Sept. 5, 1939. T. B. STILLMAN 2,172,227

FLUID HEAT EXCHANGE APPARATUS

Filed July 16, 1935 4 Sheets-Sheet 1

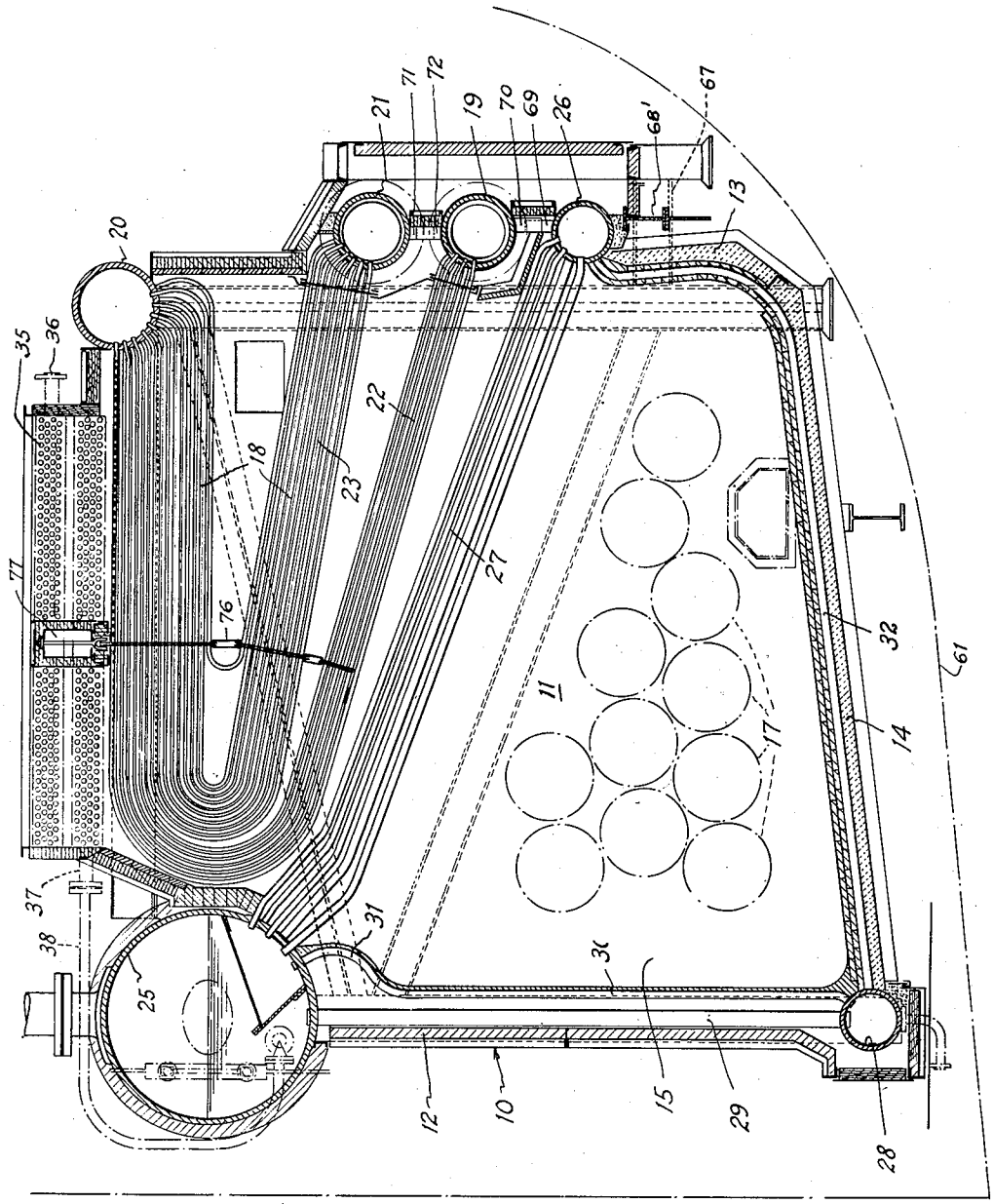


Fig. 1

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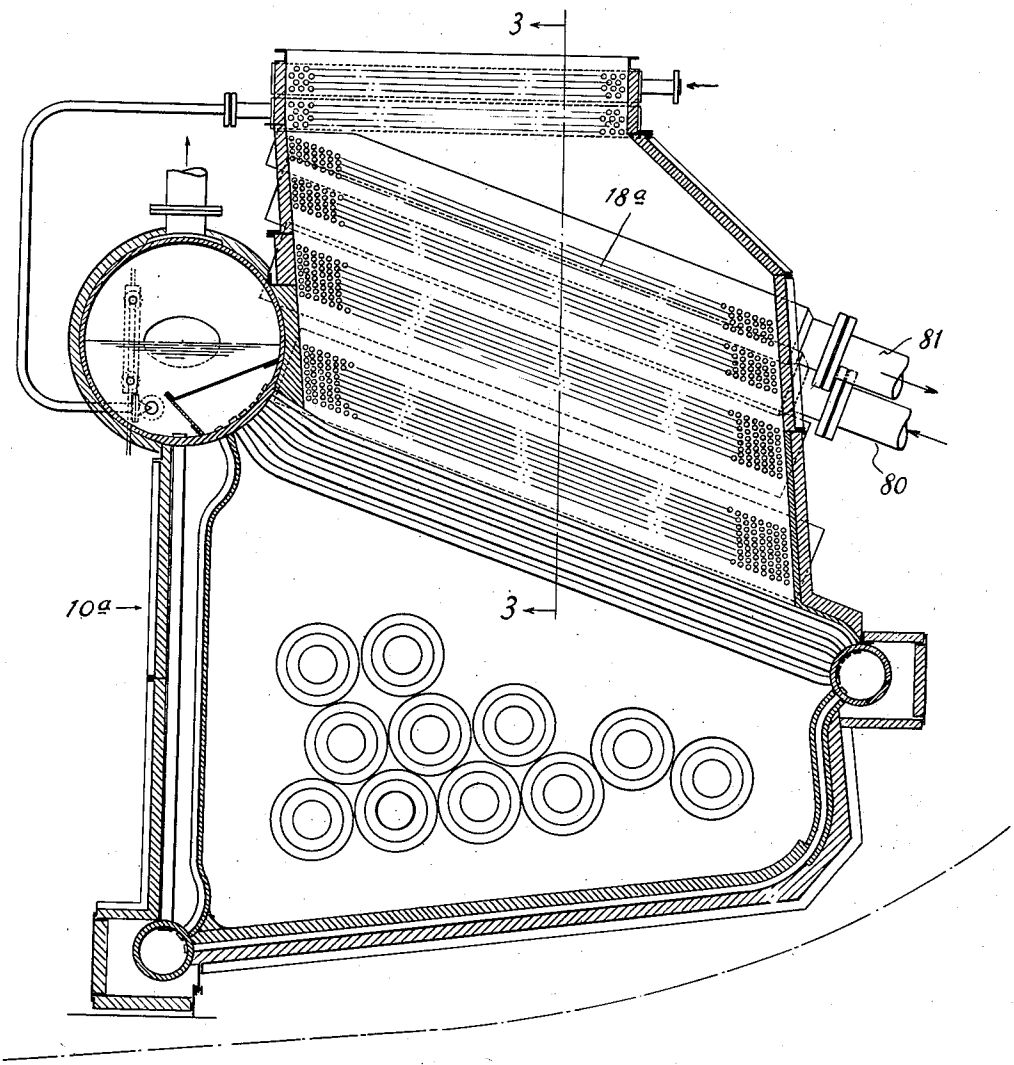
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FLUID HEAT EXCHANGE APPARATUS

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Fig. 2



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FLUID HEAT EXCHANGE APPARATUS

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Fig. 3

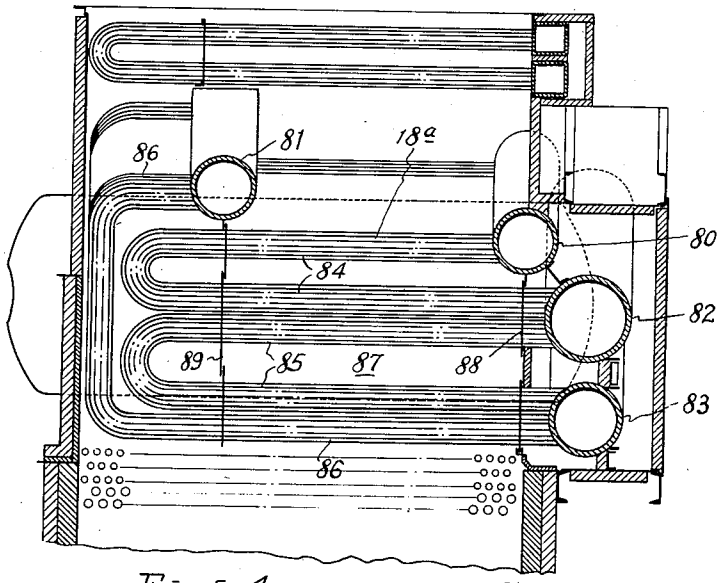
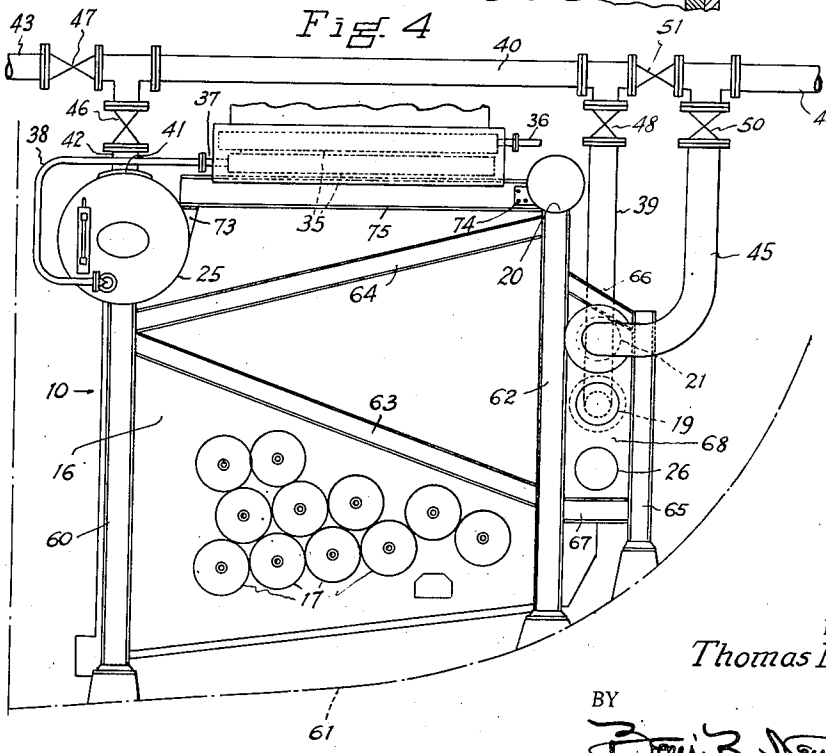


Fig. 4



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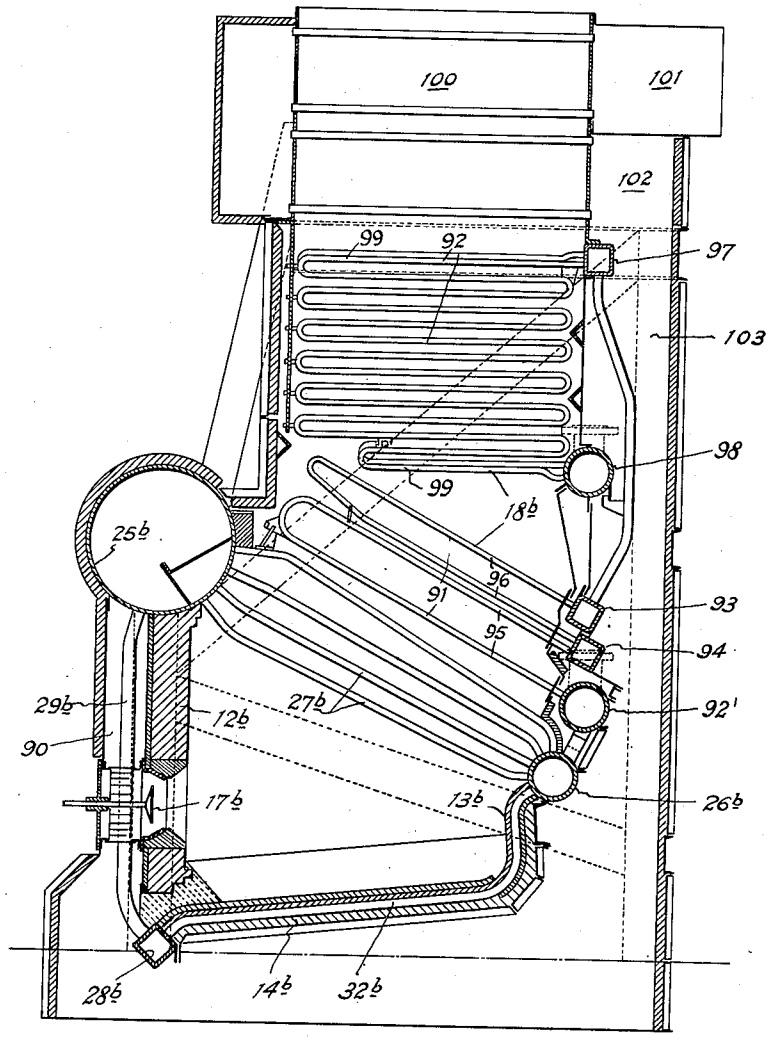
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Fig. 5



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UNITED STATES PATENT OFFICE

2,172,227

FLUID HEAT EXCHANGE APPARATUS

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Application July 16, 1935, Serial No. 31,569

3 Claims. (Cl. 122—478)

This invention relates to fluid heaters. It will be apparent as the description proceeds that the invention is especially applicable to power apparatus for use on ships. However, it is to be understood that in so far as certain of its broader aspects are concerned, it is not so limited, for certain novel features thereof may be used in connection with many types of power generating installations.

An object of the invention is to provide a direct-fired vapor superheater which is very compact and is capable of operating at relatively high rates per cubic foot of space occupied, thus providing a high-capacity unit which is admirably suited for installations where space and weight are important factors.

A further object is to provide a direct-fired vapor superheater wherein the superheat temperature may be quickly varied at will, and wherein the wall structure and heat absorbing surfaces are protected against the destructive action incident to high operating rates.

A further object is to provide a direct-fired vapor superheater wherein a bank of vapor generating tubes protects the superheating tubes from the radiant heat of the flame and wherein the surface area of the vapor generating tubes is as small as practical, consistent with the protection of the superheater.

A further object is to provide a vapor generator furnace of improved form which is capable of burning the maximum amount of fuel per unit of combustion chamber space and wherein the combustion chamber is delineated by the heat absorbing surfaces of the vapor rator.

A still further object is to provide an improved means for supporting the tubes of a superheater.

These and other objects are effected by my invention as will be apparent from an examination of the following description and claims, taken in connection with the accompanying drawings, in which:

Fig. 1 is a vertical sectional view of a steam superheater furnace unit constructed in accordance with the present invention;

Fig. 2 is a view similar to Fig. 1 and illustrating a modified form of construction;

Fig. 3 is a fragmentary sectional view taken on the line 3—3 of Fig. 2; and illustrating an improved arrangement of superheater tubes and headers, and an improved manner of supporting the superheater tubes from the headers;

Fig. 4 is a side elevation of the furnace shown in Fig. 1 and illustrates more clearly the pipe connections to the drums and headers and the supporting construction for the furnace; and

Fig. 5 is a view similar to Figs. 1 and 2 and illustrating a further modived form of superheater furnace unit.

As will appear more fully as the description proceeds, the type of apparatus disclosed in the accompanying drawings is used to superheat water vapor generated in an independent boiler unit operating with fuel burning means which are controlled independently from the burners of the superheater furnace and this type of apparatus may therefore be termed a separately-fired superheater furnace unit.

Referring now in detail to the construction illustrated and particularly to the embodiment of my invention disclosed in Figs. 1 and 4, the reference numeral 10 indicates, in its entirety, a separately-fired superheater furnace unit which includes a relatively small combustion chamber 11. The chamber 11 is defined by a relatively high side wall 12, a relatively low side wall 13, an upwardly inclined bottom wall 14, a rear wall 15 and a front wall 16.

A plurality of oil burners 17 are mounted in the front wall and they are operated to introduce fuel oil and air into the combustion chamber in a manner well known. It is to be understood at this point that, while I have elected to show a furnace fired by oil, my invention is not limited thereto in so far as all of its aspects are concerned, for other fuels may be used and other means may be provided for burning the fuel without departing from certain of the broader aspects of my invention. The burners 17 are of a type and capacity and are so arranged as to be capable of burning the maximum amount of fuel per unit of combustion chamber space.

In accordance with my invention I provide a superheater 18 in the upper portion of the unit 10, the surface area of which comprises the major portion of the heat absorbing surface of the unit. The superheater consists of an inlet header 19, an intermediate header 20, an outlet header 21, a group 22 of return-bend tubes connecting the inlet and intermediate headers, and a group 23 of return-bend tubes connecting the intermediate and outlet headers.

I also provide a means for protecting the superheater and walls of the furnace from the destructive action resulting from the relatively high rate of combustion in the relatively small combustion chamber 11. This means is shown as being in the form of a steam generating section having as small area of heat absorbing surface

as is practical, consistent with protection of the superheater.

The steam generating section comprises an upper steam and water drum 25 positioned at the upper end of the high side wall 12, a lower water drum 26 positioned at the upper end of the lower side wall 13, and a relatively small bank of steam generating tubes 27 connecting the steam and water drum 25 with the water drum 26 and being inclined downwardly from the drum 25 to the drum 26 and extending across the upper and outlet side of the combustion chamber 11. The steam generating section also comprises a water drum 28 positioned at the lower end of the high side wall 12, a row of downcomer tubes 29 within the high side wall 12 and connecting the water space of the steam and water drum 25 with the water drum 28, and a row of wall cooling tubes 30 at the combustion chamber side of the high side wall 12 and connecting the steam and water drum 25 and water drum 28, and the wall tubes 30 being curved at their upper ends as indicated at 31 to provide radial entrance into the drum 25 at points spaced from the points of entrance of the downcomer tubes 29 and also to provide for the expansion of the tubes 30 due to heat. The curved portions 31 also serve to protect the drum surface between the tubes 27 and the tubes 29. The steam generating section also comprises a row of wall cooling tubes 32 extending for the width of the bottom wall 14 and for the height of the low side wall 13, and directly connecting the drum 28 with the drum 26.

The downcomer tubes 29 are of sufficient size and sufficient in number to provide adequate circulation through the wall cooling tubes 30 of the high side wall 12, and through the wall cooling tubes 32 of the bottom wall 14 and low side wall 13 to the water drum 26 and through the bank of steam generating tubes 27 to the steam and water drum 25.

The downcomer tubes 29 and the wall cooling tubes 32 provide both for cooling the wall structure defining the combustion chamber and for the unidirectional flow of fluid through the bank of steam generating tubes 27. The ratio between the area of heat absorbing surface of the steam generating section to that of the superheater section is unusually low, and this is made possible by providing for this unidirectional flow of fluid through the bank of steam generating tubes 27, as will presently appear.

The primary function of the bank of steam generating tubes 27 is to shield or protect the superheater 18 from the radiant heat of combustion; and, in order to maintain the desired low ratio between the heat absorbing surface of the generator and that of the superheater while securing an efficient screening effect, it is necessary that the tubes forming this bank be small as and as few in number as is practical. If it were not for the fact that one way flow of fluid is provided through the bank of steam generating tubes 27, the bank would have to be deep enough to produce a sufficient difference in temperature between the tubes at the combustion chamber side and the tubes at the superheater side to provide for natural circulation between drums 25 and 26 through the bank. Such a construction would materially increase the heat absorbing surface of the bank of tubes and would also cool the furnace gases to such an extent that the desired high temperature of superheat could not be obtained. The unidirectional flow of fluid through the bank 27 could probably be provided by outside circulators between the drums 25 and 26; but this latter is not desirable because such circulators would occupy additional space in the boiler room.

In addition to the fact that the downcomer tubes 29 and row of wall cooling tubes 32 perform the novel dual function of protecting the furnace walls and of providing for the unidirectional flow of fluid through the bank of steam generating tubes 27, other features of novelty are present in the particular arrangement of the tubes to perform these functions in a highly efficient manner. By providing continuous tubes from the drum 28 to the higher drum 26, a portion of which is disposed in the vertical side wall 13, a positive flow of water is assured through each of the floor tubes, the head developed by the vertical portion overcoming the friction of the relatively long horizontally inclined portion. Also, by providing a junction header 26 at the upper end of the tubes 32, and an increased flow area in the bank of tubes 27 over that of the tubes 32, the resistance offered to the unidirectional circulation flow of fluid is reduced in that portion of the circuit where the steam-water ratio is highest, thereby assuring again a more positive circulation through the floor and wall tubes.

The separately-fired superheater furnace unit 10 is particularly suitable for applications where space and weight are at a premium, for example, in connection with steam generating apparatus for use in ships. From an examination of Figs. 1 and 4 it will be observed that the furnace unit 10 is substantially rectangular in cross section, with the steam generating section occupying the lower portion and one side of the rectangle and defining a combustion chamber which is trapezoidal in shape, and the superheater 18 being disposed in the remaining space of the rectangle which lies laterally of the steam and water drum 25 and above the inclined bank of tubes 27. This arrangement of the parts provides a highly compact unit and the superheater requires approximately no more head room than is required by the steam and water drum and requires no more width than that required by the combustion chamber. It is also noted that a highly compact economizer 35 is disposed above the superheater section and occupies very little head room.

The economizer 35 is provided with an inlet 36 which may be connected to a feed water pump (not shown), and an outlet 37 which is connected to the steam and water drum 25 by a pipe 38. The inlet header 19 of the superheater is connected by a pipe 39 to a pipe 40 and the latter is in turn connected to the steam outlet 41 of the steam and water drum 25 by a pipe 42 and to the major source of low-temperature or saturated steam by a pipe 43. The major source of steam is one or more steam generators (not shown). The outlet header 21 is connected to a pipe 44 by a pipe 45, and the pipe 44 continues to the point of use of the steam, for example, a steam turbine (not shown). A valve 46 is provided for controlling the flow of steam from the drum 25 to the pipe 40 and a valve 47 controls the flow of steam from the steam line 43 to the pipe 40. A valve 48 controls the flow of steam from the pipe 40 to the inlet header 19 of the superheater and a valve 50 controls the flow of steam from the outlet header 21 to the pipe 44. A by-pass valve 51 connects the pipes 40 and 44, and, when opened, permits low temperature or saturated steam to flow direct to

the turbine, and when closed, causes the steam to flow through the superheater to the pipe 44.

With the piping and arrangement of valves shown, the ship propulsion means may receive either low temperature steam from the pipe 43 or high temperature steam from the superheater and pipe 45. Under normal operation the steam from the pipe 43 and drum 25 flows through the pipe 40 and pipe 39 to the superheater, and from the superheater through pipe 45 to pipe 44 to the point of use. To secure this operation, valves 46, 47, 48, and 50 are open and valve 51 is closed. If, for example, in starting up the turbine or in reversing the ship, it is desired to use saturated or low temperature steam, only the pipe 43 may be connected to the pipe 40 and the latter to the pipe 44, valves 47 and 51 being opened and valves 46, 48 and 50 being closed. Under such operation, the superheater would be taken off the line, a change which can be quickly and effectively accomplished with the express-type of construction shown due to the water cooling of the combustion chamber and the readily controllable oil burners 17.

The superheater furnace unit 10 is suitably supported from the ship structure by means of frames disposed at each side of the furnace. Each of the frames comprises a column 60 supported at its lower end by the ship structure (indicated by the dot and dash line 61) and supporting at its upper end the steam and water drum 25, a column 62 also supported at its lower end by the ship structure 61 and supporting at its upper end the intermediate header 20, and struts 63 and 64 connecting the columns 60 and 62 respectively. Each frame structure also comprises a relatively short column 65 supported at its lower end by the ship structure 61 and connected to the column 62 by struts 66 and 67.

The side casing structure 68 of the furnace is secured to the columns in a manner well known, and the ends of the headers 19 and 21, and water drum 26 extend through openings provided in the side casing and are supported thereby. The water drum 26 is also supported by means of a beam 68' connecting the struts 67 at opposite sides of the furnace. The inlet header 19 is supported intermediate its ends by means of lugs 69 and 70 fixed to the drum 26 and header 19 respectively, and suitably secured together. Likewise, the intermediate header 21 is supported intermediate its ends from the inlet header 19 by means of similar lugs 71 and 72 secured to the headers 21 and 19 respectively, and also secured together. Brackets 73 and 74 are secured to the drum 25 and header 20 respectively, and spaced beams 75 are secured at their ends to the brackets 73 and 74 respectively, and serve as supports for the economizer 35. The return-bend ends of the groups 22 and 23 of superheater tubes are supported by plates 76 depending from an air-cooled beam structure 77 carried at its ends by the beams 75, just described.

Referring now to the modification of my invention shown in Figs. 2 and 3, it will be observed that I have shown a superheater furnace unit 10*a* which comprises substantially the same novel elements as that of the previously described embodiment, and the elements, with the exception of the superheater 18*a*, are constructed and arranged in substantially the same manner. The superheater 18*a* shown in Figs. 2 and 3, comprises an inlet header 80 and an outlet header 81 and intermediate headers 82 and 83. A group 84 of return-bend tubes connects the inlet header 80 with the intermediate header 82; a group 85 of return-bend tubes connects the intermediate headers 82 and 83; and a third group 86 of return-bend tubes connects the intermediate header 83 with the outlet header 81. It will be observed from an examination of Fig. 3 that the intermediate headers 82 and 83 are arranged at one side of a gas pass 87 and that the inlet and outlet headers are arranged in spaced relation in the gas pass and above the groups of return-bend tubes, with the outlet header at the side of the pass opposite the intermediate headers 82 and 83. All of the headers are suitably supported by the furnace structure. The outer return-bend ends of the tubes are supported by plates 89 depending from the header 81 and having openings therein, through which the tubes extend. A similar plate 88 depends from the header 80 and serves to define a side of the gas pass 87. This construction and arrangement provides a highly compact and efficient superheater and eliminates the necessity of extra supports for the groups of tubes which, if provided, would involve extra expense and complications and interfere with the proper flow of gases through the pass 87. An additional advantage of this construction is that the headers 80 and 81, beoing exposed to the hot gases in the pass 87, provide additional superheater surfaces.

In the modification shown in Fig. 5, it will be observed that I have included therein a large number of the advantageous features disclosed in the previously described modifications, and have shown a construction which may be profitably used in certain installations. Instead of introducing the fuel through the front wall of the furnace as was done in Figs. 1 and 2, the burners 17*b* are shown as introducing the fuel through the high side wall 12*b*. The high side wall is not water cooled as was the case in the previously described modification and the downcomer tubes 29*b* extend through a space 90 at the side of the wall 12*b* which is provided for conducting preheated air to the burners. The tubes 29*b* connect the steam and water drum 25*b* with a water drum or header 28*b*, shown as being square in cross section. The downcomers 29*b* supply the header 28*b* with the water and a row of wall cooling tubes 32*b* connect the header 28*b* with a water drum 26*b* and extend for the width of the floor 14*b* and for the heighth of the low side wall 13*b*, as was the case in the previously described modification. The water drum 26*b* is connected to the steam and water drum 25*b* by means of a bank of steam generating tubes 27*b* having an area of heat absorbing surface relatively small when considered with respect to the area of the heat absorbing surface of the superheater 18*b*. Thus, the modification shown in Fig. 5 provides for the unidirectional flow of fluid through the wall cooling tubes 32*b* and the bank of steam generating tubes 27*b*.

The superheater 18*b* is shown as comprising two sections 91 and 92 respectively; the first section 91 being disposed immediately above the bank of steam generating tubes 27*b* and being provided with an inlet header 92' and an outlet header 93 and an intermediate header 94, which headers are connected by rows 95 and 96 of return-bend tubes. The section 92 of the superheater consists of a junction inlet header 97 and a junction outlet header 98 connected by loop tubes 99 (of the superheater section 92) ar-

ranged for parallel flow of steam between the headers. By this construction and arrangement the direction of flow of the steam in the section 91, which is nearer the source of heat, is parallel to the gas flow, thereby providing the maximum protection for the superheater tubes adjacent the fire; and the direction of flow of steam through the section 92 of the superheater, which is remote from the source of heat, is counter to the direction of flow of the furnace gases, thereby incorporating in the superheater the effective counter-flow principle in that portion which has the greater surface and which is less likely to be injuriously affected by the heat of the furnace gases.

A tubular air heater 100 is disposed above the superheater 18b and is provided with an inlet 101 connected to a source of air under pressure (not shown), and an outlet 102 connected to a conduit 103 surrounding the furnace walls 13b and 14b and connected to the space 90 for conducting the hot air to the burners 17b.

While I have shown my invention in only three forms, it will be obvious to those skilled in the art that it is not so limited but is susceptible of various other changes and modifications without departing from the spirit thereof and I desire, therefore, that only such limitations shall be placed thereupon as are imposed by the prior art or as are specifically set forth in the appended claims.

I claim:

1. A separately fired superheater comprising a furnace and a steam superheating system of commensurate capacities, a natural circulation system of steaming ability below the capacity of the superheating system and incorporated as a protective means for the superheater, each of said systems having a bank of tubes disposed in a single gas pass across the furnace outlet in a manner to be subjected to a uniform transverse flow of hot gases throughout, the bank of tubes of the natural circulation system being in advance of the other to act as a radiant heat shield, a steam and water drum at the highest location in the natural circulation system, combined wall cooling and floor cooling tubes discharging into the bank of tubes of the natural circulation system, downcomers receiving water from the drum and delivering to the combined tubes, and other wall tubes connected directly to the drum and located between the furnace and downcomers for shielding the latter from the heat of the combustion chamber.

2. In a single pass separately fired superheater, a furnace, a steam and water drum, horizontally inclined steam generating tubes extending over the furnace and across the path of the furnace gases passing therefrom, a water drum positioned at the side of the furnace opposite the steam and water drum and communicating with the lower ends of said tubes, combined furnace floor and wall cooling tubes acting as parts of connections between the water space of the steam and water drum and the inlet ends of the generating tubes, means for burning fuel in the furnace, superheater inlet and outlet headers, an intermediate header positioned above the inlet and outlet headers, means for connecting the steam space of the steam and water drum to the inlet header, means for connecting the inlet header to an independent source of steam, a bank of superheater tubes including U-shaped tubes directly connecting the inlet header and the intermediate header, and similar U-tubes directly connecting the intermediate header and the outlet header, the latter U-tubes being shorter than the former and nested therein, all of the superheater tubes extending transversely of the path of the furnace gases to constitute parts of a single pass installation.

3. A combined steam generating and separately fired superheater unit comprising, in combination; means defining a furnace combustion chamber including a high side wall, a low side wall opposite the high side wall, and a floor upwardly inclined toward the low wall and connecting the lower ends of the high and low side walls; fuel burning means; a steam generator including a steam and water drum at the upper end of the high side wall, a submerged drum at the upper end of the low side wall, a small bank of steam generating tubes directly connecting the water drum and the steam and water drum and extending upwardly in a single gas pass across the path of the furnace gases, a water chamber at the lower end of the high side wall, a row of outside downcomer tubes positioned along the high side wall and connecting the water space of the steam and water drum with said water chamber, and a row of combined floor and wall tubes extending upwardly along the low side wall and connecting said water chamber to the water drum; and a superheater having tubes in the furnace setting so arranged with respect to the combustion chamber that the superheater is protected from the radiant heat of combustion by the bank of steam generating tubes, the superheater tubes and the steam generating tubes being so arranged that the furnace gases contact therewith entirely within a unidirectional single gas pass.

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