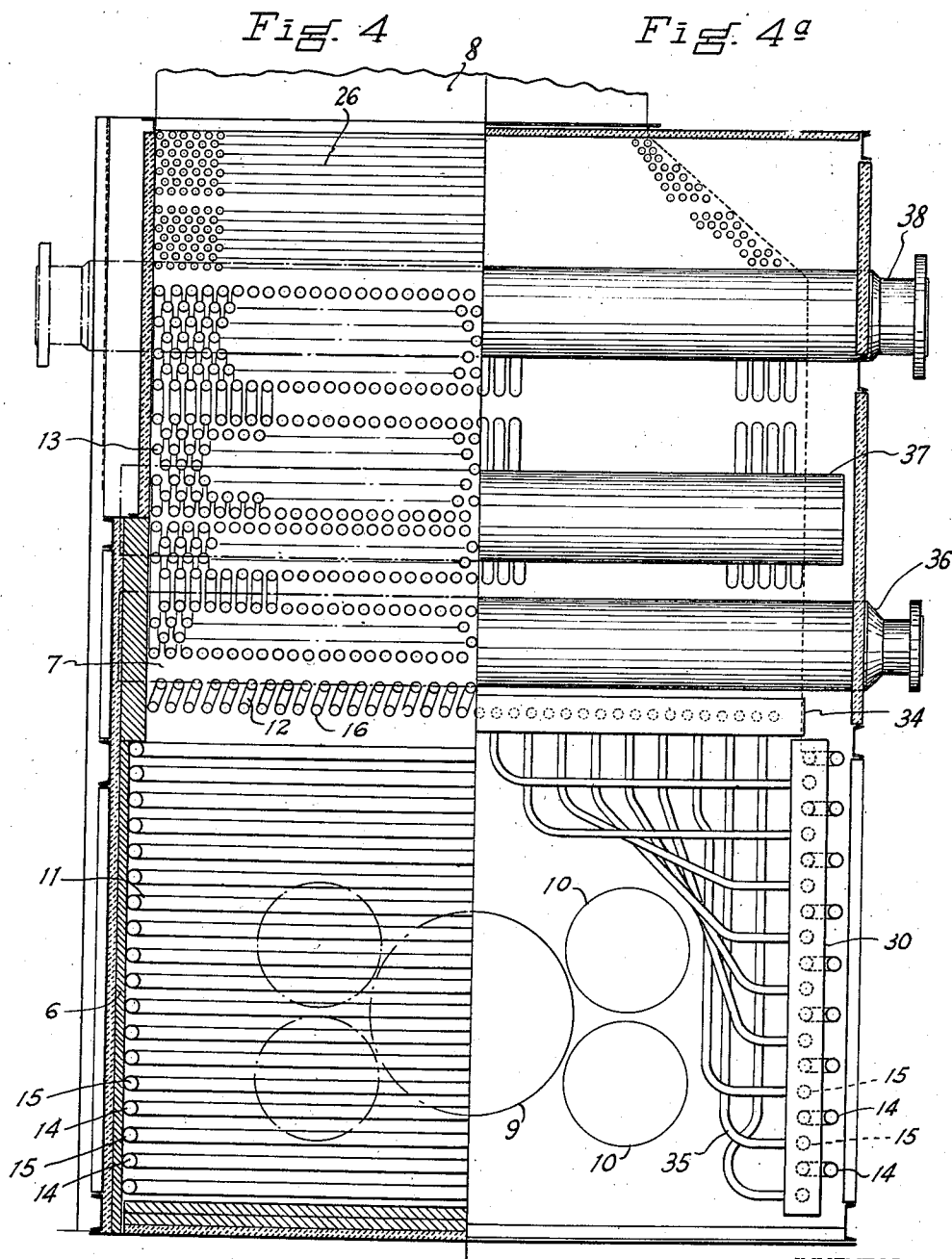
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FLUID-HEATING METHOD AND APPARATUS

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4 Sheets-Sheet 4



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FLUID-HEATING METHOD AND APPARATUS

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Application June 23, 1936, Serial No. 86,737

9 Claims. (Cl. 122-485)

My invention relates to methods and apparatus in the art of fluid-heating, with particular reference to the superheating of vapors.

An object of the invention is to provide a method and apparatus of this type, whereby superheated vapor is delivered at a substantially constant pressure over an unusually wide range in weight of vapor demand from a constant pressure source of supply of saturated vapor.

A further object is to provide a high-capacity superheater which receives at least the major portion of vapor to be superheated from independent generators having their own furnaces, and which is capable of being operated over a wide range of vapor weight demand without damage due to overheating.

A further object is to provide an improved means for equalizing distribution of vapor in a superheater of the type having parallel flow paths, including the maintenance of uniform pressure conditions at the inlet ends of the several paths, causing the vapor to flow through the paths at substantially equal velocities and pressure drops, and, with the arrangement of those paths, to insure that the condition of the vapor in corresponding portions will be substantially uniform.

A still further object is to provide a radiantly heated superheater forming a part of the wall surface of a furnace wherein equal mean temperature conditions are maintained throughout such wall surface.

These and other objects will be apparent from an examination of the following description and claims, when taken in connection with the accompanying drawings, in which:

Fig. 1 is a perspective view illustrating how my invention may be applied to a superheater of the separately-fired type;

Fig. 1A is a modified arrangement of pressure control connections;

Fig. 2 is a vertical sectional view illustrating the detail structural arrangement of the separately-fired superheater of Fig. 1;

Fig. 3 is a horizontal sectional view taken on the line 3-3 of Fig. 2;

Fig. 4 is a front sectional view for one half of the setting taken on the line 4-4 of Fig. 2;

Fig. 4a is a front elevation (with casing removed) for the other half of the setting, taken on the line 4a-4a of Fig. 2;

Fig. 5 is a longitudinal sectional view through the vapor distributor shown in Fig. 1; and

Fig. 6 is an end view of the distributor with

the tube plate broken away, as seen from the enlarged outlet end.

Referring now in detail to the construction illustrated, it will be observed that I have shown my invention as applied to a separately-fired superheater, that is to say, a superheater which receives saturated vapor to be heated, for example, steam from a generator or generators fired by means other than the means for firing the superheater and in which the pressure of the saturated vapor is controlled. Apparatus of this character and of the high capacity light construction provided, is especially useful in connection with power plants for ships wherein at times during the operation of the ship it is desirable to use saturated steam. In such cases the saturated steam may be conducted directly from the boiler to the point of use and the furnace of the separately-fired superheater may be shut down or operated at a low load which can not be accomplished in a case where the superheater is a part of the boiler structure and heated by gases from the boiler furnace.

It is to be understood at this point, however, that in so far as the broader aspects of the present invention are concerned it is not to be considered as limited to separately-fired superheaters nor to marine installations, for other applications and uses of the invention will be apparent as the description proceeds.

The separately-fired superheater is indicated generally by the reference character 1 and comprises a furnace 2 defined by a front wall 3, a rear wall 4, a side wall 5 and a side wall 6. Heat is generated in the furnace 2 by combustion of fuel and the gas passes upwardly through a gas pass 7 to an outlet 8. The furnace, here shown, is fired by oil burners 9 and 10, the burner 9 being one of large capacity, and the burners 10 of small capacity which are arranged at each side of the burner 9 in the manner shown. The purpose of providing large and small burners and arranged therein in the manner shown, is to provide a furnace which is highly flexible in operation, yet is capable of attaining unusually high fuel burning rates.

The superheating surface of the separately-fired superheater 1 comprises radiant and convection stages, that is, stages which are mainly heated respectively, by exposure to radiant heat of the furnace and by exposure to hot gases of combustion leaving the furnace. Specifically, these stages include, a radiant section 11, a first convection section 12, and a second convection section 13. The radiant section 11 comprises a

plurality of tubes 14 and 15, arranged in sets and defining parallel flow paths for the vapor to be superheated. The tubes 14 and 15 lie closely adjacent or are embedded within and form a part of the walls 4, 5 and 6 of the furnace for the purpose of securing the maximum heating surface and increasing the capacity of the superheater, for protecting the associated walls and for minimizing the duty imposed on the outer casing. The superheater section 12 comprises a row of return bend tubes 16 extending entirely across the hot gas outlet of the furnace 2. For convenience, section 12 has been described as a first convection section, but due to its location will also be subjected to radiant heat from the combustion chamber. The second convection section 13 comprises rows of return bend tubes 17 and 18 which are disposed across the gas pass 7 and are subjected to the heat of the gases from the furnace chamber.

The return-bend tubes may be suitably supported at their loop ends, and for the tubes 16, I have chosen to provide lugs 19 out of the path of hot gases, which are secured to the loop extremities and suspended from the setting by members 20 so as to permit of free expansion from the fixed header. The groups of tubes 17 and 18 may also be suspended from the setting by means of members 21 which engage lugs 22 and 23 secured to outer loops of the respective groups permitting tubes to expand from the header ends. Intermediate loops of the groups derive their support from the lug-supported loops through baffle members 24 and 25 which engage the tubes in the several rows.

An air heater 26 is located above the bank of tubes 18 and consists of a plurality of tubes extending transversely of the gas flue 7, ducts 27 and 28 being provided at opposite ends of the tubes for the accommodation respectively, of air entering and leaving the air heater.

As indicated, the tubes of the radiant section 11 extend about three sides of the combustion chamber, the side walls 5 and 6 and the rear wall 4, the tubes 14 of the one set being arranged alternately with respect to the tubes 15 of the other set. The set of tubes 14 has a vertically disposed outlet header 29 arranged at one side of the front of the furnace and the other set of tubes 15 has a vertical outlet header 30 arranged at the opposite side of the front of the furnace. The inlet ends of the tubes 14 and 15 are shown as extending respectively to tubes 31 and 32 which are connected to a distributor 33 (see Fig. 1). It will thus be seen that the vapor from the distributor flows through the sets of tubes 14 and 15 and into the respective headers 29 and 30. The vapor flows horizontally in one direction left to right through one of the sets of tubes and in the opposite direction right to left through the other set, the purpose of which is to provide similar temperature conditions throughout the furnace wall structure.

Each of the vertical outlet headers 29 and 30 is connected to a horizontally-disposed inlet header 34 of the section 12 by means of suitable tubes 35 (see Fig. 4a). The tubes 35 are preferably so proportioned and connected as to provide substantially equal resistances to the flow of vapor and thus contribute to a substantially uniform distribution of vapor throughout the several tubes of the section supplied by the inlet header 34. The inlet ends of the return-bend tubes 16 of the section 12 are connected to the header 34 and their outlet ends to the inlet header 36 of the

convection section 13. The second convection section comprises the inlet header just mentioned, an intermediate header 37, and an outlet header 38. Return bend tubes 17 connect the inlet and intermediate headers 36 and 37 respectively, and return bend tubes 18 connect the intermediate and outlet headers 37 and 38 respectively.

Referring to Fig. 1 in the drawings, the saturated vapor is supplied from one or more separate vapor generators (not shown) to vapor mains 39, here shown to be two in number. The mains 39 connect into a Y-connection 40 and through a pipe 41 and valve 42 to the inlet end of the distributor 33. Pipes 43 connected to outlet header 38 are provided with valves 44 and terminate in outlet fittings 45.

With the connections described and with valves 42 and 44 open, all of the vapor to be superheated will pass from the mains 39 into the distributor 33 and from thence through tubes 31 and 32 into the superheater tubes, flowing progressively through the several sections and finally to the outlets 45 and point of use. Special care must be taken in subdividing the entering vapor in passing from the pipe 41 into the plurality of separate paths through connections 31 and 32, and into the individual tubes of the radiant section. This is accomplished by the distributor 33 which is conical in form, expanding from the inlet diameter adjacent the valve 42 to a larger and suitable diameter at its outlet end whereby the velocity of the vapor is equalized over the whole end section. A plate 46 secured to the larger outlet end, receives the symmetrically arranged distributing connections which conduct vapor to the inlet ends of the radiantly heated tubes 14 and 15. The distributor thus equalizes vapor distribution to the inlets of the tubes and, due to its form and the arrangement of connections, effects the equalization with a minimum loss in velocity head. There is, of course, a drop in pressure due to the vapor passing through the individual sections and, being a function of the rate of vapor flow, the pressure drop will be greater for increasing loads. In order to protect those portions of the superheater which are hottest, that is, sections 11 and 12 which receive radiant heat from the furnace, provision is made for maintaining a high enough velocity of vapor through those sections at all times. The resultant pressure drop therefore, that is safe for that particular portion of the superheater for light loads, will increase with increase of load so that at maximum load the pressure at the outlet of the radiantly heated section might be reduced beyond permissible limits. The pressure drop in the convection portions will also increase with increasing loads, but not to the same degree as that in the radiant sections due to the fact that the areas provided for the flow of vapor in the convection sections are larger than the areas provided in the radiant sections.

The areas provided for the flow of vapor in the sections 11 and 12 are so proportioned as already described to produce the necessary velocity rate of vapor flow through them to prevent overheating. Upon leaving the outlet headers 29 and 30, the vapor passes through the connectors 35 whose combined area is comparable with that provided in the tubes 14 and 15. Upon leaving the header 34 the vapor passes through a single set of return bend tubes 16 where again the total area is about the same as the total flow area pro-

vided in the tubes 14 and 15 as these tubes are also exposed to radiant heat.

In the succeeding sections, however, it will be noted that greater areas are provided for the flow of the vapor, the drawings indicating, for example, four sets of return bend tubes between the header 36 and the intermediate header 37, and seven sets of return bend tubes between the intermediate header 37 and the outlet header 38.

In view of the excessive full load pressure drop under conditions such as described which impose high safe velocity values for light loads, the capacity of the superheater is considerably limited although the arrangement might be entirely suitable for certain low ranges of vapor flow from minimum to maximum. I therefore provide a more flexible method in the production of superheated vapor that will not only increase the load range, insure a uniformity in vapor temperature, but will permit the pressure drop to be maintained within specified limits throughout the entire widened load range.

According to the present invention, I provide a construction wherein those portions of the superheater which are subjected to radiant heat are protected by the desired rate of flow of vapor therethrough at all loads and at the same time the capacity of the superheater is not limited in load range by an excessive pressure drop through the radiantly heated section. I therefore also include a method of operation whereby the radiantly heated section can be employed to its best advantage by suitably controlling the amount of vapor admitted to that section and by delivering the remainder of the vapor to be superheated directly to a succeeding section of the requisite larger flow area.

For rates above a predetermined vapor flow, part of the vapor is supplied to the inlet header 36 from the mains 39 by means of pipes 47 which connect the mains with a branched fitting 48 leading to the inlet header 36, thus by-passing the radiantly heated portion of the superheater. A regulating valve 49 is arranged within the fitting 48 and serves to regulate the amount of by-passed vapor added to the header 36. The valve 49 may be controlled by any characteristic of the rate of vapor flow to, through or from the superheater. I have chosen to show a pressure-controlled valve, operating in response to variations in vapor pressure in an outlet pipe 43 leading from the outlet header of the superheater. The pipe 50 connects the outlet pipe 43 with a suitable valve-actuating device 51 which automatically operates the valve 49 in a manner well known in the art. For a given pressure in the mains 39, the pressure in the outlet pipe 43 is indicative of the pressure drop through the entire superheater, and with the pressure at the inlet end maintained substantially constant, any variations in pressure at the outlet will provide impulses for the valve 49 which are directly related to the pressure drop across the entire superheater. Similarly, controlling the valve by a pressure at some intermediate point in the path of vapor flow would provide an actuating impulse which is also directly related to the pressure drop up to the selected intermediate location.

For certain conditions, it might be preferred to have the valve 49 actuated directly in response to the difference in pressure between two selected points in the path of vapor flow, irrespective of the pressure of the vapor supplied to the superheater, in which case the valve 49 would be con-

trolled by pressures from the two selected points. Fig. 1A is representative of the arrangement thus modified wherein the valve-actuating device 151, of a known type operable in response to pressure differentials, is connected by pipes 152 and 153 respectively to points in the path of vapor flow of relatively high and low pressures; pipe 152 being connected to the header 36 by means including the elbow fitting 154 and therefore subject to pressure of vapor at the outlet end of the section comprising radiantly heated tubes 16; pipe 153 being connected to valve 142 at the entrance to distributor 33 and therefore subject to pressure of vapor being delivered to the superheater unit.

In the specific embodiments shown, when the rate of vapor flow through the superheater is such that the pressure drop over a given portion is unduly increased and the pressure of the vapor leaving the superheater is correspondingly reduced, the regulating valve 49 is automatically operated to by-pass vapor around the radiantly heated section to the inlet header of the convection section. In this manner, a predetermined amount of vapor passes through one portion of the superheater sufficient to protect it against overheating, and within the permissible pressure drop for that portion, and any additional vapor to be superheated by-passes that portion and flows through the succeeding section in which the flow path is of larger cross-sectional area. The larger area compensates for the greater rate of flow with the result that the over-all pressure drop is less than would be the case if the total amount of vapor caused to pass in series through all sections of the superheater. The pressure of the vapor in the pipes 47 is, of course, the same as the pressure of the vapor supplied to the distributor 33 but the valve 49 acts to reduce the pressure of vapor flowing direct to the convection portion below that of the vapor flowing to the radiantly heated section. Consequently, there is no interference with the flow of vapor to the radiantly heated section, and yet the pressure is not reduced to an amount which would prevent the flow of by-passed vapor into the inlet header 36. The valve 49 is opened an amount sufficient to provide vapor flow from the pipes 47 into the convection section but not to such an amount which would build up a high backpressure that might prevent or seriously reduce the flow of vapor through the radiantly heated section.

When the control valve 49 is brought into operation due to the predetermined pressure differential across the entire unit as in Fig. 1, or across a selected portion as in Fig. 1A, the vapor flowing through the bypass connection 47 being throttled by the valve 49 is then expanded to the same pressure as the pressure of vapor entering the header 36 from the radiantly heated tubes 16; the pressure drop through the bypass connection being the same as the pressure drop through the superheater tubes up to the header 36 since the two paths of flow are in parallel and are subject to equal pressure conditions at their respective ends. It is recognized that a control valve 49 of the elementary form shown might have certain characteristics of operation which would cause a temporary fluctuation in pressure and vapor flow conditions at the header 36 when changing from one load to another; however, such conditions will soon subside since the basic operation of the valve is unaffected, and the valve being continuously subject to the pressure values for which it is set will open and close the bypass con-

nection as required in response to such pressure values.

In conjunction with the distribution of vapor to the various sections of the superheater at different loads, I also provide for a regulation of combustion conditions, so that heat is supplied to the superheater in an effective manner, and in coordination with the load. A desirable method is to operate only the larger and centrally located burner 9 for the lower rates of vapor flow through the superheater, and as the load is increased, cut in one or more of the smaller burners 10 in order to maintain a required exit temperature of the vapor. The changeover from one to a plurality of burners is made at approximately the time when the regulating valve 49 is opened, and under a load condition which insures a suitable quantity of well distributed vapor passing through and protecting the radiantly heated tubes. Burner 9 may appropriately be automatically controlled in response to the temperature of the superheated vapor. The controls for burners 9 and 10, as indicated in Fig. 1, comprise control devices 111 and 112 of known types, arranged for controlling the supply of fuel through pipes 109 and 110 respectively; device 111, for burner 9, being connected by pipe 113 to a thermally responsive element 115 at the outlet of the superheater, and device 112, for one or more burners 10, being connected by pipe 114 and fitting 116 to control pipe 50 through which variations in vapor pressure are transmitted.

An additional feature of my invention consists in connecting the branched-fitting 48 with the outlets 45, by means of pipes 52 and valves 53. These additional connections are, in effect, continuations of the pipes 47, so that saturated vapor may be shunted entirely, or in part, around the superheater depending on the conditions or circumstances which would make such an arrangement desirable. By providing separate pipe connections 47 from each of the mains 39, and also separate pipe connections 43 and 52 leading to the outlet fittings 45, a greater flexibility in operation may be had. In addition to being able to by-pass the superheater as already described, it is possible to deliver saturated and superheated steam in separate streams, independent of the number of generators supplying steam to the mains.

I claim:

1. The method of superheating a variable quantity of vapor to a predetermined temperature and at pressures within given limits, which comprises delivering heat to said vapor from a source separate from that required for vapor-generation, causing a part of the vapor to flow through tubes exposed to radiant heat from said separate source, maintaining the pressure of vapor supplied to said radiantly heated tubes substantially constant causing additional vapor to be combined with the radiantly heated part for flow therewith through tubes heated by convection, regulating the quantity of vapor so combined in accordance with a factor determined by the total quantity of vapor delivered to the superheater, and increasing the amount of heat delivered in accordance with the admission of the additional vapor to the second section.

2. Furnace apparatus comprising, in combination, means providing a combustion chamber, means providing for the combustion of fuel in said chamber, a superheater comprising a radiantly heated superheater section and a convection-heated superheater section, means provid-

ing for the flow of vapor serially through the radiantly heated section and the convection-heated section, means for maintaining the pressure of vapor supplied to said superheater substantially constant, and means for bypassing the radiantly heated section and at increased loads supplying additional vapor direct to the convection-heated section when the pressure drop across the superheater reaches a predetermined value.

3. The combination with a furnace including wall means defining a combustion chamber and means for burning fuel in said chamber, of a radiantly heated superheater comprising a row of substantially parallel tubes in heat transfer relation to the wall means which define the combustion chamber and being divided into two sets with the tubes of one set arranged alternately with respect to the tubes of the other set, and means providing for the flow of separate quantities of vapor to be superheated through the sets in opposite directions including means for admitting vapor of substantially equal amounts and temperatures to the respective sets so as to produce a substantially uniform temperature condition throughout the associated wall means.

4. The combination with a furnace including wall means defining a combustion chamber and means for burning fuel in said chamber, of a radiantly heated superheater comprising a row of substantially horizontal and parallel tubes arranged in heat transfer relation to and coextensive with the greater portion of the wall means defining the combustion chamber, the row of tubes being divided into two sets with the tubes of one set arranged alternately with respect to the tubes of the other set, and means providing for the flow of separate quantities of vapor to be superheated through one of the sets in one direction and through the other set in the opposite direction including means for admitting vapor of substantially equal amounts and temperatures to the respective sets so as to produce a substantially uniform temperature condition throughout said greater portion of the wall means.

5. The method of superheating vapor under pressure at different loads which comprises passing said vapor at low loads successively through different heating zones having different resistances to vapor flow for corresponding loads, and at higher loads passing the additional vapor through a zone of lower resistance in combination with vapor heated in a zone of higher resistance, and maintaining the amount of vapor passed through said zone of higher resistance substantially constant at said higher loads in accordance with a predetermined pressure drop across at least one of said zones.

6. The method of superheating vapor under pressure throughout a given load range and within predetermined limits of pressure drop across separated points in the patch of vapor flow which comprises passing said vapor at low loads successively through different heating zones, in one of which zones the vapor is heated mainly by radiation and in another of which the vapor is heated mainly by convection, and at higher loads by-passing said radiant zone and causing the additional amounts of vapor to flow only through said convection zone in combination with vapor from said radiant zone while maintaining the amount of vapor flowing through the radiant zone substantially constant, and controlling the relative amounts of vapor flowing through said

zones for loads within said given range in accordance with a predetermined pressure drop across separated points in the path of vapor flow.

7. The method of superheating vapor under pressure at different loads which comprises passing said vapor through different heating zones, in one of which zones the vapor is heated mainly by radiant heat from burning fuel at a relatively high pressure drop for a given load and in another of which the vapor is heated mainly by convection from gases of combustion from said fuel at a relatively low pressure drop for the same load, passing vapor at one load successively through said zones of high and low resistance and at an increased load passing the additional vapor through a zone of low resistance in combination with vapor heated in a zone of high resistance, and controlling the admission of said additional vapor to said zone of low resistance in accordance with pressure drop across separated points in the path of vapor flow while maintaining the amount of vapor flowing through said zone of high resistance substantially constant.

8. The method of superheating vapor under pressure at different loads which comprises heating regulated quantities of said vapor in different heating zones, including passing a quantity of vapor successively through all of said zones and at the higher loads bypassing the vapor in excess

of said successively heated quantity through less than the total number of zones, and regulating heat input to at least one of said zones in synchronism with the bypassing of said excess vapor whereby heat input at said higher loads is increased and decreased substantially in accordance with load variations.

9. In combination with a furnace having means for the combustion of fuel therein at varying rates of heat input to said furnace, a superheater having sections of tubes in series, one section comprising tubes exposed to radiant heat from said combustion means and another comprising tubes heated mainly by convection by gases of combustion from said furnace, means for supplying vapor to be superheated to said tubes, one part being admitted to said radiantly heated section and being caused to flow through both of said sections in series, another part of said vapor being admitted intermediately of said sections and being caused to flow through said convection-heated section in combination with vapor from said radiantly heated section, means for controlling the relative amounts of vapor flowing through said sections, and means for controlling the heat input to said furnace in accordance with said relative vapor flow.

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CERTIFICATE OF CORRECTION.

Patent No. 2,196,377.

April 9, 1940.

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It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 3, second column, line 35, after "vapor" insert --were--; page 4, second column, line 63, claim 6, for the word "patch" read --path--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 9th day of July, A. D. 1940.

(Seal)

Henry Van Arsdale,
Acting Commissioner of Patents.