June 26, 1934. M. FRISCH 1,964,149

STEAM GENERATOR

Filed Oct. 16, 1931 3 Sheets-Sheet 1

Fig. 1.

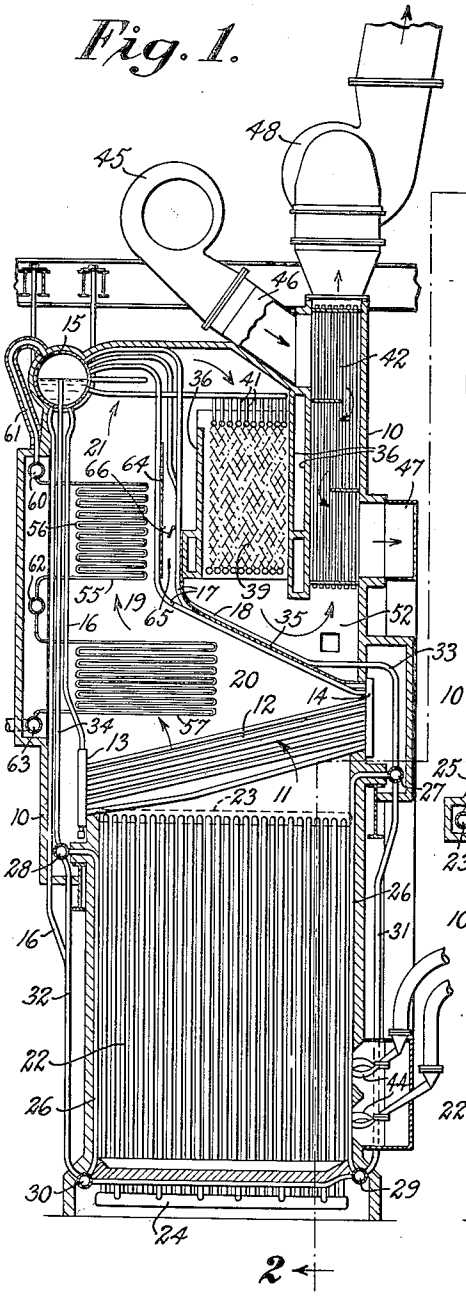
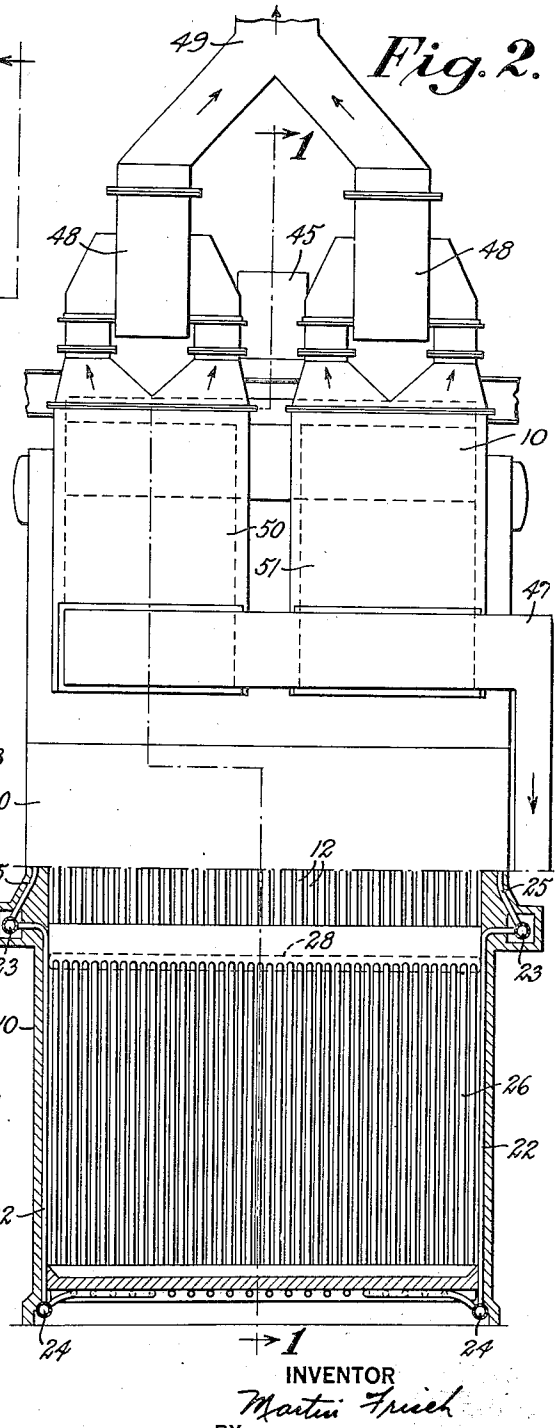


Fig. 2.



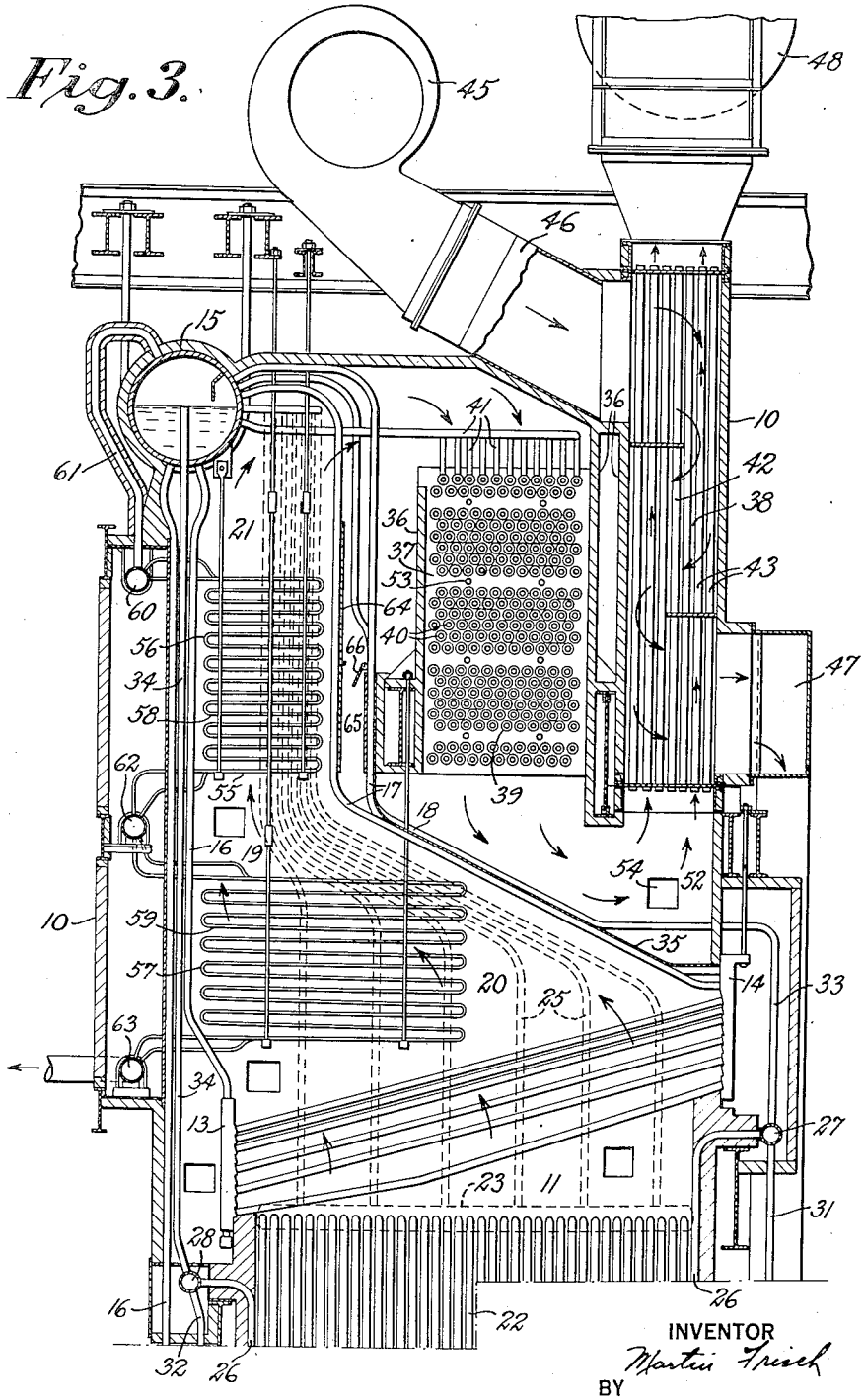
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STEAM GENERATOR

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Fig. 3.



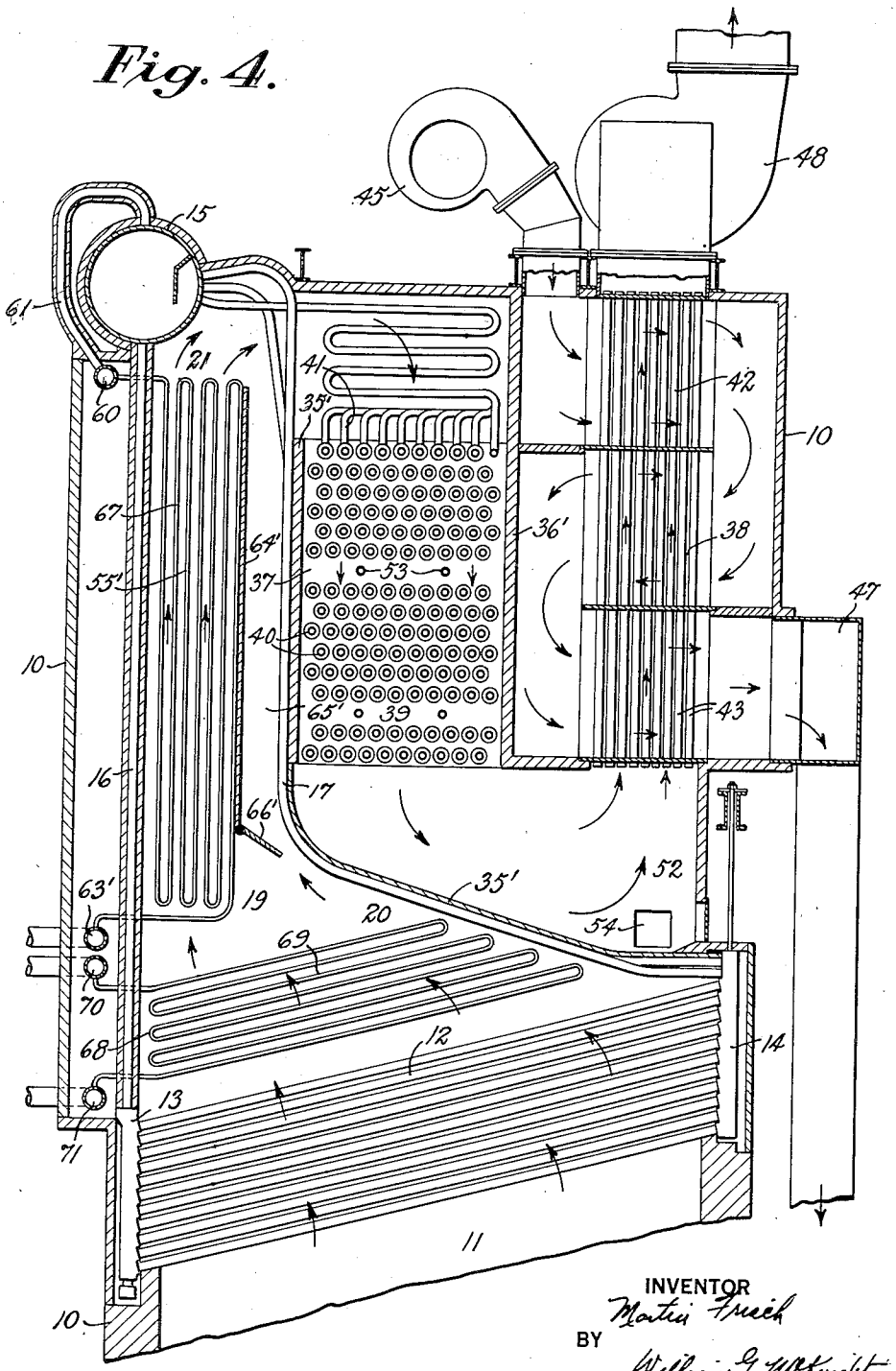
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June 26, 1934. M. FRISCH 1,964,149

STEAM GENERATOR

Filed Oct. 16, 1931 3 Sheets-Sheet 3

Fig. 4.



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UNITED STATES PATENT OFFICE

1,964,149

STEAM GENERATOR

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Application October 16, 1931, Serial No. 569,231

20 Claims. (Cl. 122—235)

The present invention relates to steam generators and has particular reference to steam generators of relatively large capacity for use in power plants.

In units of the above character the generator usually includes sufficient heat absorbing surface to reduce the temperature of the combustion gases to a relatively low value in order that the thermal efficiency of the generator as a whole may be as high as possible. In order to extract as much as possible of the heat from the combustion gases, heat absorbing surface of an auxiliary character, usually in the form of an economizer or air heater, or both, is advantageously employed and since units of the above character are ordinarily required to deliver high temperature steam, further auxiliary heat absorbing surface is employed to raise the temperature of the steam above the saturation temperature at the pressure at which it is generated. This latter auxiliary surface, which is utilized for the purpose of raising the temperature of steam and which may conveniently be termed steam heating surface may comprise either a superheater, a steam reheater (utilized, for example, to raise the temperature of steam bled from an intermediate stage of a turbine) or both. All of the above described heating surface may for purposes of convenience be termed auxiliary heating surface as distinguished from the heating surface comprising the boiler proper.

In the construction of steam generators of the character referred to, initial cost is an important factor in determining the extent to which auxiliary heat absorbing surface can advantageously be employed, since if the auxiliary heat absorbing surface exceeds a certain limit of cost the saving due to increased thermal efficiency to be derived from its use does not warrant the capital outlay required for its installation.

Experience has shown that the unit cost of the elements per se constituting the actual auxiliary heating surface is usually less than the unit cost of boiler surface, but such auxiliary heating surface ordinarily requires a considerable amount of space over and above that required for the boiler, which has a direct bearing on the cost of such surface, particularly in power plants located where the cost of land and buildings is relatively high.

The general object of the present invention is to provide a novel form of steam generator of the character in question in which the arrangement of the heating surface of the generator is such that the amount of auxiliary heating surface necessary to secure high over-all thermal efficiency of the generator can be employed, while at the same time keeping the space requirements of the generator and consequently numerous factors governing its cost, to a minimum.

Amongst the more specific objects of the invention are: To provide a steam generator having a relatively large amount of auxiliary heating surface as compared with the boiler surface; to provide a generator the arrangement of which is such that the floor space requirements of the generator are substantially no greater than the floor space requirements of a generator of like capacity not having comparable auxiliary heat absorbing surface; to provide a generator in which the auxiliary heat absorbing surface is so arranged as to permit the maximum flexibility in the proportioning of the various units providing the auxiliary heating surface; to provide a steam generator in which the units providing the auxiliary heating surface are situated within the main boiler setting in order to reduce radiation losses; to provide a steam generator in which the surface area of the setting as compared with the cubic contents of the generator is reduced to a practical minimum; to provide a generator in which a steaming economizer located within the generator setting may readily be employed; and to provide a generator in which a relatively high hydrostatic head is provided for promoting circulation through the boiler proper.

Other and more detailed objects of the invention and the advantages to be derived from its use will appear from the following detailed description of preferred forms of apparatus for carrying the invention into effect, such forms being illustrated in the accompanying drawings forming a part of this specification and on which:

Fig. 1 is a section taken on the line 1—1 of Fig. 2 and illustrating a generator embodying the invention;

Fig. 2 is a section taken on the line 2—2 of Fig. 1;

Fig. 3 is a section on an enlarged scale of a part of the generator shown in Fig. 1; and

Fig. 4 is a section similar to Fig. 3, illustrating another form of generator embodying the invention.

Referring now more particularly to Figs. 1 and 2, the setting for the generator is indicated generally at 10, and from the drawings it will be evident that the walls of the setting may be said to be generally vertical from top to bottom of the setting, so that the floor space requirements of the generator are substantially no greater than the floor space requirements for the combustion chamber in the lower portion of the setting.

The lower portion of the setting provides a combustion chamber 11 above which are located a plurality of tubes forming the major portion of the boiler proper. In the illustrated example, the boiler proper is of the horizontally inclined straight tube type comprising a plurality of tubes 12 arranged in rows and connected at their ends to a series of water compartments 13 and 14.

These tubes, comprising the steam generating tubes of the boiler, are located a material distance below the top of the setting. In the example shown, they are substantially midway of the vertical height of the setting.

Adjacent to the top of the setting there is situated the steam and water drum 15, connected by means of a group of down-flow circulators 16 with the water compartments 13 at the lower ends of the tubes 12 and with the lower water wall headers 24, 29 and 30, presently to be described. A second group of water circulators 17 extends upwardly, for a portion of the length of the circulators, in a horizontally inclined direction, as at 18, from the water compartments 14 to a point intermediate the walls of the setting, from which point they extend upwardly and then transversely to the steam and water drum 15. From an inspection of Fig. 1 it will be evident that by placing the steam and water drum 15 adjacent to the top of the setting and materially above the steam generating tubes 12, a relatively high hydrostatic head is provided for promoting rapid circulation through the boiler tubes. It will further be evident that the arrangement of the two groups of water circulators 16 and 17 provides a pass 19 for upward flow of combustion gases leaving the boiler tubes, which pass is divided into a lower portion 20 of converging cross-sectional area in the direction of gas flow and an upper vertically extending portion 21 of substantially uniform cross-sectional area, the upper portion 21 being situated to one side of the setting. The pass 19 may be said to be of generally L form.

The boiler illustrated is of the single pass type and the steam generating surface provided by the bank of tubes 12 may be augmented by water walls lining one or more of the walls of the combustion chamber. In the generator illustrated, water walls have been shown, these walls comprising a plurality of parallel vertical water tubes lining the four walls of the combustion chamber. The tubes 22 lining the side walls of the combustion chamber are joined at their upper and lower ends respectively by the headers 23 and 24, these headers being connected to the steam and water drum by suitably arranged circulating tubes such as the tubes 25.

The water wall tubes 26 lining the front and rear walls of the combustion chamber are connected at their upper ends to headers 27 and 28 and at their lower ends to headers 29 and 30. Water flows from the steam and water drum 15 to the lower headers 29 and 30 through downflow circulators 16 and some or all of the groups of tubes 31 and 32 connect these lower headers with the upper headers 27 and 28. The upper headers 27 and 28 are connected to the steam and water drum 15 by groups of circulators 33 and 34 which, as illustrated, may advantageously follow the general line of the groups of circulating tubes 16 and 17 connecting the steam and water drum 15 and water chambers 13 and 14.

By reference to Fig. 3, it will be evident that by suitably bending the circulating tubes 17 so that they lie substantially in a common plane above the bank of steam generating tubes, the horizontally inclined portions 18 of these circulating tubes may be made to form a baffle for directing the combustion gases into the upper portion of the gas pass 19. The baffling at this point is, however, advantageously made more securely gas-tight than is possible with tubes alone, and I prefer to employ a refractory baffle 35 at this point.

In the space provided within the setting above and to one side of the circulating tubes 17 and 33, baffling means 36 of any suitable form is employed to provide additional vertical gas passes within the setting, which passes are serially connected for flow of combustion gases leaving the first pass 19 deflected by the circulating tubes. In the illustrated embodiment I have shown two such additional passes, 37 and 38, the first additional pass 37 communicating at its upper end with the upper end of pass 19 and the second of said additional passes communicating at its lower end with the lower end of pass 37. These additional passes provide space within the setting for a relatively large amount of auxiliary heating surface, which may advantageously be in the form of an economizer and an air heater for the combustion air introduced into furnace 11. I have shown a counter-flow economizer 39 in pass 37, this economizer comprising a plurality of rows of transversely disposed, serially connected tubes 40 receiving water at the lower end of the economizer from a hot well or suitable feed water heater through a suitable supply conduit (not shown) and delivering to the steam and water drum 15 through one or more conduits 41. Due to the elevated position of the steam and water drum, the economizer may readily be placed at a level such that the top of the economizer is below the water level in the steam and water drum, which factor lends itself to the advantageous use, if desired, of an economizer of the steaming type.

In pass 38 I have shown an air heater 42 which may be of any suitable type. The form illustrated is of the stationary tubular type in which air is heated by contacting the exterior walls of tubes 43 through which the combustion gases flow. The specific details of the air heater form no part of the present invention.

The generator may be fired in any suitable manner. The type of furnace illustrated is most advantageously fired by means of fuel oil or powdered coal, which is fed to the combustion chamber through burners indicated generally at 44. Air for combustion is forced by means of a forced draft fan 45 through connection 46, air heater 42 and the conduit 47 to the burners 44.

In a generator of the type illustrated, the resistance to flow of the combustion gases through the several elements of the generator is such that forced or induced draft, or both, is desirable. In the present example I have illustrated in addition to the forced draft fan 45 induced draft fans 48, which may be of conventional form, for drawing the combustion gases from the last pass and delivering them to the breeching 49 leading to the stack. In a unit of the size illustrated the pass in which the air preheater is located may be divided into a plurality of sections in parallel with respect to gas flow therethrough, such as sections 50 and 51 (Fig. 2), each section being connected to a separate induced draft fan.

In the ordinary operation of a generator of the type in question, considerable dust and soot from the combustion gases is likely to accumulate in the passes in which are located the economizer and air heater. It will be evident from Fig. 1 that the arrangement of the passes in accordance with the present invention provides a conveniently situated soot collecting chamber 52 below the passes in which these elements of the generator are located, the floor of this chamber being defined by the baffling means which also defines the upper wall of the portion 20 of the

first up-flow gas pass. Soot blower units 53 of the usual type may be provided for the economizer, and soot and dust collecting on this element and blown therefrom by the soot blower will collect in chamber 52, from which it may be readily removed through the access door 54 in the setting. The sharp reversal of direction of flow of the gases between the down-pass in which the economizer is located and the up-pass containing the air heater will tend to minimize the amount of soot and dirt carried into the last pass by the combustion gases, and it will be evident that any suitable means desired may be provided for cleaning the air heater of such deposits of soot and dirt as may accumulate therein.

The first up-flow pass 19 provides space particularly suitable for the location of heat absorbing surface used for the purpose of superheating or reheating steam, or both. In the present form of generator the space provided by the pass 19 is utilized to accommodate a superheater indicated generally at 55, which superheater is advantageously divided into a primary section 56 and a secondary section 57. Each of these sections may be of any suitable form and in the illustrated embodiment comprise series of zigzag tubes 58 and 59. The tubes 58 comprising the primary section are connected to an inlet header 60, which is in turn connected to the steam space of the steam and water drum 15 by means of one or more connections 61, and to an outlet header 62 which may, as illustrated, also form the inlet header for the tubes 59 of the secondary section. The tubes of the secondary section are connected to a final outlet header 63.

The two sections of the superheater are spaced apart in the line of flow of the combustion gases, the secondary section being located in the wider lower portion 20 of the gas pass and the primary section being located in the upper narrower portion 21 of the pass.

In order to maintain a relatively constant degree of superheat when operating the boiler at different ratings, it is often desirable to provide a by-pass around all or a part of the superheater. A by-pass of this character may very readily be incorporated in a generator constructed in accordance with the present invention, and in the embodiment illustrated in Fig. 1 I have shown example of means for providing such a by-pass. In the illustrated example the vertically extending upper portions of the circulating tubes comprising the groups 17 are separated and a vertical baffle 64 is provided adjacent some of these tubes. This baffle, in conjunction with the baffling means 36 defining the wall of the down-flow pass in which is located the economizer provide a by-pass passage 65 connecting the lower portion 20 of the first up-flow pass with the upper end of the pass immediately adjacent to the entrance of the down-flow pass 37. This by-pass passage is controlled by any suitable means such as the damper 66. From an inspection of the drawings it will be evident that by adjusting the position of damper 66, more or less of the combustion gases may be caused to flow from a point immediately above the secondary section of the superheater directly to the economizer pass. Although the sectional area of the by-pass indicated is relatively small as compared with the area of the upper portion 21 of the gas pass 19, the amount of gas flowing through this by-pass passage when the damper is fully open is relatively great since the by-pass passage is substantially unobstructed by elements providing heat absorbing surface and the resistance to flow through this passage per unit area is less than that through the upper portion 21 of the pass 19. Due to the arrangement of the passes, the gases which are diverted from the pass 19 through the by-pass are thoroughly mixed with the gases which have passed over the primary section of the superheater before being delivered to the economizer, and it will further be evident that no loss in the over-all thermal efficiency of the generator will be involved by the provision of this by-pass since there is ample heat recovery surface in the economizer and the air heater for the efficient extraction of the available heat in the by-passed gases before they leave the setting.

Turning now to the form of generator illustrated in Fig. 4, the general arrangement is similar to that already described. The boiler tubes 12 are arranged in the same relation with respect to the setting as the tubes shown in Fig. 1 and are connected to the steam and water drum 15 at the top of the setting by means of two groups of circulators 16 and 17 which enter the water compartments 13 and 14 connecting the ends of the boiler tubes 12. In the present embodiment the water wall tubes for the combustion chamber and their cooperating circulating tubes have been omitted, but it will be evident that if desired a water wall structure similar to that illustrated in Fig. 1 may be employed. The circulating tubes 17 are bent in substantially the same manner as those illustrated in Fig. 1 to form a gas pass 19 having a converging lower portion 20 and an upper portion 21 of substantially uniform cross-section. Baffle 35' confines the gases to the pass thus formed and a vertical baffle 36' serves to divide the remaining space in the upper portion of the setting into two additional vertical passes in one of which is located the economizer 39 and in the other of which is located the air heater 42.

The first pass 19 for upward flow of gases is utilized in the present form to accommodate a superheater 55' comprising a series of vertically arranged zigzag tubes 67 connected at one end to inlet header 60 and at the other end to the outlet header 63'. Header 60 is connected to the steam drum by means of the usual connection 61. The lower portion 20 of pass 19 is utilized in the present case to accommodate a reheater 68 which in the illustrated form comprises a plurality of zigzag tubes the legs 69 of which lie substantially parallel to the boiler tubes 12 and which are connected at their ends to headers 70 and 71. In order to regulate the degree of superheat a vertical baffle 64' is advantageously placed alongside the superheater tubes to provide a by-pass passage 65' controlled by a suitable damper 66' at the lower end of the passage. As will be evident from the figure, the general arrangement of the several elements of the generator is substantially the same as in the embodiment previously described and the flow of combustion gases is substantially the same as that already described.

The arrangement of the superheater and reheater shown in Fig. 4 is but one of a number of different arrangements which it will be evident are possible for the steam heating surface employed. In the illustrated form the damper serves to regulate the quantity of combustion gas flowing over the superheater without regulating the quantity flowing over the reheater. It is evident that in an installation where close regulation of the

temperature of the reheated steam is desired rather than close regulation of the initial degree of superheat, the position of these two steam heating elements may be reversed and it will further be evident that both the reheater and the superheater may be divided into primary and secondary sections as is the superheater shown in Fig. 1 so that the by-pass passage will operate to regulate the temperatures of both the initially superheated and the reheated steam.

By arranging the heating surface in the above described general manner, I am enabled to assemble within a single setting the heating surface in such compact and efficient manner that the space requirements for a given capacity are as much as 30% less than the corresponding requirements for prior forms of generators of the same given capacity and this compactness of construction is obtained without sacrificing the ready accessibility of any of the heat absorbing surface employed in the generator. My improved arrangement also permits effective use of a larger proportion of the heat recovery surface than in prior forms of construction and permits the efficient use of a relatively large proportion of the heat recovery surface in the form of auxiliary heating surface, thereby tending to reduce the cost of the generator. In addition, the improved arrangement according to the present invention permits wide variation in the proportioning of the relative size of the various elements of the generator, in order to take care of the specific requirements for a given installation, without necessitating material alteration of the general form and character of the generator and without necessitating material changes in the external proportions of the setting. For example, it will be evident that the positioning of the vertical baffling means laterally of the boiler and the positioning of the upper portions of the group of circulating tubes 17 laterally of the boiler may be readily altered to alter the cross-sectional gas flow areas of the several vertical gas passes, in order to permit desired variation in the amount of surface utilized for steam heating surface, economizer surface, and air heating surface.

The elevated position of the steam and water drum of the boiler provides a relatively high head which aids materially in the promotion of rapid circulation through the boiler and by virtue of the arrangement contemplated by the invention the relatively long circulating tubes required for such elevated steam and water drum may be utilized advantageously as part of the means defining a gas pass within the setting. Furthermore, radiation losses are minimized since these circulating tubes are all within the boiler setting.

My improved arrangement permits efficient use of the desired amount of steam heating surface and further permits such surface to be proportioned and arranged in such manner as to meet the requirements for widely varying individual installations. It also affords a convenient means for including within the setting a by-pass enabling accurate control of steam temperatures to be obtained while at the same time avoiding any thermal loss due to the employment of such by-pass.

As used in the present specification, the term vertical pass is intended to describe a pass in which the general direction of the flow of gases is upward or downward, and includes passes arranged to give the gases a zigzag upward or downward flow. Furthermore, the term setting as herein employed is to be understood as referring to the setting of the generator as a whole, embracing the structure used for enclosing the several elements providing the auxiliary heating surface as well as the boiler surface.

From the foregoing description it will be evident to those skilled in the art that many changes and variations may be made in the arrangements hereinbefore illustrated by way of example, and it is to be understood that the present invention is not to be limited to the specific forms of constructional embodiment given herein, but is to be understood as including all such changes and modifications as may fall within the scope of the appended claims when they are given the broadest interpretation consistent with the state of the prior art. While I have shown the steam and water drum 15 at the extreme top of the setting, it will be understood that this is not necessary to the general attainment of the principal objects and advantages of the invention, though I prefer this arrangement. The steam and water drum may be considerably lower and even below the auxiliary heat absorbing devices within certain phases of the invention.

What I claim is:

1. A steam generator comprising a setting providing a combustion chamber, boiler surface comprising a bank of steam generating tubes located above said chamber and a material distance below the top of the setting, a steam and water drum located adjacent to the top of the setting, a plurality of circulating tubes connecting said bank with said steam and water drum, said circulating tubes being divided into groups converging within the setting above said bank to provide a vertical gas pass within the setting at one side thereof above said bank, means within the setting for providing a plurality of additional vertical gas passes above said bank, said passes being serially connected, and means providing auxiliary heat absorbing surface in each of said passes, said auxiliary heat absorbing surface comprising steam heating surface including a superheater in said first mentioned pass and an economizer and an air heater in said additional passes.

2. A steam generator comprising a setting providing a combustion chamber, boiler surface comprising a bank of steam generating tubes located above said chamber and a material distance below the top of the setting, a steam and water drum located adjacent to the top of the setting, a plurality of circulating tubes connecting said bank with said steam and water drum, said circulating tubes being divided into two groups, said groups converging within the setting above said bank to provide a vertical pass within the setting at one side thereof above said bank, means within the setting above said bank for providing two additional vertical passes above the bank, said passes being serially connected with respect to gas flow therethrough and means providing auxiliary heat absorbing surface in each of said passes, said auxiliary heat absorbing surface comprising steam heating surface including a superheater located in said first mentioned pass, an economizer located in the first of said additional passes and an air heater located in the second of said additional passes.

3. A steam generator comprising a setting providing a combustion chamber, boiler surface comprising a bank of steam generating tubes located above said chamber and a material distance below the top of the setting, a steam and water drum located adjacent to the top of the setting, a plu-

rality of circulating tubes connecting said bank with said steam and water drum, said circulating tubes being divided into groups converging within the setting above said bank to provide a vertical pass within and at one side of the setting for upward flow of combustion gases, means providing two additional vertical passes within the setting and above said bank, said additional passes comprising a down-flow pass communicating at its upper end with the upper end of said first mentioned pass and an up-flow pass communicating at its lower end with the lower end of said down-flow pass, an economizer located in said down-flow pass, said economizer being below the level of said steam and water drum, means for supplying water to the lower end of said economizer, means for connecting the upper end of said economizer to said steam and water drum and an air heater located in said last mentioned up-flow pass.

4. A steam generator comprising a setting providing a combustion chamber, boiler surface comprising a bank of steam generating tubes located above said chamber and a material distance below the top of the setting, a steam and water drum located adjacent to the top of the setting, a plurality of circulating tubes connecting said bank with said steam and water drum, said circulating tubes being divided into groups converging within the setting above said bank to provide a vertical pass within and at one side of the setting for upward flow of combustion gases, means providing two additional vertical gas passes within the setting and above said bank, said additional passes comprising a down-flow pass communicating at its upper end with the upper end of said first mentioned pass and an up-flow pass communicating at its lower end with the lower end of said downflow pass, means providing auxiliary heat absorbing surface in each of said passes, said auxiliary heat absorbing surface comprising steam heating surface including a superheater located in said first mentioned pass, and means for by-passing a portion of the combustion gases from an intermediate point in said first mentioned pass to said down-flow pass whereby to by-pass a portion of said steam heating surface.

5. A steam generator comprising a setting providing a combustion chamber, boiler surface comprising a bank of steam generating tubes located above said chamber and materially below the top of the setting, a steam and water drum adjacent to the top of the setting, circulating tubes connecting said drum and said bank, means including some of said circulating tubes for providing a vertical pass for upward flow of gases above said bank within and to one side of said setting, means providing a second vertical pass adjacent to said first pass for downward flow of gases and a third vertical pass for upward flow of gases within the setting, and means providing auxiliary heat absorbing surface in said vertical passes, some of said circulating tubes extending transversely of the setting below said second and said third passes to define the bottom of a chamber for collecting soot from the second and third passes.

6. A steam generator comprising a setting providing a combustion chamber, boiler surface comprising a bank of horizontally inclined steam generating tubes above said combustion chamber and a material distance below the top of the setting, water chambers connected to the ends of said tubes, a steam and water drum located adjacent to the top of the setting and a plurality of circulators connecting said water chambers with said steam and water drum, said circulators being divided into two groups, one of said groups extending substantially vertically adjacent to one side of the setting from the water chambers at one end of said bank to the steam and water drum and the other of said groups of circulators extending from the water chambers at the other end of said bank upwardly in a horizontally inclined direction for a portion of their length and substantially vertically from said first named portion upwardly of the setting, said groups defining between them a gas pass for upward flow of gases leaving said bank, the lower portion of said pass converging in the direction of gas flow, means within the setting providing a plurality of additional vertical gas passes within the setting above said horizontally inclined portions of the circulators in one of said groups, and means providing separate auxiliary heat absorbing surface in each of said passes, said auxiliary heating surface comprising steam heating surface including a superheater in said first mentioned pass.

7. A steam generator comprising a setting providing a combustion chamber, boiler surface comprising a bank of horizontally inclined steam generating tubes above said combustion chamber and a material distance below the top of the setting, water chambers connected to the ends of said tubes, a steam and water drum located adjacent to the top of the setting and a plurality of circulators connecting said water chambers with said steam and water drum, said circulators being divided into two groups, one of said groups extending substantially vertically adjacent to one side of the setting from the water chambers at one end of said bank to the steam and water drum and the other of said groups of circulators extending from the water chambers at the other end of said bank upwardly in a horizontally inclined direction for a portion of their length and substantially vertically from said first mentioned portion upwardly of the setting, said groups defining a gas pass between them for upward flow of gases leaving said bank, the lower portion of said pass converging in the direction of gas flow, means within the setting providing a plurality of additional vertical gas passes within the setting above said horizontally inclined portion of the circulators in one of said groups, and means providing auxiliary heat absorbing surface in each of said passes, said auxiliary heating surface comprising steam heating surface including a superheater in said first mentioned pass and said steam heating surface comprising a plurality of tubes in the lower portion of said first named pass substantially parallel to the tubes in said bank and a plurality of tubes vertically arranged in the upper portion of said first mentioned pass.

8. A steam generator comprising a setting providing a combustion chamber, boiler surface comprising a bank of horizontally inclined steam generating tubes above said combustion chamber and a material distance below the top of the setting, water chambers connected to the ends of said tubes, a steam and water drum located adjacent to the top of the setting and a plurality of circulators connecting said water chambers with said steam and water drum, said circulators being divided into two groups, one of said groups extending substantially vertically adjacent to one side of the setting from the water chambers at one end of said bank to the steam and water drum and the other of said groups of circulators extending from the water chambers at the other end of

said bank upwardly in a horizontally inclined direction for a portion of their length and substantially vertically from said first mentioned portion upwardly of the setting, said groups defining a gas pass between them for upward flow of gases leaving said bank, the lower portion of said pass converging in the direction of gas flow, means within the setting providing a plurality of additional vertical gas passes within the setting above said horizontally inclined portion of the circulators in one of said groups, and means for by-passing a portion of the combustion gases from the lower portion of said first mentioned pass directly to the inlet end of the first of said additional passes.

9. A steam generator comprising a setting providing a combustion chamber, boiler surface comprising a bank of horizontally inclined steam generating tubes above said combustion chamber and a material distance below the top of the setting, water chambers at the ends of said tubes, a steam and water drum located adjacent to the top of the setting and a plurality of circulators connecting said water chambers and said steam and water drum, said circulators being divided into two groups, one of said groups extending substantially vertically adjacent to one side of the setting from the water chambers at one end of said bank to the steam and water drum and the other of said groups of circulators extending from the water chambers at the other end of said bank upwardly in a horizontally inclined direction for a portion of their length and substantially vertically from said first mentioned portion upwardly of the setting, said groups defining a gas pass between them for upward flow of gases leaving said bank, the lower portion of said pass converging in the direction of gas flow, means within the setting providing a plurality of additional vertical gas passes within the setting above said horizontally inclined portion of one of the groups of circulating tubes and means providing auxiliary heat absorbing surface in each of said passes, said auxiliary heat absorbing surface including a two stage superheater having a first section located in the lower converging portion of said first named pass and a second section located in the upper portion of the same pass, and means for by-passing combustion gases around said second section.

10. A steam generator comprising a setting providing a combustion chamber, boiler surface comprising a bank of horizontally inclined steam generating tubes above said combustion chamber and a material distance below the top of the setting, water chambers at the ends of said tubes, a steam and water drum located adjacent to the top of the setting and a plurality of circulators connecting said water chambers and said steam and water drum, said circulators being divided into two groups, one of said groups extending substantially vertically adjacent to one side of the setting from the water chambers at one end of said bank to the steam and water drum and the other of said groups of circulators extending from the water chambers at the other end of said bank upwardly in a horizontally inclined direction for a portion of their length and substantially vertically from said first mentioned portion upwardly of the setting, said groups defining a gas pass between them for upward flow of gases leaving said bank, the lower portion of said pass converging in the direction of gas flow, means within the setting providing a plurality of additional vertical gas passes within the setting above said horizontally inclined portion of one of the groups of circulating tubes and means providing auxiliary heat absorbing surface in each of said passes, said auxiliary heat absorbing surface including a two stage superheater having a first section located in the lower converging portion of said first named pass and a second section located in the upper portion of the same pass, an economizer in the first of said additional passes, and means for by-passing combustion gases around said second section to said economizer.

11. A steam generator comprising a setting providing a combustion chamber, boiler surface comprising a bank of horizontally inclined steam generating tubes above said combustion chamber and a material distance below the top of the setting, water chambers at the ends of said tubes, a steam and water drum located adjacent to the top of the setting and a plurality of circulators connecting said water chambers and said steam and water drum, said circulators being divided into two groups, one of said groups extending substantially vertically adjacent to one side of the setting from the water chambers at one end of said bank to the steam and water drum and the other of said groups of circulators extending from the water chambers at the other end of said bank upwardly in a horizontally inclined direction for a portion of their length and substantially vertically from said first mentioned portion upwardly of the setting, said groups defining a gas pass between them for upward flow of gases leaving said bank, the lower portion of said pass converging in the direction of gas flow, means within the setting providing a plurality of additional vertical gas passes within the setting above said horizontally inclined portion of one of the groups of circulating tubes and means providing auxiliary heat absorbing surface in each of said passes, said auxiliary heat absorbing surface including steam heating surface comprising a superheater and a reheater located in said first mentioned pass, an economizer in the first of said additional passes, and means for by-passing combustion gases around a portion of said steam heating surface to said economizer.

12. A steam generator comprising a setting providing a combustion chamber, boiler surface comprising a bank of horizontally inclined steam generating tubes above said combustion chamber and a material distance below the top of the setting, water chambers at the ends of said tubes, a steam and water drum located adjacent to the top of the setting and a plurality of circulators connecting said water chambers and said steam and water drum, said circulators being divided into two groups, one of said groups extending substantially vertically adjacent to one side of the setting from the water chambers at one end of said bank to the steam and water drum and the other of said groups of circulators extending from the water chambers at the other end of said bank upwardly in a horizontally inclined direction for a portion of their length and substantially vertically from said first mentioned portion upwardly of the setting, said groups defining a gas pass between them for upward flow of gases leaving said bank, the lower portion of said pass converging in the direction of gas flow, means within the sttting providing a plurality of additional vertical gas passes within the setting above said horizontally inclined portion of one of the groups of circulating tubes and means providing auxiliary heat absorbing surface in each of said passes, said auxiliary heat absorbing surface in-

cluding steam heating surface comprising a superheater located in the upper portion of said first mentioned pass and a reheater located in the lower portion of said pass, an economizer located in the first of said additional passes and means for by-passing combustion gases around said superheater to the economizer.

13. A steam generator comprising a setting providing a combustion chamber, boiler surface comprising a bank of steam generating tubes located above said chamber and a material distance below the top of the setting, means within the setting above said bank for providing a plurality of serially connected vertical passes for flow of combustion gases leaving the bank, the first of said passes being of generally L form in vertical cross-section and the remaining plurality of passes being situated above the horizontally projecting lower portion of the first pass, and separate auxiliary heat absorbing surface in each of said passes.

14. A steam generator comprising a setting providing a combustion chamber, boiler surface comprising a bank of steam generating tubes located above said chamber and a material distance below the top of the setting, means within the setting above said bank for providing a plurality of serially connected vertical passes for flow of combustion gases leaving the bank, the first of said passes being of generally L form in vertical cross-section and the remaining passes being situated above the horizontally projecting lower portion of the first pass, an auxiliary heat absorbing surface comprising steam heating surface in the first pass and an economizer and an air heater in the remaining passes.

15. A steam generator comprising a setting providing a combustion chamber, boiler surface comprising a bank of steam generating tubes located above said chamber and a material distance below the top of the setting, means within the setting above said bank for providing three serially connected vertical passes for flow of combustion gases leaving the bank, the first of said passes being of generally L form in vertical cross-section and the two remaining passes being situated above the lower horizontally projecting portion of the first pass, a superheater in the first pass, an economizer in the second pass and an air heater in the last pass.

16. A steam generator comprising a setting providing a combustion chamber, boiler surface comprising a bank of steam generating tubes disposed above said chamber and a material distance below the top of the setting, a steam and water drum located adjacent to the top of the setting, a plurality of circulating tubes connecting said bank with said steam and water drum, said circulating tubes providing a vertical gas pass within the setting at one side thereof above said bank, means within the setting for providing a plurality of additional vertical gas passes above said bank, said passes being serially connected and means providing heat absorbing surface other than steam generating surface in each of said passes.

17. A steam generator comprising a setting providing a combustion chamber, boiler surface comprising a bank of steam generating tubes disposed above said chamber and a material distance below the top of the setting, a steam and water drum located adjacent to the top of the setting, a plurality of circulating tubes connecting each end of said bank with said steam and water drum, said circulating tubes converging within the setting above said bank to provide a vertical gas pass within the setting at one side thereof above said bank, means within the setting for providing a plurality of additional vertical gas passes above said bank, said passes being serially connected and means providing heat absorbing surface other than steam generating surface in each of said passes.

18. A steam generator comprising a setting providing a combustion chamber, boiler surface comprising a bank of horizontally inclined steam generating tubes above said combustion chamber and a material distance below the top of the setting, water chambers connected to the ends of said tubes, a steam and water drum located adjacent to the top of the setting, a plurality of circulators connecting each of said water chambers with said steam and water drum, said circulators providing a vertical gas pass within the setting at one side thereof above said bank, means within the setting for providing a plurality of additional vertical gas passes above said bank, said passes being serially connected, means providing auxiliary heat absorbing surface in each of said passes and means for by-passing a portion of the combustion gases from the lower portion of the first-mentioned pass to the inlet end of one of said additional passes.

19. A steam generator comprising a setting providing a combustion chamber, boiler surface comprising a bank of steam generating tubes located above said chamber and a material distance below the top of the setting, a steam and water drum above said bank of steam generating tubes, a plurality of circulating tubes connecting said bank with the steam and water drum, said circulating tubes defining a pass for the flow of combustion gases leaving said bank, means within the setting above said bank for providing a plurality of additional passes for the flow of combustion gases leaving the first-mentioned pass and means providing heat absorbing surface other than steam generating surface in each of said passes.

20. A steam generator comprising a setting providing a combustion chamber, boiler surface comprising a bank of steam generating tubes disposed above said chamber and a material distance below the top of the setting, a steam and water drum located adjacent to the top of the setting, a plurality of circulating tubes connecting said bank with said steam and water drum, said circulating tubes providing a vertical gas pass within the setting at one side thereof above said bank, means within the setting for providing a plurality of additional vertical gas passes above said bank, said passes being serially connected and means providing auxiliary heat absorbing surface in each of said passes, said auxiliary heat absorbing surface comprising steam heating surface including a superheater disposed in the first-mentioned pass, an economizer disposed in the first of said additional passes and an air heater disposed in the second of said additional passes.

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