Oct. 20, 1964 J. A. DANKO ETAL 3,153,402

STEAM GENERATOR

Filed Oct. 22, 1962 4 Sheets-Sheet 1

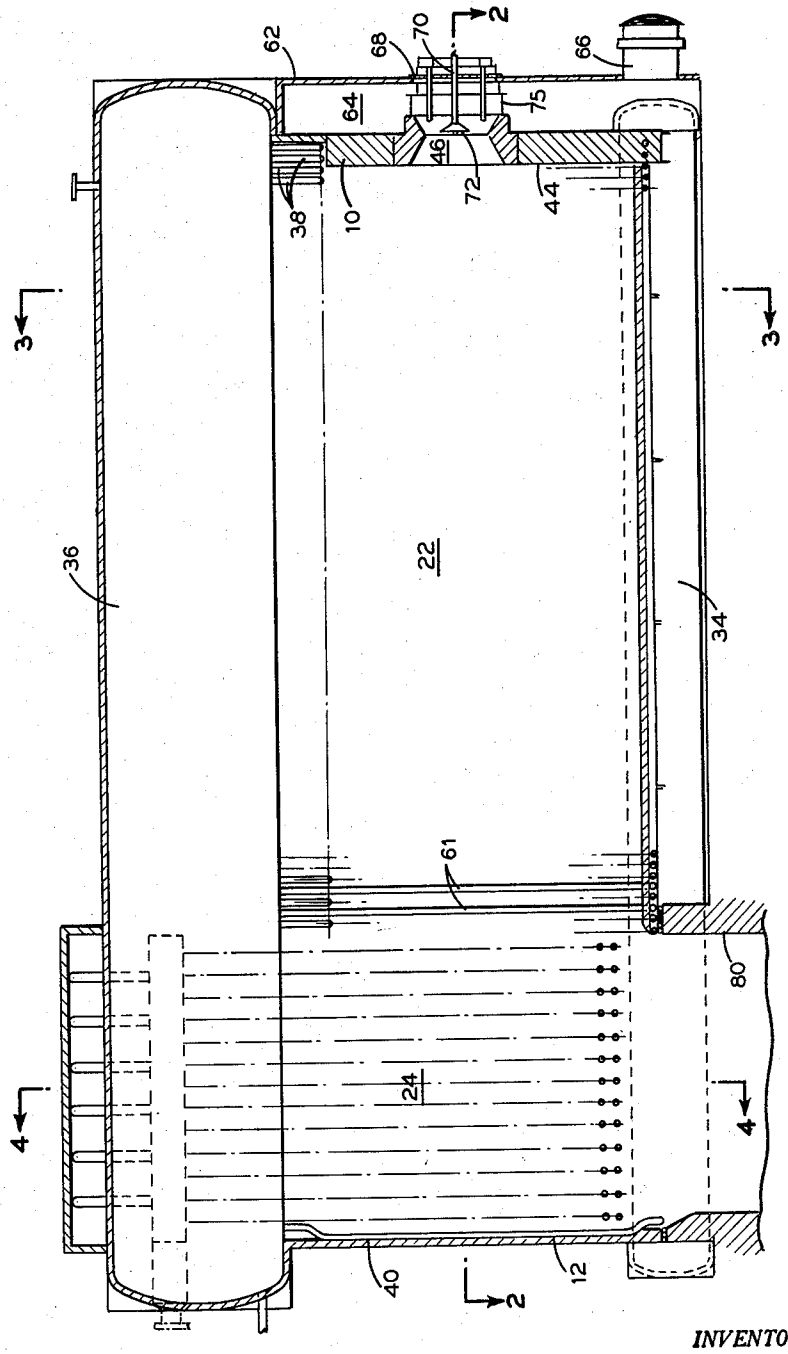


FIG. 1

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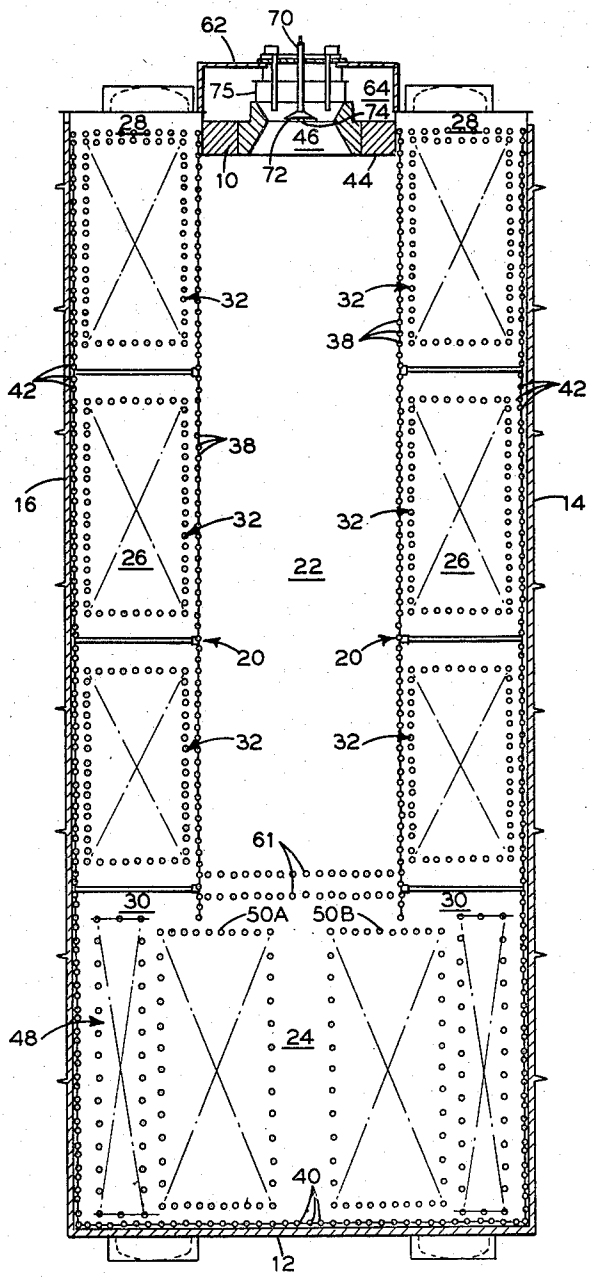
BY

ATTORNEY

STEAM GENERATOR

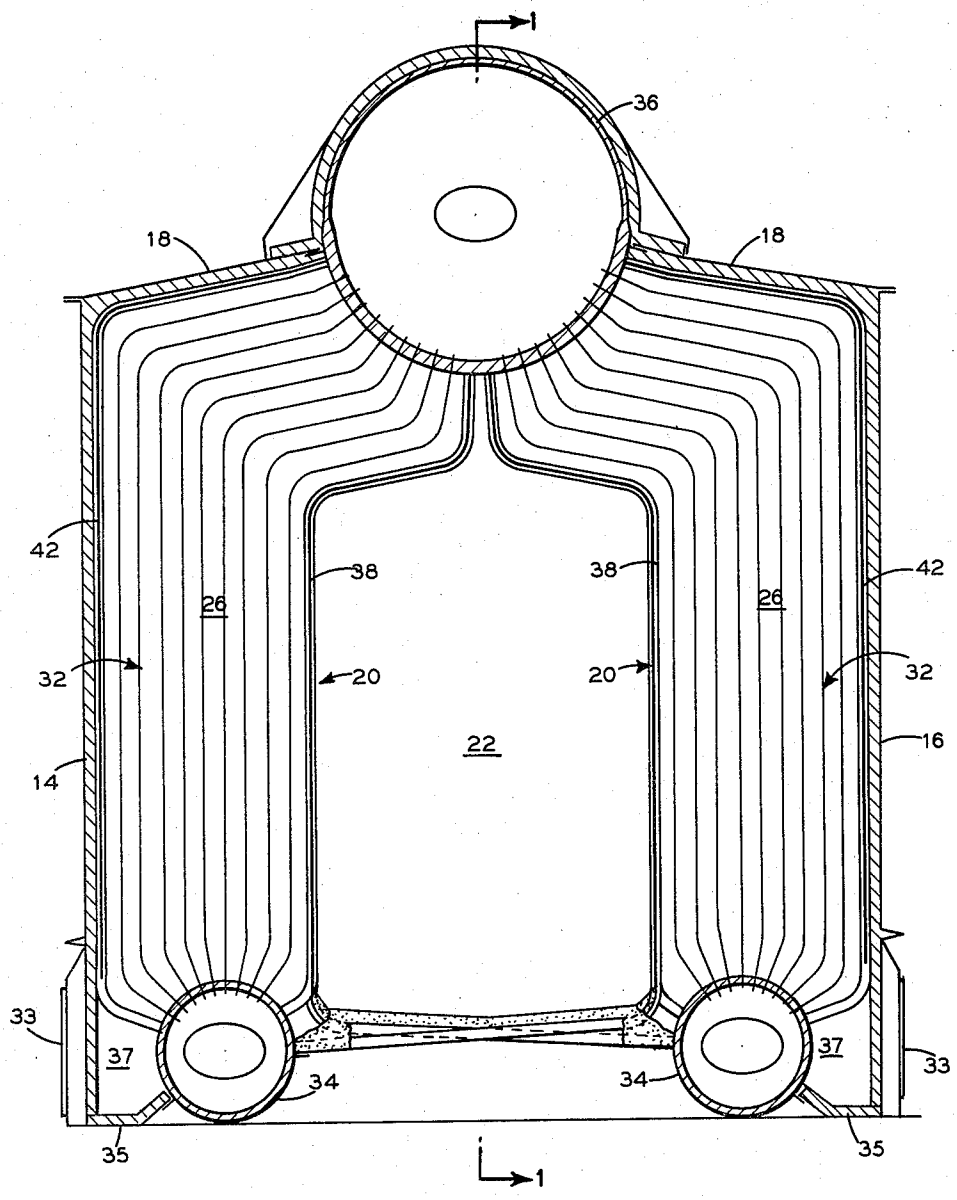
Filed Oct. 22, 1962 4 Sheets-Sheet 2

FIG.2



Oct. 20, 1964 J. A. DANKO ETAL 3,153,402
STEAM GENERATOR
Filed Oct. 22, 1962 4 Sheets-Sheet 3

FIG. 3

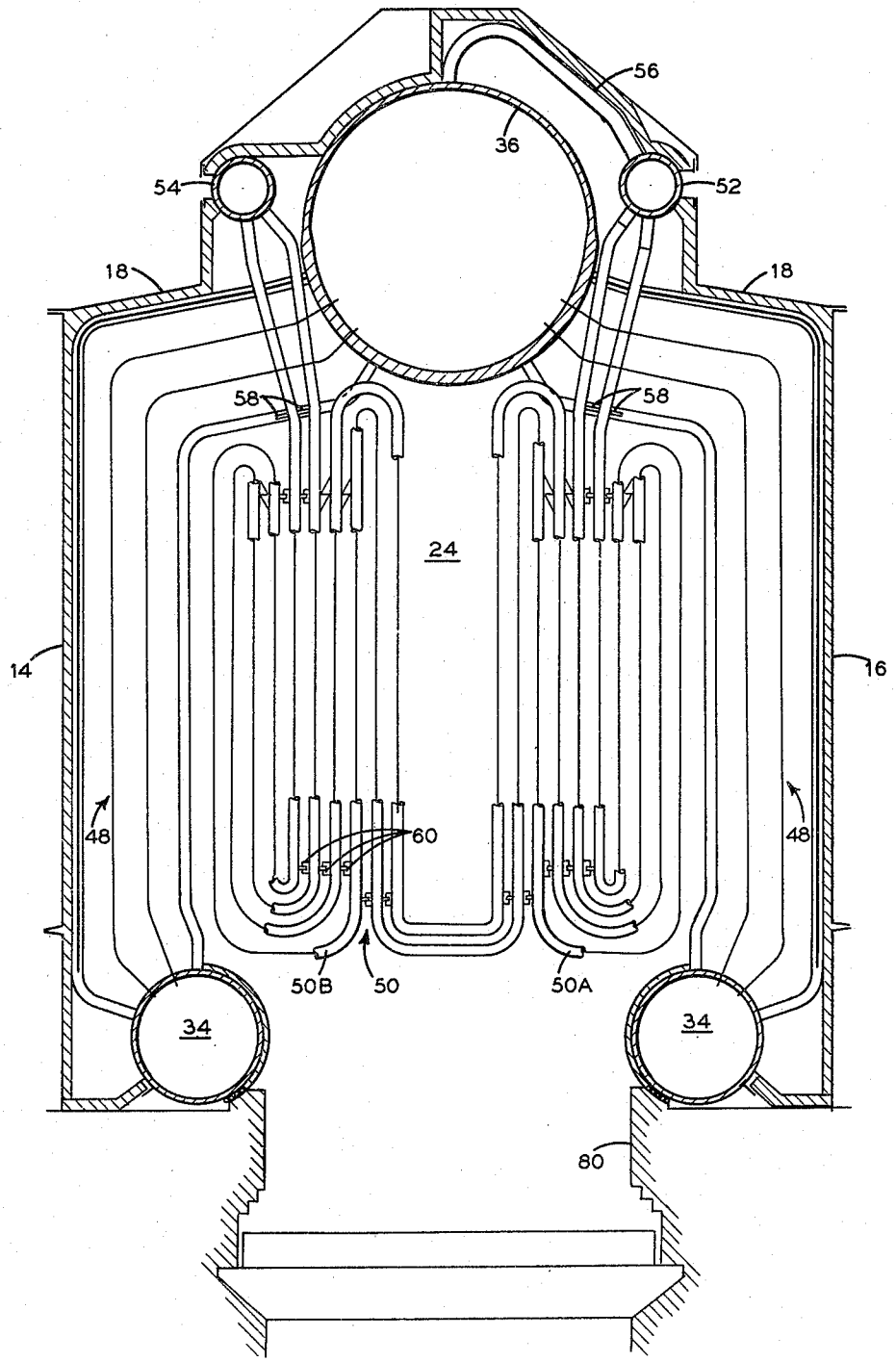


Oct. 20, 1964 J. A. DANKO ETAL 3,153,402

STEAM GENERATOR

Filed Oct. 22, 1962 4 Sheets-Sheet 4

FIG. 4



United States Patent Office 3,153,402 Patented Oct. 20, 1964

3,153,402

STEAM GENERATOR

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Filed Oct. 22, 1962, Ser. No. 232,040
8 Claims. (Cl. 122—7)

This invention relates in general to the construction and operation of steam generators and more particularly to improvements in the construction and operation of watertube boilers of the shop-assembled type especially adapted for utilizing waste heat gases of industrial furnaces and for direct firing.

The general object of the present invention is the provision of a shop-assembled steam generator possessing the virtues of compactness, portability, simplicity, reliability and ability to sustain efficient operation at high ratings with a minimum of physical size for the output achieved and a low draft loss. A further and more specific object of the invention is the provision of a steam generating unit of the type described which is characterized by an arrangement of convection heating surfaces adapted to effectively absorb the heat of waste gases generated in and supplied from an industrial furnace or furnaces; all fluid supply and steam generating tubes directly terminating in the steam and water drums, thereby eliminating headers and permitting easy inspection access to and mechanical cleaning of all such tubes; an arrangement of auxiliary fuel burning provisions and a furnace construction permitting the burning of an auxiliary fuel at high rates of heat release per cubic foot of furnance space; its readiness upon delivery to be skidded or lifted onto the foundation, hooked up and placed in operation, thereby saving in cost of building and erection; its ability to respond to wide and frequent load swings; and its ability to achieve design steam capacity by the utilization of the heat of waste gases and of gases generated by the direct firing of the furnace when the waste gases are not at their maximum design conditions.

In accordance with the invention the steam generating unit comprises walls including steam generating tubes forming a setting divided by partition into a pair of convection heating gas passes at opposite sides of the setting. a furnace intermediate the heating gas passes, and a superheating gas pass opening to one end of the furnace and of each of the convection heating gas passes and extending the width of the setting. The pressure parts of the unit include an upper steam and water drum extending longitudinally of and overlying the furnace and superheating gas pass and a pair of lower horizontal water drums disposed at opposite sides of and extending the length of the setting, with each of the heating gas passes being occupied by a bank of steam generating tubes having their upper ends connected to the steam and water drum and their lower ends connected to the lower water drum on the corresponding side of the setting. The superheating gas pass is occupied by a superheater connected for flow of steam from the upper drum and disposed across the gas discharge end of the furnace. Provisions are made for supplying waste heat gases directly to the bottom of the superheating gas pass and effecting a flow of waste heat gases through the superheating gas pass and then in parallel through the convection heating gas passes; and for generating heating gases in the opposite end of the furnace and effecting flow thereof through the furnace to and through the superheating gas pass for mixing with the waste heat gases and then reversely and in parallel along with the waste heat gases through the convection heating gas passes.

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.

In the drawings:

FIG. 1 is a vertical section of a steam generator constructed in accordance with the invention taken along the line 1—1 of FIG. 3;

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

FIG. 3 is a vertical section taken along the line 3—3 of FIG. 1; and

FIG. 4 is a vertical section taken along the line 4—4 of FIG. 1.

In the drawings the invention has been illustrated as embodied in a shop-assembled bottom-supported natural circulation steam generating and superheating unit designed to receive 350,000 lbs. of waste gas per hour at 1350° F. from an open hearth furnace or furnaces and to cool the waste gases to 560° F., the resultant steam quantity being 62,500 lbs. per hour at 650° F. and 300 p.s.i. operating pressure. The unit is also provided with an oil or gas burner for direct firing of the furnace capable of providing 30,000 lbs. of steam per hour when the open hearths are down or for supplementing the steam flow when the waste gases are not at their maximum design conditions.

The steam generating unit comprises a setting of rectangular cross-section having upright front and rear walls 10 and 12, respectively, opposing side walls 14 and 16, and an upper enclosing wall or roof 18. The space within the setting is divided by a pair of upright partition walls 20 into a furnace 22, a superheating gas pass 24 opening to the rear or discharge end of the furnace, and a pair of convection heating gas passes 26 symmetrically arranged at opposite sides of the setting and each having a gas outlet 28 at one end thereof and a gas inlet 30 at its opposite end opening to the superheating gas pass 24. Heating gas passes 26 and furnace 22 are of substantially the same length and extend along about ¾ of the length of the setting. Each of the heating gas passes 26 is occupied by three banks of upwardly extending tubes 32 of relatively small diameter, preferably 2 inches outside diameter, disposed across the gas flow path. The cross-flow of gas over the tubes 32 provides the most advantageous use of this convection heat absorbing surface and contributes to high steam generating capacity within the space available.

Tube banks 32 extend between and are connected to a pair of lower horizontally disposed water drums 34 symmetrically arranged at opposite sides of the setting at a common level and an upper horizontally arranged steam and water drum 36 of about twice the diameter of the drums 34 extending parallel to the lower drums and having its longitudinal axis in the same vertical plane as the longitudinal centerline of the furnace. All of the drums extend the full length of the setting. The lower portion of each side wall 14, 16, along the length of the corresponding gas pass 26, is formed with access opening provided with doors 33 and cooperates with a portion of the adjacent drum 34 and a floor 35 to form a collection chamber 37 for ash or other solid matter released from the heating gases or blown from the tubes 32 during cleaning periods. The tubes of each tube bank 32 extend downwardly and outwardly from the drum 36, and then vertically downward for connection to the drum 34 on the corresponding side of the setting. Tubes 32 are arranged on alternate wide and narrow back spacing to facilitate tube replacement; to provide an optimum quantity of heat absorption sur-

face in the space available thereby insuring high efficiency operation, and to minimize draft loss. The relatively small diameter of these tubes together with the cross-flow of gases thereover provide optimum rates of heat transfer form the hot gases to the fluid in the tubes. The rapid flow of heat through the tubes to the small column of fluid in each tube makes the unit a notably fast steamer, capable of coming on the line quickly and rapidly handling sudden load changes.

Each of the partition walls 20 extends upwardly from the drum 34 on the corresponding side of the setting to the upper drum 36 and longitudinally of the setting from the front wall 10 to a location spaced from the rear wall 12 to provide the furnace opening to the superheating gas pass 24. Each partition wall is formed by closely spaced tubes 38 of relatively small outside diameter, preferably 2 inches, to promote high rates of heat transfer, having their intertube spaces closed by metallic webs welded to the tubes along the lengths thereof so that the wall is imperforate to gas flow. Tubes 38 of the partition walls 20 are similar in form to the tubes 32; have their upper portions bent inwardly and upwardly at a slight angle to the horizontal to form with the metallic studs therebetween the roof of the furnace 22, and terminate in the drum 36 immediately adjacent to and on opposite sides of the vertical axis thereof to protect the drum 36 from excessive furnace heat. Alternate tubes 38 of each partition wall will have their lower portion bent inwardly and downwardly to form with refractory material therebetween the floor of the furnace 22 and terminate in the drum 34 on the opposite side of the furnace; while the remaining tubes 38 of each wall 20 have their lower ends connected to the drum 34 on the corresponding side of the furnace. The floor of the furnace is covered with two courses of firebrick.

Rear wall 12, side walls 14, 16 and roof 18 of the setting are formed by gas-tight metallic casing lined by insulation and fluid cooled tubes of relatively small outside diameter, preferably 2 inches, to promote high rates of heat transfer. Rear wall 12 includes a row of closely spaced tubes 40 having their intertube spaces closed by refractory covered metallic studs secured to the tubes, with the tubes on either side of the longitudinal centerline of the setting having their upper ends conected to the drum 36 and their lower ends connected to the drum 34 on the corresponding side of the setting. Each side wall includes a row of tubes 42 having their upper portions bent inwardly and upwardly to line the roof 18, their opposite ends connected to the durm 36 and the drum 34 on the corresponding side of the setting, and their intertube spaces almost completely closed by metallic studs welded to the tubes along the entire lengths thereof except the lower portions whose intertube spaces provide passage for ash flow to the corresponding chamber 37. Front wall 10 comprises insulation covered refreactory 44 extending transversely between the partition walls 20 and formed with a circular port 46 to permit supply of auxiliary fuel and combustion air to the furnace 22.

Superheating gas pass 24 is occupied by two banks 48 of vapor generating tubes symmetrically arranged at opposite sides of the setting and by a superheater 50 disposed between the tube banks 48. Each tube bank 48 comprises three laterally spaced rows of tubes arranged on wide side and back spacing to preclude plugging by solid matter in the heating gases, having a form similar to that of tubes 32, and extending between and connected to drum 36 and the drum 34 on the corresponding side of the setting. Superheater 50 comprises two groups 50A, 50B of vertically disposed nested multi-looped tubes extending from a level just above the top of the drums 34 to a level just below the bottom of the drum 36 and arranged in horizontally spaced vertically extending panels, with corresponding panels serially connected to define parallel flow paths for vapor flow between horizontally arranged inlet and outlet headers 52 and 54, respectively, extending longitudinally of and disposed on opposite sides of the drum 36. Header 52 is connected to the vapor space of the drum 36 by supply tubes 56. The inlet and discharge portions of the tubes of the superheater 50 pass betwen the tubes of the tube banks 48 and the tubes lining the roof 18 for connection to the headers 52 and 54, with the bank spacing between superheater tube panels being maintained by lugs 58 associated with the tubes of the innermost row of each tube bank 48 and with the inlet and discharge portions of the superheater tubes, and with the side spacing between tubes of each superheater tube panel being maintained by lugs 60. The lugs 58 and 60 cooperate with the tubes with which they are associated to restrain lateral movement of the superheater tubes, while permitting vertical movement thereof. Superheater 50 is partially screened against the high temperature heating gases passing thereto from the furnace 22 by two rows of widely spaced tubes 61 disposed in the discharge end of the furnace and adjacent the superheater, with tubes 61 on either side of the longitudinal centerline of the furnace having their upper ends connected to the drum 36 and their lower ends connected to the drum 34 on the corresponding side of the furnace.

The dead weight of the drum 36 is transmitted through the steam generating tubes and downcomer tubes to the lower drums 34 as a uniformly distributed load. This load is adapted to be supported by a simple slab type foundation, eliminating the need for a more complicated foundation, such as the structural steel type.

Fuel and air supply provisions for the furnace 22 comprise metallic casing 62 suitably connected to the front wall 10 and forming a windbox 64 to which combustion air is supplied by a forced draft fan 66. Casing 62 is formed with an aperture closed by a circular cover plate 68 through which extends a horizontal distance piece 70 formed at its inner end with an impeller 72 and adapted to support the barrel of a liquid fuel burner 74. Windbox 64 is occupied by an air register 75 of circular cross-section opening to the port 46, surrounding the fuel burner barrel 74, connected at its opposite ends to the casing 62 and wall 10, provided with a series of circumferentially spaced adjustable vanes arranged to impart a whirling motion to the entering combustion air.

In accordance with the invention, high temperature heating gases from an open hearth furnace or furnaces, not shown, are admitted directly to the superheating gas pass 24 by way of a vertical duct 80 of rectangular cross-section formed of refractory and opening to the superheating gas pass 24 along the full length thereof and between the drums 34 and at a position directly below the superheater 50. Duct 80 has its opposite sides sealingly connected to the drums 34 while its rear wall is sealingly connected to the drum 34 and to the lower end of the wall 12 and its front wall is sealingly connected to the drums 34 and the rear end of the floor of the furnace 22.

In operation waste heat gases admitted to the superheating gas pass 24 flow upwardly therethrough while expanding laterally and dividing into parallel streams which flow over the tubes of the superheater 50 and tube banks 48 and then pass forwardly and horizontally through the heating gas passes 26 and over the tubes of the tube banks 32 to the gas outlets 28.

The auxiliary heating gases resulting from the combustion of the fuel and air introduced into the front end of the furnace 22 flow horizontally and rearwardly through the furnace and over the screen tubes 61 to the superheating gas pass 24, then flow over the tubes of the superheater 50 while mixing with the waste heat gases and dividing into parallel streams which thereafter follow the same path as the waste heat gases.

With the boiler construction described, feed water enters the drum 36 and flows downwardly in parallel through the last few side wall tubes 42 in the low gas temperature end of the heating gas passes 26 and the tubes of the last few rows, with respect to gas flow, of the rearmost tube banks 32. These downcomer tubes are connected for parallel

supply of fluid, by way of the drums 34, to the remaining tubes of the tube banks 32, the screen tubes 61, the tubes of the tube banks 48, and the riser tubes of all the boundary walls of the furnace 22, the heating gas passes 26, and the superheating gas pass 24. Saturated steam is supplied from the drum 36 to the superheater 50 by way of the tubes 56 and inlet header 52, the steam then passing through the tubes of the superheater and the outlet header 54 to the point of use.

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 our invention may sometimes be used to advantage without a corresponding use of other features.

What is claimed is:

1. A steam generator comprising:
(*a*) walls including steam generating tubes forming a setting;
(*b*) a pair of partition walls including steam generating tubes dividing said setting into a pair of heating gas passes at opposite sides of the setting, a furnace intermediate said heating gas passes, and a superheating gas pass opening to one end of said furnace and to one end of each of said heating gas passes and extending the width of said setting;
(*c*) an upper horizontal steam and water drum extending along the length of said setting;
(*d*) a pair of lower horizontal water drums disposed at opposite sides of and extending along the length of said setting;
(*e*) a bank of steam generating tubes in each of said heating gas passes extending between and connected to the upper drum and the lower drum on the corresponding side of the setting;
(*f*) means including tubes of said partition walls forming a floor and roof for said furnace;
(*g*) a superheater connected for flow of steam from said upper drum and disposed within said superheating gas pass;
(*h*) means supplying waste heat gases generated externally of said generator to said generator at a location between the opposite end of said furnace and said heating gas passes and effecting a flow of waste heat gases through said superheating gas pass and then in parallel through said heating gas passes; and
(*i*) means supplying heating gases directly to the opposite end of the furnace and effecting a flow of heating gases through said furnace to and through said superheating gas pass for mixing with said waste heat gases and then reversely and in parallel along with the waste heat gases through said heating gas passes.

2. A steam generator comprising:
(*a*) walls including steam generating tubes forming a setting;
(*b*) a pair of partition walls including steam generating tubes dividing said setting into a pair of heating gas passes at opposite sides of the setting, a furnace intermediate said heating gas passes, and a superheating gas pass opening to one end of said furnace and to one end of each of said heating gas passes and extending the width of said setting;
(*c*) an upper horizontal steam and water drum extending longitudinally of and overlying said furnace and superheating gas pass;
(*d*) a pair of lower horizontal water drums disposed at opposite sides of and extending the length of said setting;
(*e*) a bank of steam generating tubes in each of said heating gas passes extending between and connected to the upper drum and the lower drum on the corresponding side of the setting;
(*f*) means including tubes of said partition walls forming a floor and roof for said furnace;
(*g*) a superheater connected for flow of steam from said upper drum and disposed within said superheating gas pass; and
(*h*) means supplying waste heat gases directly to said superheating gas pass and effecting a flow of waste heat gases through said superheating gas pass and then in parallel through said heating gas passes, said last named means including a waste heat gas supply duct opening to the bottom of said superheating gas pass along the full length thereof at a position intermediate said lower drums and having its terminal boundary connected to said lower drums and to one end of the floor of the furnace.

3. A steam generator comprising:
(*a*) walls including steam generating tubes forming a setting;
(*b*) a pair of partition walls including steam generating tubes dividing said setting into a pair of heating gas passes at opposite sides of the setting, a furnace intermediate said heating gas passes, and a superheating gas pass opening to one end of said furnace and to one end of each of said heating gas passes and exetnding the width of said setting;
(*c*) an upper horizontal steam and water drum extending longitudinally of and overlying said furnace and superheating gas pass;
(*d*) a pair of lower horizontal water drums disposed at opposite sides of and extending the length of said setting;
(*e*) a bank of steam generating tubes in each of said heating gas passes extending between and connected to the upper drum and the lower drum on the corresponding side of the setting;
(*f*) means including tubes of said partition walls forming a floor and roof for said furnace;
(*g*) a superheater connected for flow of steam from said upper drum and disposed within said superheating gas pass and across said one end of the furnace;
(*h*) means supplying waste heat gases directly to said superheating gas pass and effecting a flow of waste heat gases through said superheating gas pass and then in parallel through said heating gas passes; and
(*i*) means supplying heating gases directly to the opposite end of said furnace and effecting a flow of heating gases through said furnace to and through said superheating gas pass for mixing with said waste heat gases and then reversely and in parallel along with the waste heat gases through said heating gas passes.

4. A steam generator comprising:
(*a*) walls including steam generating tubes forming a setting;
(*b*) a pair of partition walls including steam generating tubes dividing said setting into a pair of heating gas passes at opposite sides of the setting, a furnace intermediate said heating gas passes, and a superheating gas pass opening to one end of said furnace and to one end of each of said heating gas passes and extending the width of said setting;
(*c*) an upper horizontal steam and water drum extending longitudinally of and overlying said furnace and superheating gas pass and having its longitudinal axis in the same vertical plane as the longitudinal axis of said furnace;
(*d*) a pair of lower horizontal water drums disposed at opposite sides of and extending the length of said setting;
(*e*) a bank of steam generating tubes in each of said heating gas passes extending between and connected to the upper drum and the lower drum on the corresponding side of the setting;
(*f*) means including tubes of said partition walls forming a floor and roof for said furnace;

(g) a superheater connected for flow of steam from said upper drum and disposed within said superheating gas pass and across said one end of the furnace;

(h) means supplying waste heat gases directly to said superheating gas pass and effecting a flow of waste heat gases through said superheating gas pass and then in parallel through said heating gas passes, said last named means including a waste heat gas supply duct opening to the bottom of said superheating gas pass along the full length thereof at a position intermediate said lower drums and having its terminal boundary connected to said lower drums and to one end of the floor of the furnace; and

(i) means supplying heating gases directly to the opposite end of said furnace and effecting a flow of heating gases through said furnace to and through said superheating gas pass for mixing with said waste heat gases and then reversely and in parallel along with the waste heat gases through said heating gas passes.

5. A steam generator comprising:

(a) walls including steam generating tubes forming a setting;

(b) a pair of partition walls including steam generating tubes dividing said setting into a pair of heating gas passes at opposite sides of the setting, a furnace intermediate said heating gas passes, and a superheating gas pass opening to one end of said furnace and to one end of each of said heating gas passes and extending the width of said setting;

(c) an upper horizontal steam and water drum extending longitudinally of and overlying said furnace and superheating gas pass and having its longitudinal axis in the same vertical plane as the longitudinal axis of said furnace;

(d) a pair of lower horizontal water drums disposed at opposite sides of and extending the length of said setting;

(e) a bank of steam generating tubes in each of said heating gas passes extending between and connected to the upper drum and the lower drum on the corresponding side of the setting;

(f) means including tubes of said partition walls forming a floor and roof for said furnace, the tubes of each partition wall communicating at their upper ends with said upper drum and having their upper portions bent laterally and inwardly to form the roof of the furnace, alternate tubes of each of said partition walls terminating in the lower drum on the corresponding side of the setting and the remaining tubes of each partition wall terminating in the lower drum on the opposite side of the setting and having their lower portions bent laterally and inwardly to form the floor of the furnace;

(g) a superheater connected for flow of steam from said upper drum and disposed within said superheating gas pass and across said one end of the furnace, said superheater comprising a plurality of horizontally spaced tube panels arranged in vertical planes, each panel including a plurality of nested vertically extending return bend tubes;

(h) means supplying waste heat gases directly to said superheating gas pass and effecting a flow of waste heat gases through said superheating gas pass and then in parallel through said heating gas passes, said last named means including a waste heat gas supply duct opening to the bottom of said superheating gas pass along the full length thereof at a position intermediate said lower drums and having its terminal boundary connected to said lower drums and to one end of the floor of the furnace; and

(i) means supplying heating gases directly to the opposite end of said furnace and effecting a flow of heating gases through said furnace to and through said superheating gas pass for mixing with said waste heat gases and then reversely and in parallel along with the waste heat gases through said heating gas passes.

6. A steam generator comprising:

(a) walls including steam generating tubes forming a setting;

(b) a pair of partition walls including steam generating tubes dividing said setting into a pair of heating gas passes at opposite sides of the setting, a furnace intermediate said heating gas passes, and a superheating gas pass opening to one end of said furnace and to one end of each of said heating gas passes and extending the width of said setting;

(c) an upper horizontal steam and water drum extending longitudinally of an overlying said furnace and superheating gas pass and having its longitudinal axis in the same vertical plane as the longitudinal axis of said furnace;

(d) a pair of lower horizontal water drums disposed at opposite sides of and extending the length of said setting;

(e) a bank of steam generating tubes in each of said heating gas passes extending between and connected to the upper drum and the lower drum on the corresponding side of the setting;

(f) means including tubes of said partition walls forming a floor and roof for said furnace the tubes of each partition wall communicating at their upper ends with said upper drum and having their upper portions bent laterally and inwardly to form the roof of the furnace, alternate tubes of each of said partition walls terminating in the lower drum on the corresponding side of the setting and the remaining tubes of each partition wall terminating in the lower drum on the opposite side of the setting and having their lower portions bent laterally and inwardly to form the floor of the furnace;

(g) a pair of banks of steam generating tubes disposed within and at opposite sides of said superheating gas pass, each bank of tubes extending between and connected to the upper drum and the lower drum on the corresponding side of the setting;

(h) a superheater connected for flow of steam from said upper drum and disposed within said superheating gas pass intermediate the tube banks therein and across said one end of the furnace, said superheater comprising a plurality of horizontally spaced tube panels arranged in vertical planes, each panel including a plurality of nested vertically extending return bend tubes;

(i) means supplying waste heat gases directly to said superheating gas pass and effecting a flow of waste heat gases through said superheating gas pass and then in parallel through said heating gas passes, said last named means including a waste heat gas supply duct opening to the bottom of said superheating gas pass along the full length thereof at a position intermediate said lower drums and having its terminal boundary connected to said lower drums and to one end of the floor of the furnace; and

(j) means supplying heating gases directly to the opposite end of said furnace and effecting a flow of heating gases through said furnace to and through said superheating gas pass for mixing with said waste heat gases and then reversely and in parallel along with the waste heat gases through said heating gas passes.

7. A steam generator comprising:

(a) walls including steam generating tubes forming a setting;

(b) partition means dividing said setting into a heating gas pass, a furnace laterally adjoining said heating gas pass, and a superheating gas pass opening to one end of said furnace and to one end of said heating gas pass;

(c) an upper steam and water drum extending longi-

tudinally of and overlying said furnace and superheating gas pass;

(*d*) a lower water drum;

(*e*) a bank of steam generating tubes in said heating gas pass extending between and connected to said upper and lower drums;

(*f*) a superheater connected for flow of steam from said upper drum and disposed within said superheating gas pass;

(*g*) means supplying waste heat gases generated externally of said generator to said generator at a location between the opposite end of said furnace and said heating gas pass and effecting a flow of waste heat gases through said superheating gas pass and then through said heating gas pass; and

(*h*) means supplying heating gases directly to the opposite end of the furnace and effecting a flow of heating gases through said furnace to and through said superheating gas pass for mixing with said waste heat gases and then reversely along with the waste heat gases through said heating gas pass.

8. A steam generator comprising:

(*a*) walls including steam generating tubes forming a setting;

(*b*) partition means including steam generating tubes dividing said setting into a heating gas pass, a furnace laterally adjoining said heating gas pass, and a superheating gas pass opening to one end of said furnace and to one end of said heating gas pass;

(*c*) an upper steam and water drum extending longitudinally of and overlying said furnace and superheating gas pass;

(*d*) a lower water drum;

(*e*) a bank of steam generating tubes in said heating gas pass extending between and connected to said upper and lower drums;

(*f*) means including tubes of said partition wall means forming a floor and roof for said furnace;

(*g*) a superheater connected for flow of steam from said upper drum and disposed within said superheating gas pass;

(*h*) means for supplying waste heat gases generated externally of said generator to said superheating gas pass and effecting a flow of waste heat gases through said superheating gas pass and then through said heating gas pass, said last named means including a waste heat gas supply duct arranged to pass waste heat gases to said superheating gas pass and having a portion of its terminal boundary connected to the floor of said furnace; and

(*i*) means supplying heating gases directly to the opposite end of the furnace and effecting a flow of heating gases through said furnace to and through said superheating gas pass for mixing with said waste heat gases and then reversely along with the waste heat gases through said heating gas pass.

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