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Dungey et al.

[11] **3,927,646**

[45] **Dec. 23, 1975**

[54] **VAPOR GENERATOR**

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[21] Appl. No.: **479,588**

Related U.S. Application Data

[63] Continuation of Ser. No. 447,699, April 13, 1965, abandoned.

[52] **U.S. Cl.** ..... **122/6 A**; 122/406 S; 122/510

[51] **Int. Cl.²** **F22B 29/06**; F22B 37/24

[58] **Field of Search** ..... 122/DIG. 4, DIG. 5, 1, 122/6 A, 235 A, 250, 406 S, 406 ST, 448 S, 451 S, 479 S, 510

[56] **References Cited**

UNITED STATES PATENTS

2,035,908	4/1936	Michel	122/250
2,325,583	8/1943	Artsay	122/235
2,987,052	6/1961	Armacost	122/6
2,989,036	6/1961	Hake et al.	122/DIG. 4
3,003,479	10/1961	Bock et al.	122/1
3,007,459	11/1961	Koch	122/406
3,033,535	5/1962	Shaap	122/235
3,108,576	10/1963	Michel	122/235
3,125,995	3/1964	Koch	122/406
3,162,179	12/1964	Strohmeyer, Jr.	122/406
3,237,612	3/1966	Koch et al.	122/406

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[57] **ABSTRACT**

The present invention relates in general to the construction and operation of a forced flow fluid heating unit and more particularly to improvements in the construction and arrangement of fluid heating circuits especially adapted for use in a forced circulation once-through steam generating and superheating unit.

9 Claims, 6 Drawing Figures

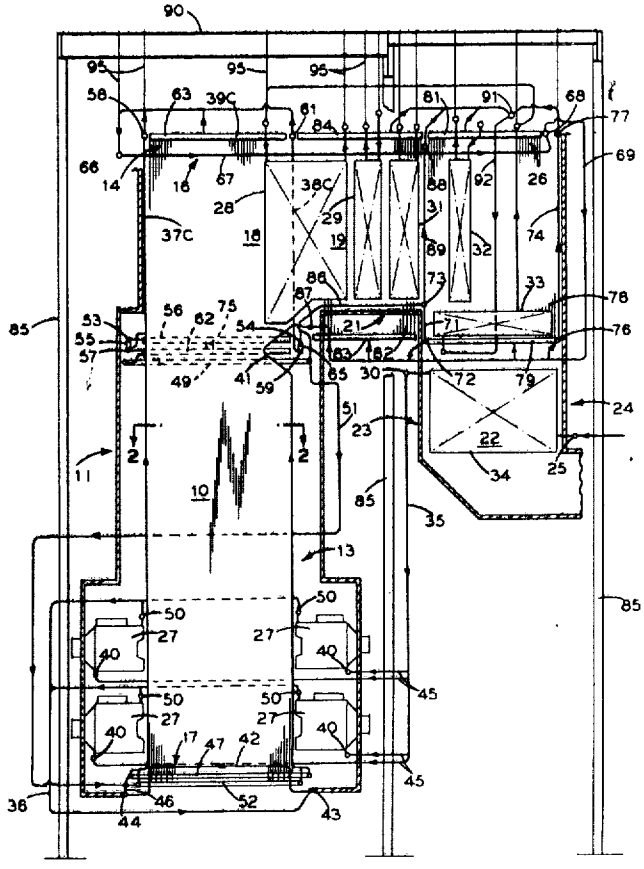

FIG. 1

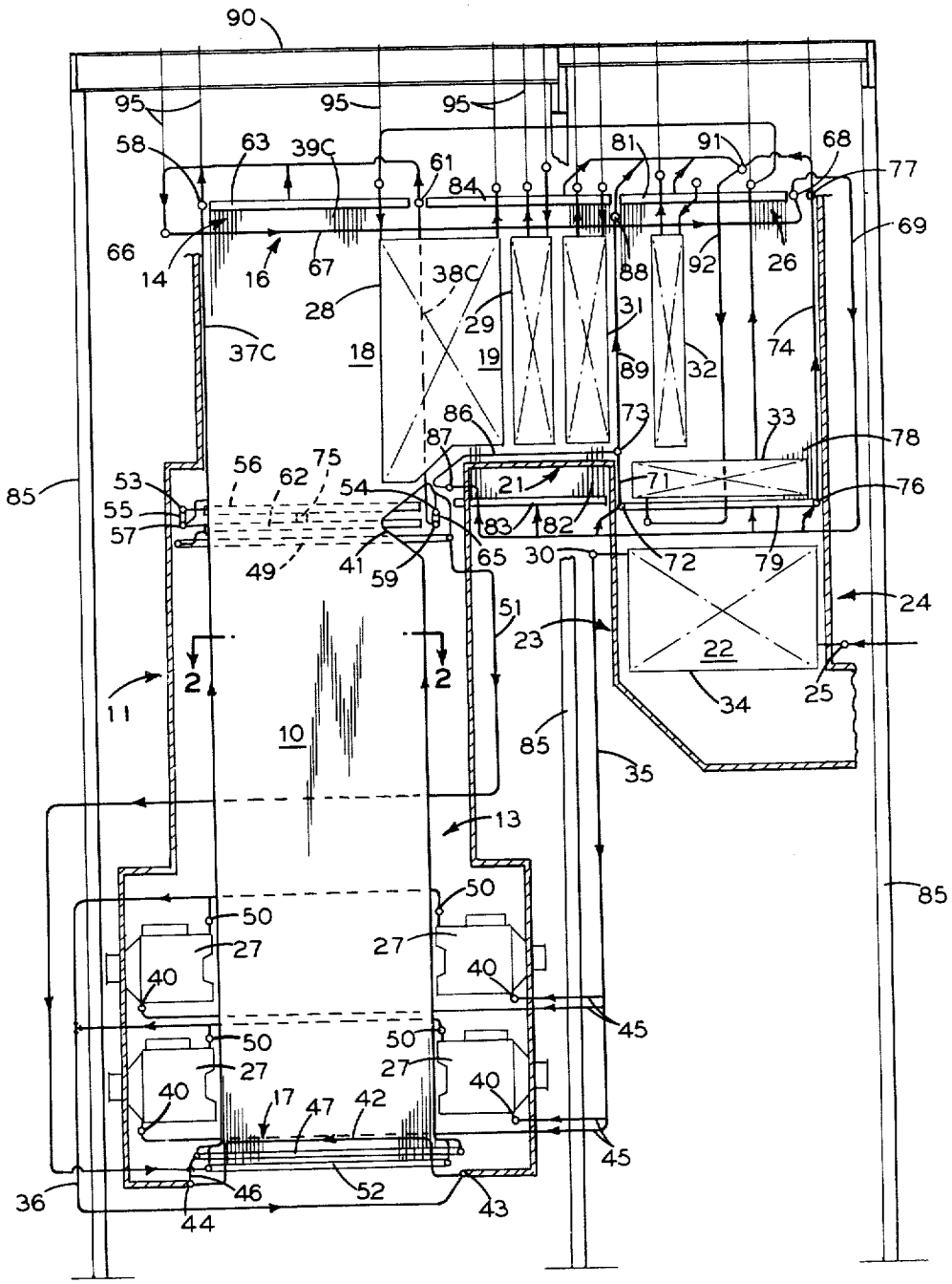

FIG. 2

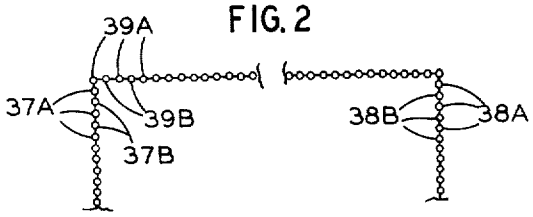

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FIG. 3

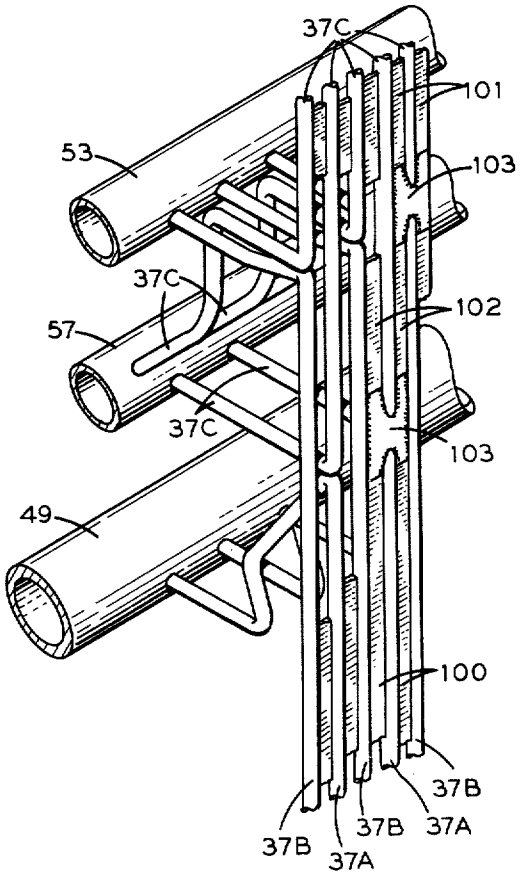

37C
101
53
103
37C
102
57
37C
103
49
100
37B
37B
37B
37A
37A

FIG. 5

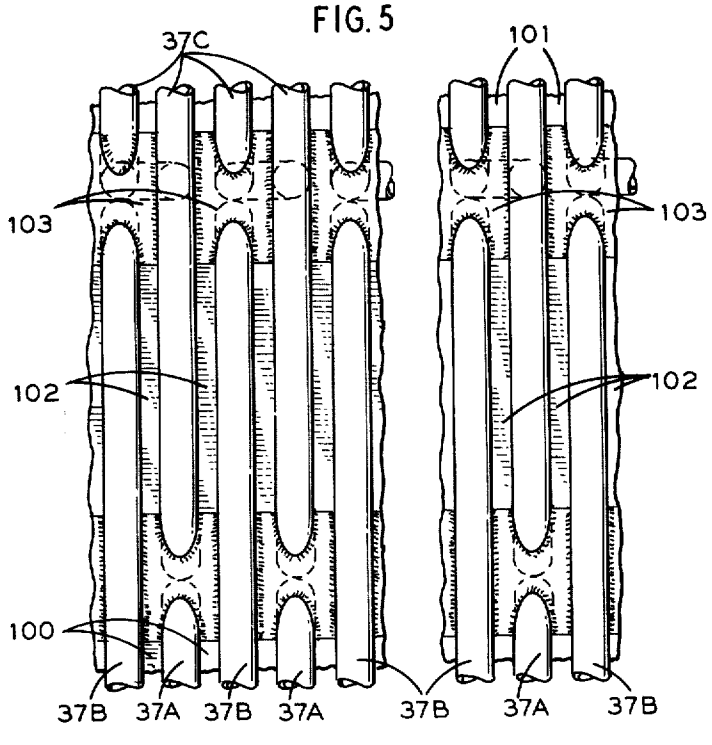

37C
101
103
103
102
102
100
37B
37A
37B
37A
37B
37A
37B

FIG. 6

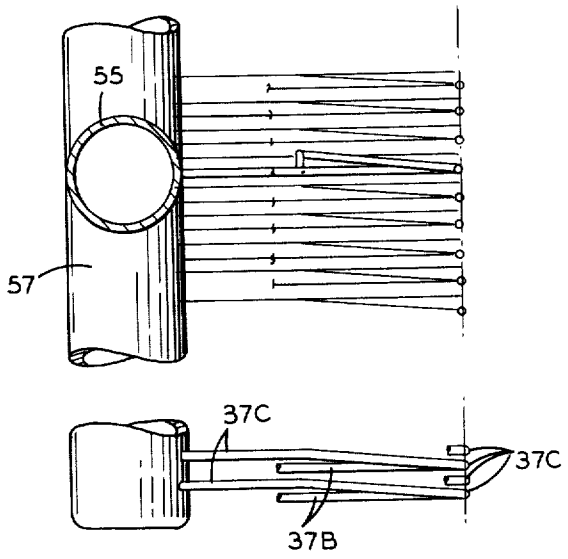
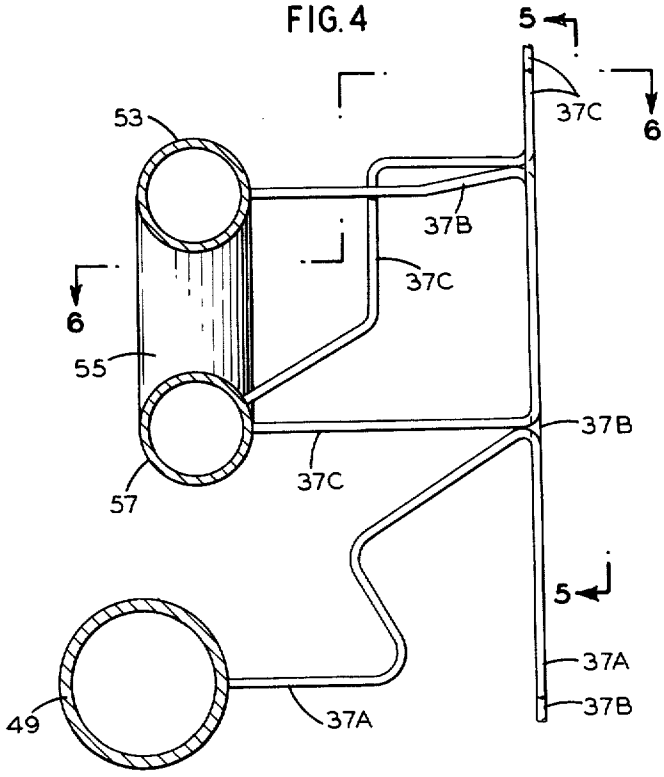


FIG. 4



VAPOR GENERATOR

This is a continuation of application Ser. No. 447,699, filed Apr. 13, 1965, now abandoned.

The construction of forced circulation oncethrough steam generators requires the use of a large number of parallel flow circuits connected between inlet and outlet headers. One of the fundamental problems involved with such a steam generator is the control of the flow through the various parallel flow circuits in order that the flow in each circuit will be stable and the enthalpy of the fluid discharged from any individual circuit will be close to the average of that from all circuits, in which case the circuit will be in a balanced flow condition. Unbalanced flow may be caused by unequal heat absorption in parallel flow circuits due to an unsymmetrical arrangement of heating surface, slag accumulation, or part-load operation with burners out of service; or may be due to unequal resistances caused by different lengths of circuits. When steam or water, or mixtures thereof, is heated in parallel flow paths provided by the furnace wall tubes or tubular panels disposed in the furnace, unbalanced heat and/or fluid distribution may lead to excessive localized tube metal temperature and/or to excessive temperature differentials between adjacent furnace wall tubes and, thereby, to undue thermal stresses in the furnace wall-forming components.

Many variations of furnace wall fluid heating circuitry have been applied to vapor generators of the character described. Most of these have one or more shortcomings including excessive thermal stresses, uneven thermal expansion, and/or lack of sufficient stability against transient conditions of heat absorption inherent in the operation of a vapor generator of the character described. For example, fluid heating circuitry of the meandering type or of the type including heated up and downflow tubes present stability difficulties, while furnace boundary walls of the type having serially connected side-by-side tube panels welded together present thermal expansion and stress difficulties.

The present invention solves the foregoing problems by subdividing the furnace boundary walls into a plurality of specially arranged fluid heating passes and by special provisions for mixing the heat absorbing medium as it flows from one fluid heating pass to another. In accordance with the invention, in a unit of the character described the upright boundary walls of the furnace are subdivided into a plurality of separate continuous upflow fluid heating passes, with the parallel flow tubes of one of the fluid heating passes being interlaced and coextensive with the parallel flow tubes of another of the fluid heating passes, and with special provisions for interconnecting the tubes of the fluid heating passes to provide a serial flow of fluid successively through the respective fluid heating passes and for mixing the fluids to equalize fluid enthalpies as they flow from one furnace fluid heating pass to another.

The various features of novelty which characterize our invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, its operating advantages and specific objects attained by its use, reference should be had to the accompanying drawings and descriptive matter in which we have illustrated and described a preferred embodiment of the invention.

OF THE DRAWINGS

FIG. **1** is a sectional elevation of a once-through forced flow steam generator embodying the invention;

FIG. **2** is a partial sectional view taken along the line **2—2** of FIG. **1**;

FIG. **3** is a partial perspective view of the fluid heating circuitry of the front wall of the furnace and of the fluid collection, mixing and distribution system provided therefor;

FIG. **4** is an enlarged view of part of the front wall of FIG. **1**;

FIG. **5** is a sectional view taken along line **5—5** of FIG. **4**; and

FIG. **6** is a sectional view taken along line **6—6** of FIG. **4**.

In the drawings the invention has been illustrated as embodied in a top-supported forced flow once-through steam generator intended for central station use. The particular unit illustrated is designed to produce a maximum continuous steam output of 3,840,00 lbs/hour at a pressure of 3600 psig and a total temperature of 1000° at the superheater outlet, based on feedwater being supplied at a temperature of 548°, with provisions for reheating the steam.

The main portions of the unit illustrated include an upright furnace chamber **10** of substantially rectangular horizontal cross section defined by front wall **11**, rear wall **13**, side walls **14**, a roof **16** and a floor **17** and having a gas outlet **18** at its upper end opening to a horizontally extending gas pass **19** of rectangular vertical cross section formed by a floor **21** and extensions of the furnace roof **16** and side walls **14**. Gas pass **19** communicates at its rear end with the upper end of an upright gas passage **22** of rectangular horizontal cross section formed by a front wall **23**, a rear wall **24**, side walls **26** and an extension of the roof of the gas pass **19**.

The fuel firing section comprises independently operable horizontally extending cyclone type furnaces **27** of relatively small volume and boundary wall area disposed on opposite walls **11** and **13** at the lower portion of the furnace chamber **10**. Each cyclone furnace is arranged to burn solid fuel at high rates of heat release and separately discharge high temperature gaseous products of combustion and separated ash residue as a molten slag into the lower portion of the chamber **10**. Floor **17** is formed with suitable openings, not shown, for the discharge of molten slag to a slag tank, not shown.

Gas pass **19** is occupied by a secondary superheater **28**, a high pressure reheater section **29** and a low pressure reheater **31** arranged in series with respect to gas flow; while gas pass **22** is occupied in the direction of gas flow by a high pressure reheater section **32**, a primary superheater **33** and an economizer **34**.

In the normal operation of the fluid heating unit, combustion air and a relatively coarse crushed fuel is supplied to the cyclone furnaces from independently controllable sources and the fuel is burned in the cyclone furnaces at high rates of heat release sufficient to maintain a normal mean temperature therein above the fuel-ash fusion temperature. Ash separates as a molten slag which flows into the lower portion of the chamber **10** and is discharged to the slag tank, while gases with a relatively small amount of slag particles in suspension discharge into the lower portion of the chamber **10**. The heating gases then flow upwardly through chamber **10** to the outlet **18** of gas pass **19**, then pass succes-

sively over and between the tubes of secondary superheater 28, reheater 29, and reheater 31 in gas pass 19 and over and between the tubes of reheater 32, primary superheater 33 and economizer 34 in gas pass 22, and then discharge to another heat trap, not shown, before flowing to the stack. It will be understood that in accordance with well-known practice, each of the superheater and reheater sections extends across the full width of its corresponding gas pass and is formed for serial flow of steam by multiple looped tubes.

The vapor generator setting is top-supported by structural steel members including upright members 85 and cross beams 90 from which hangers 95, of which only a few are illustrated, support all walls.

Feedwater at high pressure is supplied by a feed pump, not shown, to economizer inlet header 25, then passes through economizer 34 to outlet header 30 from which it flows through a downcomer 35 to the cyclone furnace fluid heating circuits. Each cyclone furnace has its boundary walls lined or formed by tube panels constructed and arranged in a manner similar to that described in U.S. Pat. No. 3,081,748. The high pressure fluid from the downcomer 35 flows in parallel to cyclone furnace supply headers 40 by way of supply tubes 45, each one of the parallel flow streams passing through the circumferential wall tubes of the corresponding cyclone furnace to a discharge header 50. Streams of fluid discharging from headers 50 are collected in a conduit 36 for flow to the furnace boundary wall fluid heating circuitry, which will be hereinafter described. From the furnace boundary wall fluid heating circuitry the fluid passes to a common mixing header 66 which is arranged to distribute the fluid to tubes 67 forming the roof of furnace 10 and gas passes 19 and 22 and having their discharge ends connected to a header 68. From header 68 the fluid flows through a conduit 69 for distribution to boundary wall tubes of gas passes 19 and 22.

Each of the upright boundary walls of gas passes 19 and 22 includes upright parallel tubes, front wall 23 having tubes 71 extending between inlet and outlet headers 72 and 73, rear wall 24 having tubes 74 extending between inlet and outlet headers 76 and 77, each side wall 26 having tubes 78 extending between inlet and outlet headers 79 and 81, and each side wall of gas pass 19 having tubes 82 extending between inlet and outlet headers 83 and 84. Floor 21 is lined by a row of tubes 86 having their inlet ends connected to headers 87 and their outlet ends to headers 73, with headers 73 being connected for flow of fluid to headers 88 by a row of screen tubes 89. Headers 72, 76, 79, 83 and 87 are connected for parallel supply of fluid from conduit 69, while headers 77, 81, 84 and 88 are arranged for discharge to a common collection header 91 from which fluid passes to the primary superheater 33 by way of a conduit 92. From primary superheater 33 the partly superheated vapor passes to secondary superheater 28 within which the vapor receives its final superheating before passing to a high pressure turbine (not shown). Partially expanded steam from the high pressure turbine successively passes through reheater sections 32 and 29 to and through an intermediate pressure turbine, not shown, then flows through reheater 31 to a low pressure turbine, not shown, wherein final expansion takes place.

In accordance with the invention, each of the upright boundary walls of furnace 10 is formed by upwardly extending parallel tubes arranged to provide three upflow fluid heating passes and having their intertube spaces closed by metallic webs welded to adjacent tubes to provide a gas-tight construction. Special header provisions are made for mixing the heat absorbing medium as it flows from one pass to another, the mixing system between each of the furnace fluid heating passes being used to keep the wall tube temperature differences to a minimum. With differences in furnace cleanliness and variation in flow quantities in the parallel flow tubes of a fluid heating pass it is possible to develop a temperature difference between adjacent tubes of a magnitude placing high stresses on the tubes and the metallic webs therebetween. By limiting the magnitude of the B.t.u. pick-up in any furnace fluid heating pass the degree of the unbalance is also limited. Accordingly, the furnace boundary wall fluid heating surface is so proportioned and arranged that the temperature of the fluid in any tube at any furnace level differs no more than 100°F from the average fluid temperature of all furnace wall tubes at that level; that the maximum temperature differential between adjacent tubes is below a predetermined critical limit; that fluid flow unbalances are minimized; and that the tubes of each fluid heating pass are sufficient in number and in inside diameter along their lengths to provide adequate circulation velocities. Further, all heated tubes of the furnace boundary walls are arranged for upflow of fluid, for we have determined that the stability of fluid heating passes having their tubes so arranged is markedly improved compared to circuitry having heated downflow as well as upflow tubes. The flow unbalances for the same average and upset heat absorption conditions are considerably less with all upflow tubes in a fluid heating pass than with heated downflow and upflow tubes in such a pass. Thus front wall 11 comprises initial upflow tubes 37A, second upflow tubes 37B disposed in the spaces between initial upflow tubes 37A, and third upflow tubes 37C. Rear wall 13 includes initial upflow tubes 38A, second upflow tubes 38B situated in the spaces between tubes 38A, and third upflow tubes 38C forming a screen extending through gas pass 19. Each side wall 14 has initial upflow tubes 39A, second upflow tubes 39B located in the spaces between tubes 39A, and third upflow tubes 39C. Rear wall tubes 38A, 38B have their upper portions bent inwardly and upwardly and then rearwardly and upwardly to form a nose arch 41. Floor 17 is lined by a row of tubes 42 extending between an inlet header 43 and an outlet header 44, with header 43 being arranged for supply of fluid from conduit 36 and header 44 being connected by a conduit 46 for discharge of fluid to a ring shaped header 47 extending about and outside of the lower end of furnace 10 and adapted to supply fluid to initial upflow tubes 37A, 38A and 39A of furnace 10.

Initial upflow tubes 37A, 38A and 39A of the front, rear and side walls of furnace 10 have their outlet ends connected to a ring shaped header 49 extending about and outside of furnace 10 at about the level of nose arch 41. Fluid passing through initial upflow tubes 37A, 38A and 39A is collected in header 49 and then passed through a conduit 51 to a ring shaped header 52 disposed about and outside of furnace 10 at around the level of floor 17 and arranged to supply fluid to second upflow tubes 37B, 38B and 39B. The second upflow tubes of the front, rear and side walls of furnace 10 extend from the floor 17 to about the level of nose arch 41 and have their upper ends connected to horizontal

headers **53, 54** and **56,** respectively, located superjacent header **49.**

Third pass upflow tubes **37C, 38C** and **39C** extend from the level of nose arch **41** to the top of the furnace, tubes **37C** extending between horizontal inlet and outlet headers **57** and **58,** tubes **38C** between horizontal inlet and outlet headers **59** and **61,** and tubes **39C** between horizontal inlet and outlet headers **62** and **63,** with headers **57, 59** and **62** being respectively connected by conduits **55, 65** and **75** for supply of mixed fluid from headers **53, 54** and **56.** Headers **57, 59** and **62** are located subjacent and extend parallel to headers **53, 54** and **56,** respectively, and are situated superjacent and extend parallel to the portion of header **49** of the corresponding wall.

From the above description it is evident that tubes **37A, 38A** and **39A** constitute the first fluid heating pass of the furnace, tubes **37B, 38B** and **39B** the second fluid heating pass, and tubes **37C, 38C** and **39C** the third fluid heating pass, with the tubes of the first and second fluid heating passes of each upright wall of the furnace being coplanar along almost their entire extent. The tubes of the first and second fluid heating passes coextend from the floor **17** to nose arch **41** and have their intertube spaces closed by metallic webs **100** weld-united to the tubes along substantially their entire lengths so that each web has one of its longitudinal edges welded to a tube of the first fluid heating pass and its other longitudinal edge welded to a tube of the second fluid heating pass. Tubes of the third fluid heating pass extend from nose arch **41** to roof **16** and, with the exception of screen tubes **38C,** have their intertube spaces closed by metallic webs **101** weld-united to the tubes along substantially their entire lengths. Tubes of the third fluid heating pass of each upright wall of the furnace are coplanar along almost their entire extent and are coplanar with the tubes of the first and second fluid heating passes of the corresponding wall.

Since the construction and arrangement of the fluid collection, mixing and distribution systems and their associated tubes are substantially the same in all walls, the construction and arrangement of only the front wall system and its associated fluid heating passes will be described. The discharge portions of tubes **37A** are bent outwardly from the plane of the wall at a level intermediate headers **49** and **57** and then extend downwardly and outwardly for radial connection to ring header **49** wherein the fluids discharging from the first fluid heating pass are collected and mixed to neutralize the differences in amount of heat picked up. From header **49** the fluids so mixed pass through conduit **51** to header **52** which provides uniform distribution of the fluids to the parallel flow tubes of the second fluid heating pass. The discharge portions of tubes **37B** are bent outwardly from the plane of the wall at about the level of header **53** for radial connection header **53** where the fluids discharging from the front wall tubes of the second fluid heating pass are collected and then mixed in conduit **55** to neutralize the differences in amount of heat picked up while passing to header **57** for uniform distribution to parallel flow tubes of the front wall third fluid heating pass. Inlet portions of alternate tubes **37C** extend radially and horizontally from header **57** to enter front wall **11** at a position above and in nearly contacting relation with the discharge portions of tubes **37A,** and then extend upwardly in the plane of the wall between tubes **37B** and in alignment with wall tubes **37A.** Inlet portions of the remaining tubes **37C** extend radially and generally upwardly from header **57,** then extend horizontally to enter front wall **11** at a location above and in nearly contacting relation with the discharge portions of tubes **37B,** and then extend upwardly in the plane of the wall in alignment with wall tubes **37B.** Webs **100** close the spaces between tubes **37A** and **37B** up to about the level of header **57,** while webs **101** close the spaces between tubes **37C** down to about the level of header **53.** The wall intertube spaces intermediate headers **57** and **53** are closed by metallic webs **102** except at the points where tubes **37A, 37B** and **37C** bend out of the plane of the wall. Wall seals are provided at these points by H-shaped plates **103** suitably welded to the adjacent tube portions.

Thus at the locations provided for mixing of the fluids as they flow from one furnace fluid heating pass to another, the tubes of the second fluid heating pass are interlaced with those of the first and third fluid heating passes and cooperate therewith and with the webs and plates therebetween to provide a gas-tight structure.

The weight or load of the front wall below header **57** is transferred through tubes **37B** and webs **102** into those of the tubes **37C** that enter the wall at the elevation of header **57,** with the latter tubes in turn transferring the load to the steelwork by way of hangers **95.** The actual load transfer through webs **102** to tubes **37C** is accomplished by shear stresses rather than by tension. Webs **102** are of sufficient length to assure that the shear stresses are of a low magnitude and are fluid cooled by tubes **37B** and **37C** so that they are capable of withstanding high stresses. Since webs **102** are in the plane of the wall, the load is transferred without bending stresses.

In operation high pressure fluid discharges from conduit **36** to header **43;** then passes through floor tubes **42;** then flows upwardly in parallel through the radiant heat absorbing initial upflow tubes **37A, 38A** and **39A** of the front, rear and side walls of the furnace to collecting header **49;** then passes through conduit **51** to header **52** while being mixed; then flows in parallel upflow through second upflow tubes **37B, 38B** and **39B** to collecting headers **53, 54** and **56,** respectively, the fluids from these headers respectively passing to fluid distribution headers **57, 59** and **62** by way of fluid mixing conduits **55, 65** and **75;** then flows in parallel through third upflow tubes **37C, 38C** and **39C** to headers **58, 61** and **63;** and then passes to header **66** for distribution to the furnace roof tubes **67.** The mass flow in the third fluid heating pass is considerably less than that in the preceding passes in order to save on pressure drop. This reduced mass flow is permissible because of the lower heat absorption rates in the upper part of the furnace.

By way of example, and not of limitation, the tubes of the first and second fluid heating passes combining to form the lower portion of the furnace enclosure are 1 inch O.D. on 1 ½ inches centerlines, the first and second fluid heating passes each having **216** tubes in the front wall, **216** tubes in the rear wall, and **128** tubes in each side wall; and the tubes of the front, rear and side walls of the third fluid heating pass are 1 inch O.D. on 1 ½ inches centerlines, while tubes **38C** of the third fluid heating pass are **36** in number and 2 31/32 inches O.D. on 18 inches centerlines, with the front wall having 432 tubes, and each side wall 256 tubes.

It will be understood that the number of tubes in the first and second fluid heating passes need not be identi-

cal and can be varied to satisfy mass flow requirements for tube metal temperature limits, considering the different fluid enthalpies, and consequent different fluid heat transfer properties, in the respective fluid heating passes.

While in accordance with the provisions of the statutes, we have illustrated and described herein the best form and mode of operation of the invention now known to us, those skilled in the art will understand that changes may be made in the form of the apparatus disclosed without departing from the spirit of the invention covered by our claims, and that certain features of the invention may sometimes be used to advantage without a corresponding use of other features.

What is claimed is:

1. In a fluid heating unit, walls forming a furnace for flow of heating gases, means supplying high temperature heating gases to said furnace, one of said walls including a first group of upwardly extending fluid heating tubes forming a lower portion of said one wall and arranged for parallel flow of fluid therethrough, a second group of upwardly extending fluid heating tubes forming an upper portion of said one wall and arranged for parallel flow of fluid therethrough, means connecting the second group of tubes for series flow of fluid from the first group of tubes, means supplying fluid in parallel flow relation to the first group of tubes, said first and second groups of tubes being constructed and arranged to provide flow of fluid in the furnace only in an upward direction, some of the tubes of the second group having lower portions interlaced with upper portions of some of the tubes of the first group, means for supporting said one wall including means rigidly uniting said interlaced tube portions of the first and second groups of tubes and transmitting the load of the first group of tubes to the second group of tubes, and means for top supporting the second group of tubes.

2. In a forced circulation fluid heating unit, upright walls forming a furnace for flow of heating gases, means supplying high temperature heating gases to the furnace, one of the walls including a first group of upwardly extending laterally spaced fluid heating tubes rigidly united by metallic webs disposed in the intertube spaces to form a lower portion of said one wall, a second group of upwardly extending laterally spaced fluid heating tubes rigidly united by metallic webs disposed in the intertube spaces to form an upper portion of said one wall and having their longitudinal axes aligned with the longitudinal axes of tubes of the first group, means supplying fluid to tubes of the first group, header means communicating with and receiving and mixing fluids flowing from tubes of the first group and distributing mixed fluids to tubes of the second group, the first and second groups of tubes being constructed and arranged to provide flow of fluid in the furnace only in an upward direction, some of the tubes of the first and second tube groups being bent out of the plane of the wall at first and second levels, respectively, for connection to the header means and interlaced with and laterally spaced from each other in the plane of the wall between the first and second levels, the second level being subjacent the first level, each pair of axially aligned tubes of the first and second tube groups being bent out of the plane of the wall at positions contiguous to each other for connection to the header means to provide substantially continuous tubular surface exposed to the heating gases, and means for supporting said one wall including metallic webs disposed in the spaces between and weld united to the interlaced tube portions of the first and second groups of tubes and transmitting the load of the first group of tubes to the second group of tubes, and means for top-supporting the second group of tubes.

3. In a forced circulation fluid heating unit, upright walls forming a furnace flow of heating gases, means supplying high temperature heating gases to said furnace, one of said walls including a first group of upwardly extending laterally spaced fluid heating tubes rigidly united by metallic webs disposed in the intertube spaces to form a lower portion of said one wall, a second group of upwardly extending laterally spaced fluid heating tubes arranged for parallel flow of fluid therethrough and rigidly united by metallic webs disposed in the intertube spaces to form an upper portion of said one wall and having their longitudinal axes aligned with the longitudinal axes of tubes of the first group, header means communicating with and receiving and mixing fluids flowing from tubes of the first group and distributing mixed fluids to tubes of the second group, means supplying fluid to tubes of the first group, said first and second groups of tubes being constructed and arranged to provide flow of fluid in the furnace only in an upward direction, some of the tubes of the first and second tube groups being bent out of the plane of the wall at first and second levels, respectively, for connection to the header means and interlaced with and laterally spaced from each other in the plane of the wall between the first and second levels, the second level being subjacent the first level, and means for supporting said one wall including metallic webs disposed in the spaces between and weld united to the interlaced tube portions of the first and second groups of tubes and transmitting the load of the first group of tubes to the second group of tubes, and means for top-supporting the second group of tubes.

4. In a fluid heating unit, upright walls forming a furnace for flow of heating gases, means supplying high temperature heating gases to the furnace, one of said walls including a first group of upwardly extending laterally spaced fluid heating tubes forming first and second fluid heating passes and rigidly united by metallic webs disposed in the intertube spaces to form a lower portion of said one wall, the tubes of the second fluid heating pass being interlaced with the tubes of the first fluid heating pass, a second group of upwardly extending laterally spaced fluid heating tubes forming a third fluid heating pass and rigidly united by metallic webs disposed in the intertube spaces to form an upper portion of said one wall and having their longitudinal axes aligned with the longitudinal axes of tubes of the first group, means including header means interconnecting said fluid heating passes to provide serial flow of fluid successively through tubes of the first fluid heating pass, tubes of the second fluid heating pass, and tubes of the third fluid heating pass, the tubes of each fluid heating pass being constructed and arranged to provide flow of fluid in the furnace only in an upward direction, some of the tubes of the first and second tube groups being bent out of the plane of the wall at first and second levels, respectively, for connection to the header means and interlaced with and laterally spaced from each other in the plane of the wall between the first and second levels, the second level being subjacent the first level, each pair of axially aligned tubes of the first and second tube groups being bent out of the plane of the wall at positions contiguous to each other for

connection to the header means to provide substantially continuous tubular surface exposed to the heating gases, means for supporting said one wall including metallic webs disposed in the spaces between and weld united to the interlaced tube portions of the first and second group of tubes and transmitting the load of the first group of tubes to the second group of tubes, and means for top supporting the second group of tubes.

5. In a forced circulation fluid heating unit, upright walls forming a furnace for flow of heating gases, means supplying high temperature heating gases to the furnace, the walls including first and second fluid heating passes each comprising a multiplicity of upflow tubes arranged in spaced relation and for parallel flow of fluid therethrough, all heated tubes of the upright furnace walls being constructed and arranged to provide flow of fluid in the furnace only in an upward direction, means supplying a vaporizable fluid to tubes of the first fluid heating pass, means interconnecting the fluid heating passes to provide serial upflow of fluid successively through tubes of the first fluid heating pass and tubes of the second fluid heating pass, and means rigidly uniting the passes and the tubes thereof to each other to provide a substantially gas-tight furnace wall construction.

6. In a forced circulation fluid heating unit, upright walls forming a furnace for a flow of heating gases, means supplying high temperature heating gases to the furnace, the walls including coextensive first and second fluid heating passes of substantially the same length each comprising a multiplicity of upflow tubes arranged in spaced relation and for parallel flow of fluid therethrough, all heated tubes of the upright furnace walls being constructed and arranged to provide flow of fluid in the furnace only in an upward direction, means supplying a vaporizable fluid to tubes of the first fluid heating pass, means interconnecting the fluid heating passes to provide serial upflow of fluid successively through tubes of the first fluid heating pass and tubes of the second fluid heating pass, and means rigidly uniting the passes and the tubes thereof to each other along substantially their entire lengths to provide a substantially gas-tight furnace wall construction.

7. In a forced circulation fluid heating unit, upright walls forming a furnace for flow of heating gases, means supplying high temperature heating gases to said furnace, one of said walls including a first fluid heating pass comprising a multiplicity of upflow tubes arranged in spaced relation and for parallel flow of fluid therethrough, a second fluid heating pass of substantially the same length as the first fluid heating pass comprising a multiplicity of upflow tubes arranged for parallel flow of fluid therethrough and interlaced and coextensive with the upflow tubes of the first fluid heating pass, said first and second fluid heating passes being constructed and arranged to provide flow of fluid in the furnace only in an upward direction, means for passing a vaporizable fluid to the tubes of the first fluid heating pass, means interconnecting said fluid heating passes to provide serial upflow of fluid successively through the tubes of the first fluid heating pass and the tubes of the second fluid heating pass, and metallic web means rigidly uniting the tubes of the first and second fluid heating passes along substantially their entire lengths.

8. In a forced circulation fluid heating unit, upright walls forming a furnace for flow of heating gases, means supplying high temperature heating gases to said furnace, said walls including a first fluid heating pass comprising a multiplicity of upflow tubes arranged in spaced relation and for parallel flow of fluid therethrough, a second fluid heating pass comprising a multiplicity of upflow tubes arranged for parallel flow of fluid therethrough and interlaced with and of substantially the same length as the upflow tubes of the first fluid heating pass, said first and second fluid heating passes being constructed and arranged to provide flow of fluid in the furnace only in an upward direction, means for passing a vaporizable fluid to the tubes of the first fluid heating pass, means interconnecting said fluid heating passes to provide serial upflow of fluid successively through the tubes of the first fluid heating pass and the tubes of the second fluid heating pass, and metallic web means rigidly uniting the tubes of the first and second fluid heating passes along substantially their entire lengths.

9. In a fluid heating unit, walls forming a furnace for flow of heating gases, means supplying high temperature heating gases to said furnace, one of said walls including a first group of upwardly extending rigidly united fluid heating tubes arranged in spaced relation to form a lower portion of said one wall and arranged for parallel flow of fluid therethrough, a second group of upwardly extending rigidly united fluid heating tubes arranged in spaced relation to form an upper portion of said one wall and arranged for parallel flow of fluid therethrough, means connecting the second group of tubes for series flow of fluid from the first group of tubes, means supplying fluid in parallel flow relation to the first group of tubes, said first and second groups of tubes being constructed and arranged to provide flow of fluid in the furnace only in an upward direction, some of the tubes of the second group having lower portions interlaced with upper portions of some of the tubes of the first group, means for supporting said one wall including web means rigidly uniting said interlaced tube portions of the first and second groups of tubes and transmitting the load of the first group of tubes to the second group of tubes, and means for top supporting the second group of tubes.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,927,646 Dated December 23, 1975

Inventor(s) Harold J. Dungey; Arthur M. Frendberg

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 5, "oncethrough" should read -- once-through --;

Column 2, line 21, "3,840,00" should read -- 3,840,000 --;

Column 5, line 56, before "header" insert -- to --;

Column 6, line 41, delete "while being mixed"

line 43, before "headers" insert -- and mixing --;

line 45, delete "fluid mixing";

Signed and Sealed this

Seventh Day of September 1976

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 3,927,646

DATED : December 23, 1975

INVENTOR(S) : Harold J. Dungey et al.

It is certified that error appears in the above—identified patent and that said Letters Patent is hereby corrected as shown below:

On the title page "9 claims" should read -- 14 claims --.

Column 10, after line 55, insert the following claims.

10. In a forced circulation fluid heating unit, upright walls forming a furnace for flow of heating gases, means supplying high temperature heating gases to said furnace, one of said walls including a first fluid heating pass comprising a multiplicity of upflow tubes arranged in spaced relation and for parallel flow of fluid therethrough, a second fluid heating pass comprising a multiplicity of upflow tubes interlaced and coextensive with the upflow tubes of the first fluid heating pass, a third fluid heating pass comprising a multiplicity of upflow tubes above the tubes of the first and second fluid heating passes, means for passing a vaporizable fluid to the tubes of the first fluid heating pass, means interconnecting said fluid heating passes to provide serial upflow of fluid successively through the tubes of the first fluid heating pass, the tubes of the second fluid heating pass and the tubes of the third fluid heating pass, metallic web means rigidly uniting the tubes of the first and second fluid heating passes along substantially their entire lengths, and metallic web means rigidly uniting the tubes of the third fluid heating pass.

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 3,927,646

DATED : December 23, 1975

INVENTOR(S) : Harold J. Dungey et al.

It is certified that error appears in the above—identified patent and that said Letters Patent is hereby corrected as shown below:

11. In a forced circulation fluid heating unit, upright walls forming a furnace for flow of heating gases, means supplying high temperature heating gases to said furnace, said walls including a first fluid heating pass comprising a multiplicity of upflow tubes arranged in spaced relation and for parallel flow of fluid therethrough, a second fluid heating pass of substantially the same length as the first fluid heating pass comprising a multiplicity of upflow tubes interlaced and coextensive with the upflow tubes of the first fluid heating pass, a third fluid heating pass comprising a multiplicity of upflow tubes above the tubes of the first and second fluid heating passes, means for passing a vaporizable fluid to the tubes of the first fluid heating pass, means interconnecting said fluid heating passes to provide serial upflow of fluid successively through the tubes of the first fluid heating pass, the tubes of the second fluid heating pass and the tubes of the third fluid heating pass, metallic web means rigidly uniting the tubes of the first and second fluid heating passes along substantially their entire lengths, and metallic web means rigidly uniting the tubes of the third fluid heating pass along substantially their entire lengths.

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 3,927,646

DATED : December 23, 1975

INVENTOR(S) : Harold J. Dungey et al.

It is certified that error appears in the above—identified patent and that said Letters Patent is hereby corrected as shown below:

12. In a forced circulation fluid heating unit, upright walls forming a furnace for flow of heating gases, means supplying high temperature heating gases to said furnace, one of said walls including a first fluid heating pass comprising a multiplicity of upflow tubes arranged in spaced relation and for parallel flow of fluid therethrough, a second fluid heating pass of substantially the same length as the first fluid heating pass comprising a multiplicity of upflow tubes interlaced and coextensive with the upflow tubes of the first fluid heating pass, a third fluid heating pass comprising a multiplicity of upflow tubes above and in alignment with the tubes of the first and second fluid heating passes, means for passing a vaporizable fluid to the tubes of the first fluid heating pass, means interconnecting said fluid heating passes to provide serial upflow of fluid successively through the tubes of the first fluid heating pass, the tubes of the second fluid heating pass and the tubes of the third fluid heating pass, metallic web means rigidly uniting the tubes of the first and second fluid heating passes along substantially their entire lengths, and metallic web means rigidly uniting the tubes of the third fluid heating pass.

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 3,927,646

DATED : December 23, 1975

INVENTOR(S) : Harold J. Dungey et al.

It is certified that error appears in the above—identified patent and that said Letters Patent is hereby corrected as shown below:

13. In a forced circulation fluid heating unit, upright walls forming a furnace for flow of heating gases, means supplying high temperature heating gases to said furnace, one of said walls including a first fluid heating pass comprising a multiplicity of tubes arranged in spaced relation, a second fluid heating pass comprising a multiplicity of tubes interlaced with the tubes of the first fluid heating pass, a third fluid heating pass comprising a multiplicity of tubes arranged in spaced relation, means for passing a vaporizable fluid to the tubes of the first fluid heating pass, means interconnecting said fluid heating passes to provide serial flow of fluid successively through the tubes of the first fluid heating pass, the tubes of the second fluid heating pass and the tubes of the third fluid heating pass, said last named means including a first header, a second header, and a third header, tubes of the first fluid heating pass having their discharge portions bent out of the plane of the wall for connection to said first header, tubes of the second fluid heating pass having their discharge portions bent out of the plane of the wall for connection to said second header, tubes of the third fluid heating pass being connected for supply of fluid from said third header with alternate third pass tubes having wall inlet portions interlaced with tubes of the second fluid heating pass and aligned with tubes of the first fluid heating pass and with the remaining third pass tubes having wall inlet portions aligned with tubes of the first fluid heating pass, web means rigidly uniting the tubes of the first and second fluid heating passes, and web means rigidly uniting the tubes of the third fluid heating pass.

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 3,927,646

DATED : December 23, 1975

INVENTOR(S) : Harold J. Dungey et al.

It is certified that error appears in the above—identified patent and that said Letters Patent is hereby corrected as shown below:

14. In a forced circulation fluid heating unit, upright walls forming a furnace for flow of heating gases, means supplying high temperature heating gases to said furnace, one of said walls including a first fluid heating pass comprising a multiplicity of upwardly extending tubes arranged in spaced relation, a second fluid heating pass of substantially the same length as the first fluid heating pass comprising a multiplicity of upwardly extending tubes interlaced and coextensive with the tubes of the first fluid heating pass, a third fluid heating pass comprising a multiplicity of tubes arranged in spaced relation, web means rigidly uniting tubes of the first and second fluid heating passes, web means rigidly uniting tubes of the third fluid heating pass, means interconnecting said fluid heating passes to provide serial flow of fluid successively through tubes of the first fluid heating pass, tubes of the second fluid heating pass, and tubes of the third fluid heating pass, tubes of the third fluid heating pass having lower portions interlaced with upper portions of tubes of the second fluid heating pass and aligned with tubes of the first fluid heating pass, and means for supporting said one wall including web means rigidly uniting said interlaced tube portions of the second and third fluid heating passes and transmitting the load of the tubes of the first and second fluid heating passes to tubes of the third fluid heating pass, and means for top-supporting the tubes of the third fluid heating pass.

Signed and Sealed this

Seventh Day of *April 1981*

[SEAL]

Attest:

RENE D. TEGTMEYER

Attesting Officer *Acting Commissioner of Patents and Trademarks*