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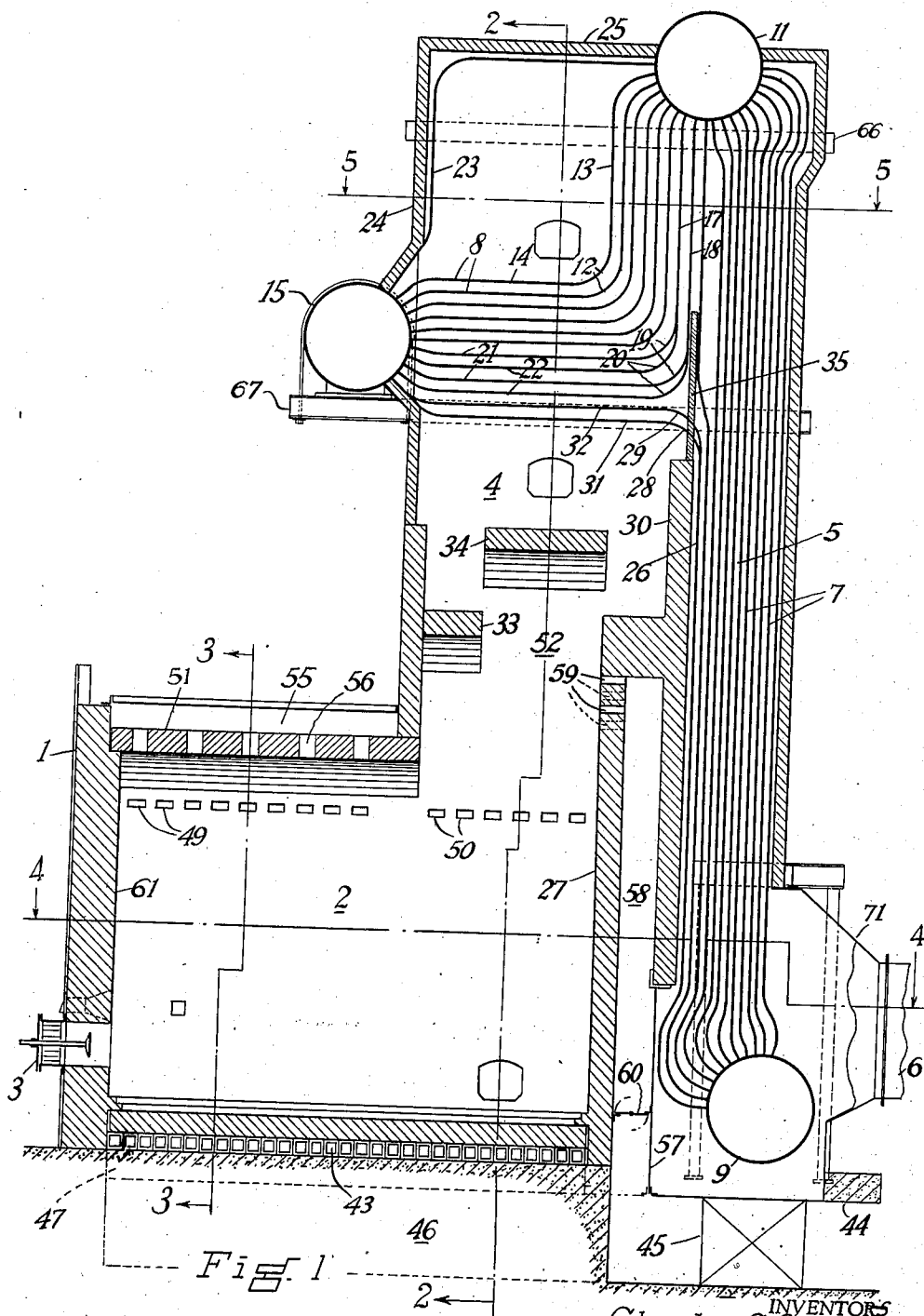
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2,257,821

FLUID HEATING UNIT

Filed April 7, 1938

4 Sheets-Sheet 1



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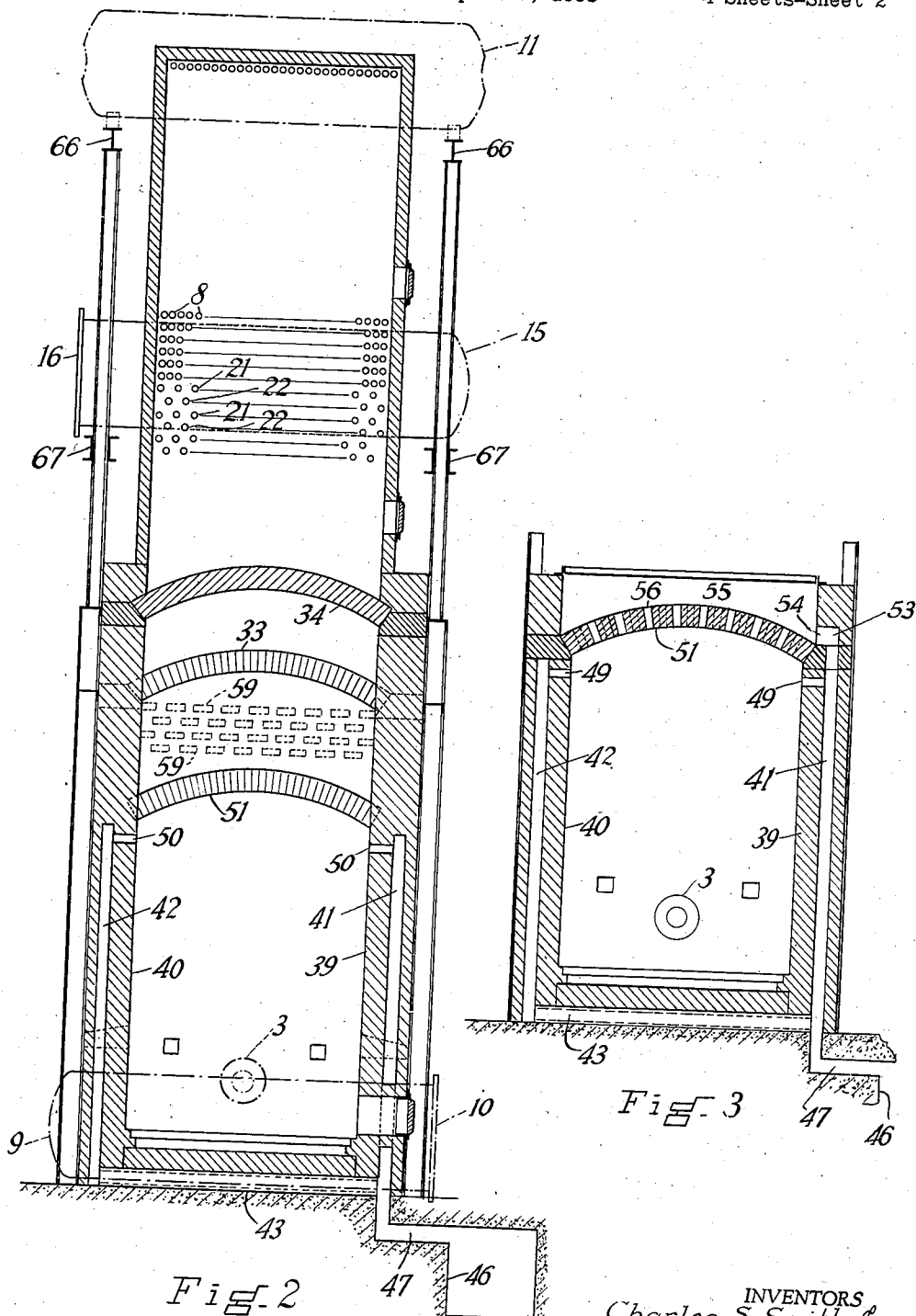
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FLUID HEATING UNIT

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4 Sheets-Sheet 2



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FLUID HEATING UNIT

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4 Sheets-Sheet 3

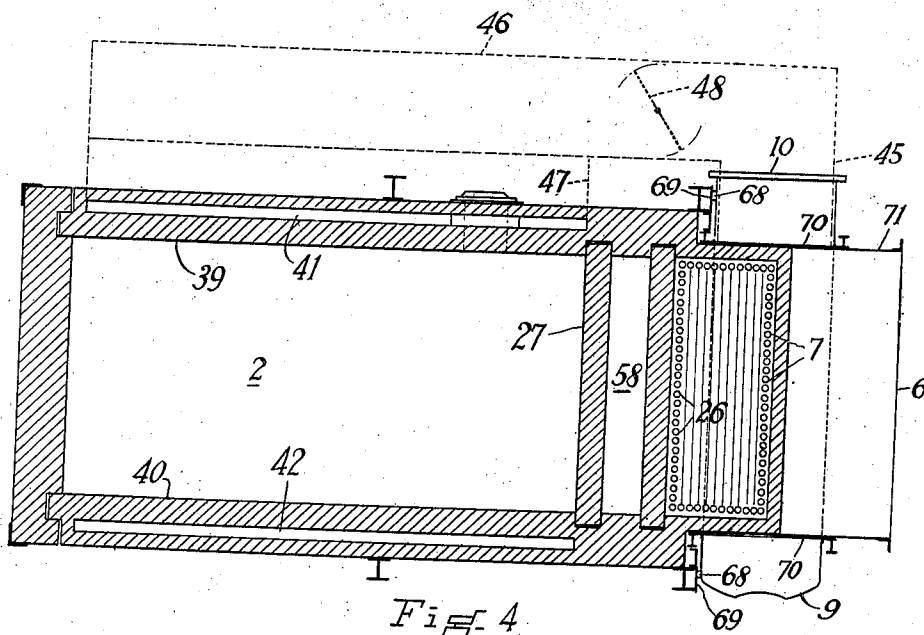


Fig. 4

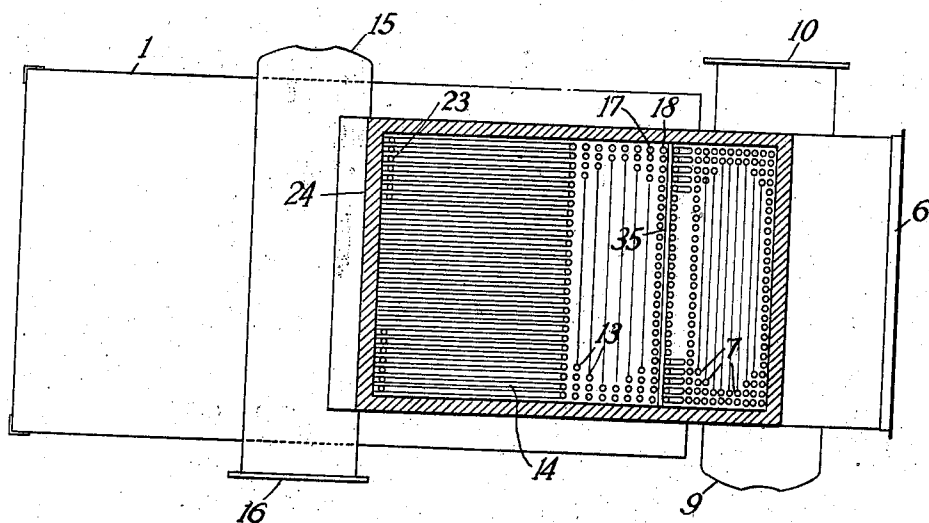


Fig. 5

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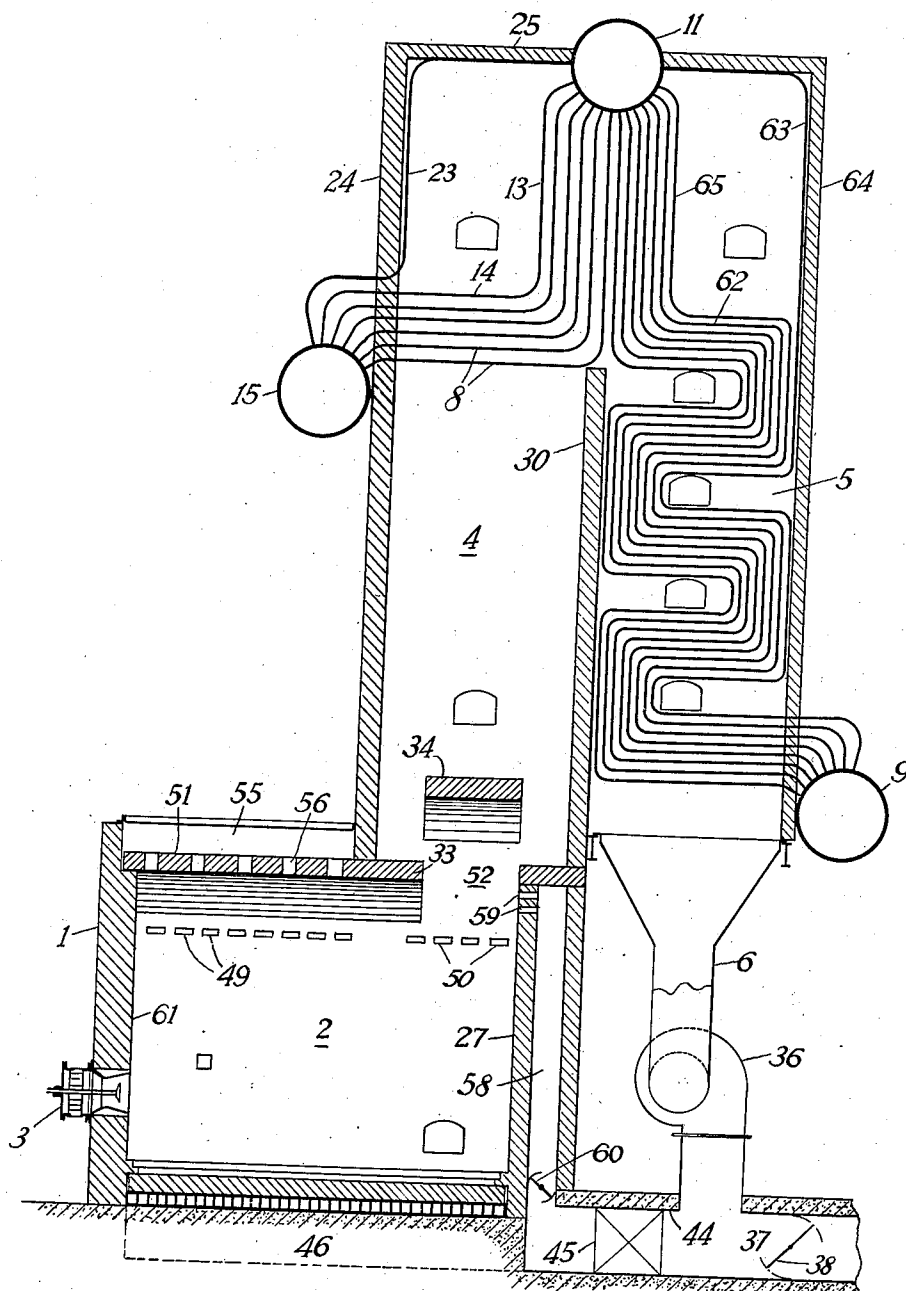
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FLUID HEATING UNIT

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4 Sheets-Sheet 4

Fig 6



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UNITED STATES PATENT OFFICE

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FLUID HEATING UNIT

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Application April 7, 1938, Serial No. 200,598

22 Claims. (Cl. 122—336)

The invention disclosed herein relates to a fluid heater wherein the fluid to be heated is conducted through tubes which are exposed to heating gases, an important objective being an improved form of device for heating a fluid such as air, particularly where the air is heated continuously to relatively high temperatures and is maintained at relatively high pressures. In a practical embodiment of the invention the device is a direct-fired unit in which the air enters the heater at about 300° F. and is discharged at a final temperature of about 850° F., the air being forced through the heater at a pressure of approximately 45 lbs./sq. in. with a maximum pressure drop of about 1 lb./sq. in. from inlet to outlet. The usual forms of air heaters are unsuitable for such conditions, being generally adapted for use only at low pressures or, where higher pressures are involved, are intermittent in their action, such as the air heaters used for heating blast furnace air. Consequently, in order to meet the imposed conditions, this invention employs an air heater wherein the air passages are formed by tubes which have their ends connected to pressure vessels, the hot heating gases contacting the tubes exteriorly in such a manner as to insure the maximum air heating capacity while preventing metal temperatures from rising to values that would weaken or oxidize the metal.

In order to raise the temperature of the air to approximately 850° F. the heating gases may have an initial temperature of more than 1500° F. and the invention provides means to insure that under such conditions, the temperature of the tube metal does not exceed a safe working value for the material used. This involves a continuous progressive movement of the fluid inside all of the tubes and the maintenance of a sufficient mass velocity of flow through each of the tubes, in relation to local gas temperatures and local gas velocities outside, or to the intensity of the heating source, to prevent overheating of the tube metal at any location.

An additional object, therefore, is in the arrangement of tubular heating surface whereby the flow of fluid through the tubes is progressive from inlet to outlet and preferably in a generally counter-current direction with respect to the flow of heating gases; other objects being to establish suitable relations between the velocities of air and heating gases, and to maintain as high a rate of heat absorption throughout as is consistent with the relation of metal temperatures to temperatures of the gas and air.

Further objects contemplate the protection of

the tubular heating surfaces from over-heating, due to high fluid temperatures within the tubes, and high gas temperatures without, by causing the inside fluid to flow through a selected high-temperature portion of the fluid heater at a higher mass velocity than through other portions; by maintaining a lower mass velocity of the outside fluid over a high-temperature portion than over other portions; and by restricting the amount of radiant heat absorption. Such protective features are of particular importance when air is the fluid being heated, as the tendency for oxidation at high temperatures is greater than with other fluids.

The invention also includes the arrangement of heating furnace and means associated therewith for recirculation of combustion gases whereby the temperature of the heating gases may be controlled to prevent injury to the tubes, and whereby the high efficiency of operation is unimpaired, and the desired heating effect may be secured at reasonable cost.

Additional features will appear from the description which follows, particularly when read in conjunction with the accompanying drawings in which selected embodiments of the invention are illustrated.

In the drawings:

Fig. 1 is a sectional side elevation showing an embodiment of the invention in an air heater of the direct or separately fired type;

Fig. 2 is a vertical section along the line 2—2 of Fig. 1;

Fig. 3 is a vertical section along the line 3—3 of Fig. 1 showing details of the furnace;

Fig. 4 is a sectional plan along the line 4—4 of Fig. 1;

Fig. 5 is a sectional plan along the line 5—5 of Fig. 1; and

Fig. 6 is a sectional side elevation similar to Fig. 1 but showing a modification.

The arrangement in general comprises a furnace 1 having its combustion chamber 2 provided with suitable firing means such as one or more oil or gas burners 3. The hot gases of combustion are conducted from the chamber 2 through the connected upright passages or flues 4 and 5, flowing upwardly through the flue 4 and downwardly through the flue 5, and being discharged from the setting through the gas outlet 6. The tubular heating surface as shown includes the banks of tubes 7 and 8 which are so arranged that a portion of the total heating surface lies within each of the flues 4 and 5, the tubes of each bank having upright portions extending across the gas

passage which connects the flues. The air or other fluid to be heated, is delivered to the inlet header 9 under pressure through the inlet opening 10 at one end and is caused to flow through the tubes 7 from header 9 at their lower ends to an intermediate header 11 at their upper ends, the tubes 7 extending longitudinally of the upright flue 5 and being spaced apart in rows throughout their lengths, as indicated in the sectional views Figs. 4 and 5.

The tubes 8 form a substantially L-shaped bank in which the tubes are bent intermediate their ends as at 12 to provide upright leg portions 13 which are connected at their upper ends to the intermediate header 11, and horizontally disposed leg portions 14 which are connected at their outer ends to an outlet header 15 having an end opening 16 for discharge of the heated fluid.

Thus, the tubes 7 and 8 provide parallel paths for the flow of air within the respective banks, and in flowing first through the tubes 7 and then through the tubes 8, the air flows in a direction generally countercurrent to the flow of the heating gases. Since the heating gases follow an inverted U-shaped flow path, the portions 14, 13 of the tubes 8 are contacted successively, and the flow of gas is transverse to the tube lengths comprising each portion. In their downward flow through the flue 5, the heating gases sweep the tubes 7 longitudinally.

The tubes 8 in each of the vertical rows 17, 18, for example, are bent as at 19, 20 to form a plurality of horizontal rows 21, 22 wherein the tubes are staggered and more widely spaced than tubes in upper rows of the bank. An additional row of tubes 23 between the headers 11 and 15 forms a protective screen for the front wall 24 and end wall 25 at the upper portion of the flue 4, so that radiation of heat from the refractory walls, which would otherwise be active, is largely or wholly neutralized.

A row of tubes 26 extends upwardly from the inlet header 9 within the flue 5 adjacent the outer face of bridge wall 27, the tubes 26 being bent at 28, 29 above the bridge wall extension 30 into a plurality of horizontal rows such as 31, 32 wherein the tubes are staggered at relatively wide spacings, similar to the tubes in the upper succeeding rows 21, 22. The tubes 26 are connected at their outlet ends to the outlet header 15 and thus form a path for fluid flow from the inlet header 9 which bypasses the intermediate header and affords a lower flow resistance as compared with other tubes. Consequently, more air is conducted through the tubes 26 than through other tubes, and since the air is of lower temperature than the air flowing through the tubes 8, their horizontal portions 31, 32 serve as a radiation screen for the tubes above without themselves becoming overheated. The tubes in the flue 4 are shielded from direct radiation of heat from the furnace by the arches 33, 34 which being offset and at different levels, provide the necessary gas flow area therebetween; however, the tubes in the lower rows receive a limited amount of radiant heat, partly by reflection from the walls of the flue and partly by radiation from the hot gases in the space above the arches 33 and 34.

The baffle 35 projects upwardly from the bridge wall extension 30 and being spaced at its upper end from the intermediate header 11, directs the heating gases across the upper portions of tubes

8 in passing to the flue 5 where the gases flow in contact with the upright tubes 7.

In this embodiment, the tubes 7, 8 and 26 are of equal diameters and spaced at equal distances across the width of the setting except in the lower horizontal rows 21, 22, 31, 32 where the spacing of tubes is increased as already described. However, the spacing between rows is progressively decreased in the direction of gas flow, thus reducing the effective gas flow area as the gases become cooler and maintaining as high a rate of heat absorption throughout as will not cause overheating of the tube metal; the spacing between rows being a maximum for the rows containing the horizontal portions of tubes 8 and 26, an intermediate spacing for the rows containing the vertical portions 13 of tubes 8, and a minimum spacing for the rows of upright tubes 7.

The tubes 8 and 26 in the lower rows 21, 22, and 31, 32, respectively, where the gases are hottest, are widely spaced so that while the heat received by radiation is relatively high, the heat transfer by convection is relatively reduced, in order to keep the metal temperature more close to that of the inside air. However, for the succeeding rows where the gases are cooler and there is little or no radiation, the tubes 8, including the vertical portions 13, are more closely spaced in order to provide a high rate of heat absorption by convection without overheating the tube metal. In the flue 5, the spacing of tubes 7 is further reduced to increase the mass velocity and heat transfer rate, which here is safe and proper, due to the fact that the gases are lower in temperature and flow of gas is longitudinally of the tubes 7 instead of across the tubes as in the case of tubes 8 and 26.

The tubes in the flue 4 are exposed to the hottest gases and since the flow of gases is transverse to those tubes, the heat transfer between the gases and tubes by convection is higher than for longitudinal flow, and a correspondingly high mass velocity of fluid flow through such tubes helps to prevent the metal of the tubes from becoming overheated. Accordingly, the mass velocity of the internal fluid is increased as the fluid flows in series through the banks of tubes 7 and 8 from inlet to outlet; as shown, the tubes being of equal diameters, with a greater number of tubes 7 connecting the headers 9 and 11 than of tubes 8 connecting the headers 11 and 15. Due to the lower flow resistance of tubes 26, a still greater mass velocity is maintained through these tubes to further protect those portions which extend across the flue 4 and are initially traversed by the hottest gases.

Since the fluid in the tubes 8 is at its highest temperature and these tubes are exposed to the hotter gases, the tubes 8 are preferably formed of a metal having higher heat resisting characteristics than the tubes 7 which are in a zone of cooler heating gases and carry the inside fluid at lower temperatures. Consequently, the use of an intermediate header 11 is advantageous in connecting the banks of tubes 7 and 8 when different metals are used, and when the numbers of tubes in the banks are different.

The gas outlet 6 is preferably subjected to an induced draft by connection to a fan 36 for example, as shown in Fig. 6, and a portion of the gas discharged from the fan is returned to the combustion chamber and adjoining passages for mixture with the heating gases before their contact with the air heater tubes, the remainder

of the gas being discharged through a suitable flue 37, having a damper 38, to a stack (not shown).

Opposing side walls 39, 40 of the furnace have hollow interiors 41, 42 which are connected at the bottom by the hollow tile 43 disposed beneath the furnace floor. A duct 44 leading from the discharge side of the induced draft fan is connected through a branch 45 to a duct 46 paralleling the furnace along one side and a passage 47 connects the duct 46 with the bottom of the side wall space 41, a portion of the gas from passage 47 being directed through the tile 43 to the opposite wall space 42. The amount of gas admitted through the passage 47 is controlled by means of damper 48. The walls are provided with openings 49, 50 for the discharge of gas from the spaces 41, 42 into the upper portion of the combustion chamber. The openings 49, 50 are arranged in spaced groups along each side wall, one group comprising openings 49 discharging directly below the main arch 51 and another group comprising openings 50 discharging below the outlet passage 52 through which the heating gases flow from the furnace into the flue 4.

The side wall space 41 to which the returned gas is first admitted, is extended vertically as at 53 to provide communication through one or more openings 54 with the enclosed space 55 above the furnace arch 51. The gas admitted to space 55 from the wall space 53 is discharged downwardly into the combustion chamber through the openings 56. In order to equalize the flow of gas through the side openings 49, 50 in opposite walls, the openings 54 above the furnace arch are at one side only to compensate for the greater flow resistance for the opposite side where the gas is required to travel through the hollow floor tile 43.

A connection 57 conducts gas from duct 44 to the hollow interior 58 of the bridge wall 27, from whence it is discharged through the rows of openings 59 into the stream of hot gases leaving the combustion chamber 2 through the outlet passage 52. A damper 60 in the connection 57 controls the amount of gas recirculated in this manner.

The arrangement of the gasports 49, 50, 56 and 59 as well as the direction of discharge there-through, is advantageous in promoting thorough mixing of the returned gas with the combustion gases prior to contact of the mixture with the tubular heating surface; furthermore, the gas is returned to the furnace at locations where there is a minimum of interference with combustion of the fuel. The gases are introduced at a plurality of locations in intersecting directions and, being admitted through relatively small ports, form jets which penetrate the body of hotter gases to produce an intimate mixture of lower and substantially uniform temperature throughout the stream of heating gases. The jets from the wall ports 49 enter the combustion chamber from opposite sides and the jets from the arch ports 56 enter in a downward and intersecting direction; the jets from the ports 50 also enter from opposite sides and intersect the stream of heating gases adjacent the outlet from the chamber; and at a succeeding location, the jets from ports 59 penetrate the gas stream in a direction transverse to the jets from the ports 50. In this manner, maximum effectiveness of recirculation is insured, and the desired tempering action obtained, with the least amount of gas being returned, thus reducing the load on the fan and

maintaining efficiency as high as possible under the working conditions.

There is also a cooling action on the furnace walls due to the admission of relatively cool gases through the furnace arch 51 and beneath the same, to provide a constantly moving layer of circulated gases which serve to protect the arch 51 and front wall 61 from radiant heat of the burning fuel. The bridge wall 27 is also maintained at a safe working temperature due to the circulation of cooled gas through the interior space 58. In addition to the thorough mixing of recirculated gases with the fresh gases within the combustion chamber, there is a further mixing action afforded by the admission of flue gas through the openings 59 and by the arrangement of arches within the flue 4, which being offset and at different levels as at 33, 34 deflect and mix the heating gases in advance of their contact with the air heater tubes.

In the modification shown in Fig. 6, there is the same general arrangement of furnace and connecting flues, as well as means for tempering the heating gases, as in the embodiment hereinbefore described; consequently, the same reference characters have been applied to parts which correspond. The heating surface, as before, is divided between the two flues 4, 5 and provides a greater velocity of flow through tubes 8 in the hotter zone than through tubes 62 in a cooler zone. The tubes 62 are bent back and forth at successive levels to form continuous lengths of return bend tubes between the inlet header 9 and the intermediate header 11. The tubes of one row 63 have portions lying adjacent the end wall 25 and rear wall 64 of the flue 5 where the gases turn to flow downwardly. Both groups of tubes 8, 62 have vertical portions 13, 65 respectively, extending across the gas passage connecting the flues above the bridge wall extension 30, and the flow of air from inlet header 9 is generally counter flow throughout with respect to the heating gases, the air flowing in parallel through tubes 62 from inlet header 9 to intermediate header 11 and thence through tubes 8 to the outlet header 15.

In the embodiment shown in Fig. 1, the intermediate and outlet headers 11 and 15, are supported respectively on structural members 66 and 67, while the inlet header 9, at the lower end of flue 5, is suspended from the intermediate header by means of the upright tubes 7. The inlet header has a bearing member 68 near each end which is in sliding engagement with the frame plate 69 and is thus permitted to move in a vertical plane to allow for expansion and contraction of the tubes 7. The sliding seals 70 at opposite sides of the outlet casing 71 prevent leakage of gas from the setting during movement of the header 9. In Fig. 6, the support for headers 11 and 15 may be the same as in Fig. 1, and inlet header 9 may be fixed in its relation to the intermediate header 11 since the tubes 62 which connect headers 9, 11, due to the plurality of bends therein, will fully compensate for expansional and contractional variations in length.

It is to be understood that other forms and embodiments are permissible within the scope of this invention, and with respect to some of the features, and for certain purposes, the fluid to be heated may be liquid or gaseous, or may be a mixture of a liquid and its vapor. Consequently, it is intended that the definition of invention as set forth in the appended claims,

be broadly interpreted and made subject only to such restrictions as are specifically expressed or imposed by prior art.

We claim:

1. A fluid heater comprising means forming first and second upright flues and means forming a gas passage connecting said flues at their upper ends, a bank of tubes within each flue and each bank including tubes having portions extending upwardly across said passage, fluid-pressure means maintaining a progressive flow of fluid through the tubes of each bank in succession, means maintaining a flow of heating gases in contact with said tubes in substantially countercurrent relation to the progressive flow of fluid therethrough, and means for increasing the mass velocity of said gases and of said fluid in the respective directions of flow.

2. In a fluid heating unit, means forming adjacent first and second upright flues connected at their upper ends for serial flow of heating gases therethrough in an inverted U-shaped path, a bank of tubes within said first flue so formed and arranged relative to the path of heating gases as to cause said gases to traverse different portions of the bank in succession, a bank of tubes within said second flue, means admitting fluid to the lower ends of the tubes in said second flue, means connecting said banks of tubes at their upper ends, fluid-pressure means for causing said fluid to flow in series through the tubes of both banks, and means for increasing the mass velocity of said gases and of said fluid in the respective directions of flow.

3. In a fluid heater comprising means forming adjacent upright flues having a connection at their upper ends for the flow of heating gases therethrough in an inverted U-shaped path, a bank of tubes having portions extending horizontally across one flue and other portions extending vertically across said connection, a bank of tubes extending longitudinally of said adjacent flue, means forming a fluid flow connection between the upper ends of the tubes of said banks, means for causing said gases to flow along said longitudinally extending tubes at a greater mass velocity than across said horizontally and vertically extending portions, and means for causing fluid to flow in series through the tubes of said banks.

4. In a fluid heater comprising tubes forming a bank having angularly related portions and means directing a flow of heating gases successively across said portions in transverse relation to the tubes thereof, said tubes being disposed in rows extending transversely of the flow of gases and including tubes more widely spaced in said rows in the portion first contacted by said gases than in a subsequently contacted portion.

5. In a fluid heater comprising tubes forming a bank having angularly related portions and means directing a flow of heating gases successively across said portions in transverse relation to the tubes thereof, said tubes being disposed in rows extending transversely of the flow of gases and including tubes bent intermediate their lengths to form a greater number of rows in one portion than in an angularly related portion, said greater number of rows being arranged forwardly of the portion first contacted by said gases and providing a greater area for the flow of gases across said rows than across any succeeding row of said bank.

6. In a fluid heater comprising tubes forming a bank having angularly related portions and means directing a flow of heating gases succes-

sively across said portions in transverse relation to the tubes thereof, said tubes being disposed in rows extending transversely of the flow of gases and including tubes bent intermediate their lengths to provide a greater tube spacing in rows first contacted by the heating gases as compared with the tube spacing in rows subsequently contacted.

7. Fluid heating apparatus comprising connected banks of tubes, the tubes of one bank having a greater combined internal cross-sectional area than the tubes of a connected bank, means directing a stream of heating gases first over the tubes of smaller area and then over the tubes of larger area, and means causing a fluid to be heated to flow in parallel through the tubes of each bank and successively through the tubes of said connected banks in countercurrent relation to the flow of heating gases, said gases being directed transversely of tubes first contacted and longitudinally of tubes last contacted at mass velocities increasing to a maximum for said longitudinal flow.

8. Fluid heating apparatus comprising means forming first and second upright flues and means forming a gas passage connecting said flues at their upper ends, a bank of upright tubes extending longitudinally of said second flue and across said passage, an L-shaped bank comprising tubes having portions extending across said first flue and other portions across said passage, said upright tubes providing a greater combined fluid flow area than the tubes of said L-shaped bank, means forming a fluid flow connection between the tubes of both banks at their upper ends, means directing heating gases through said flues in contact with all of said tubes, and means admitting a fluid to be heated to the lower ends of said upright tubes and causing said fluid to flow successively through said upright tubes and through the tubes of said L-shaped bank in a direction generally counter to the flow of heating gases.

9. In a fluid heater comprising an inlet and an outlet header, means including tubes forming separate fluid flow paths connecting said headers each having portions of the tubes thereof arranged in rows, means forcing fluid through said tubes under pressure from said inlet header, means directing a stream of heating gases successively over said portions, and means whereby the fluid carried by tubes in at least one of the rows first traversed by said heating gases is maintained separate from the fluid carried by tubes in other rows and heated to a lower temperature than the fluid carried by tubes in rows subsequently traversed.

10. A fluid heater comprising tubes bent to form horizontally and vertically extending leg portions, means for directing a flow of heating gases transversely of said horizontally extending portions and subsequently over said vertically extending portions, fluid-pressure means for causing fluid to flow through said tubes, and means for maintaining the fluid in tubes whose horizontally extending portions are first contacted by said gases at a lower temperature than the fluid in tubes whose horizontally extending portions are subsequently contacted.

11. In a fluid heater, a plurality of tubes arranged in rows and having portions disposed in intersecting planes, means directing a stream of heating gases successively over said portions, means connecting the tubes in all of said rows at the end of at least one of said portions, and

means causing fluid to pass through portions of the tubes first contacted by said gases at a higher mass velocity and lower temperature than the velocity and temperature of fluid passing through corresponding portions of tubes subsequently contacted.

12. In a fluid heater having first and second upright flues and means forming a gas passage connecting said flues at their upper ends, tubes within each of said flues and having portions extending upwardly across said gas passage, a header connecting said tubes at the upper ends of said portions, the tubes in said first flue having portions disposed in successive horizontal rows, means for causing heating gases to flow through said flues in transverse relation to said rows and upwardly extending portions, contacting first said horizontally disposed portions and subsequently said upright portions, means causing a fluid to flow through said tubes under pressure, and means maintaining the fluid in the lowermost of said horizontal rows at a lower temperature than the fluid in succeeding rows.

13. In a fluid heater having first and second upright flues and means forming a gas passage connecting said flues at their upper ends, an inlet header at the lower portion of said second flue, an outlet header adjacent an outer wall of said first flue and an intermediate header adjacent said passage, tubes within said flues having their lower ends connected respectively to said inlet and outlet headers and their upper adjacent ends connected to said intermediate header, and other tubes within said flues connected at their opposite ends to said inlet and outlet headers, means causing heating gases to flow successively through said flues in initial contact with said other tubes, and means admitting fluid to said inlet header at a pressure sufficient to maintain a progressive unidirectional flow of fluid throughout all of said tubes from said inlet to said outlet header.

14. In a direct-fired fluid heater in combination with its furnace, an upright flue having gas inlet and gas outlet openings at its opposite ends, said flue having its inlet opening in communication with the combustion chamber of said furnace for the admission of heating gases to said flue, a bank of fluid heating tubes within said flue intermediate said inlet and outlet openings, means whereby gas discharged from said outlet opening is combined with said heating gases prior to their contact with said tubes, and an interrupted baffle formation intermediate said gas-combining means and said tubes comprising offset portions at different levels.

15. In a direct fired fluid heater, in combination with its heating furnace having fuel firing means adjacent one end and means forming an outlet for heating gases from its upper portion adjacent its opposite end, fluid heating tubes and means directing heating gases from said outlet over said tubes whereby the temperature of said gases is reduced, and means for mingling a controllable portion of said cooled gases with the body of heating gases prior to discharge through said outlet, said cooled gases being directed into said heating gases in jets penetrating said heating gases in intersecting directions adjacent each end of said furnace.

16. In a direct fired fluid heater, in combination with its heating furnace having walls of hollow construction, inlet and outlet flues connected for sequential passage of heating gases from said furnace, fluid heating tubes in the path of said

gases within said flues and connected for progressive flow of fluid therethrough under pressure in counter-current relation to said heating gases, and means for controlling the temperature of said heating gases comprising connections between said outlet flue and said hollow walls and means for directing cooled gases from the interiors of said walls into the heating gases prior to contact of said gases with said tubes, said means being arranged to direct the cooled gases into the heating gases in a plurality of jets in intersecting directions adjacent at least one of said walls.

17. In a fluid heater comprising a bank of spaced tubes arranged in successive rows and having a common connection at one end, the tubes in one or more rows constituting a group of tubes different from a group in one or more other rows, means for directing heating gases over said groups of tubes in succession, means for directing fluid under pressure separately through tubes of the respective groups toward said common connection, and means for maintaining the fluid directed through tubes of a group first contacted by said gases at a lower temperature than the fluid directed through tubes of a group subsequently contacted.

18. In a fluid heater comprising a bank of spaced tubes arranged in successive rows and having a common connection at one end, the tubes in a plurality of adjacent rows constituting a group of tubes different from a group in a plurality of other adjacent rows, means for directing heating gases over said groups of tubes in succession, means for directing fluid under pressure separately through tubes of the respective groups toward said common connection, and means for maintaining the fluid directed through tubes of a group first contacted by said gases at a lower temperature than the fluid directed through tubes of a group subsequently contacted.

19. A fluid heater comprising means forming adjacent first and second flues having a connection for serial flow of heating gases therethrough, a bank of tubes within each flue and at least one of said banks including tubes having portions extending across said connection, fluid pressure means for maintaining a progressive flow of fluid through the tubes of each bank and through said banks in succession, means for maintaining a flow of heating gases in contact with said tubes in substantially countercurrent relation to the progressive flow of fluid therethrough, and means for increasing the average mass velocity of said gases and of said fluid in the respective directions of flow substantially throughout the extent of said flues and banks.

20. A fluid heater comprising means forming first and second substantially parallel flues and means forming a gas passage connecting said flues at their adjacent ends, a bank of tubes within each flue including tubes having portions extending across said passage, fluid-pressure means maintaining a progressive flow of fluid through the tubes of each bank in succession, means maintaining a flow of heating gases in contact with said tubes in substantially countercurrent relation to the progressive flow of fluid therethrough, and means for increasing the mass velocity of said gases and of said fluid in the respective directions of flow.

21. In a direct fired fluid heater, in combination with its heating furnace having fuel firing means adjacent one end and means forming an outlet for heating gases from its upper portion

adjacent its opposite end, fluid heating tubes and means directing heating gases from said outlet over said tubes whereby the temperature of said gases is reduced, and means for mingling a controllable portion of said cooled gases with the body of heating gases prior to discharge through said outlet, said cooled gases being directed into said heating gases in jets penetrating said heating gases in intersecting directions adjacent one end of said furnace.

22. In a direct fired fluid heater, in combination with its heating furnace having fuel firing means adjacent one end and means forming an

outlet for heating gases from said furnace adjacent its opposite end, fluid heating tubes and means directing heating gases from said outlet over said tubes whereby the temperature of said gases is reduced, and means for mingling a controllable portion of said cooled gases with the body of heating gases prior to discharge through said outlet, said cooled gases being directed into said heating gases in jets penetrating said heating gases in a downward direction adjacent the fuel-firing end of said furnace.

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