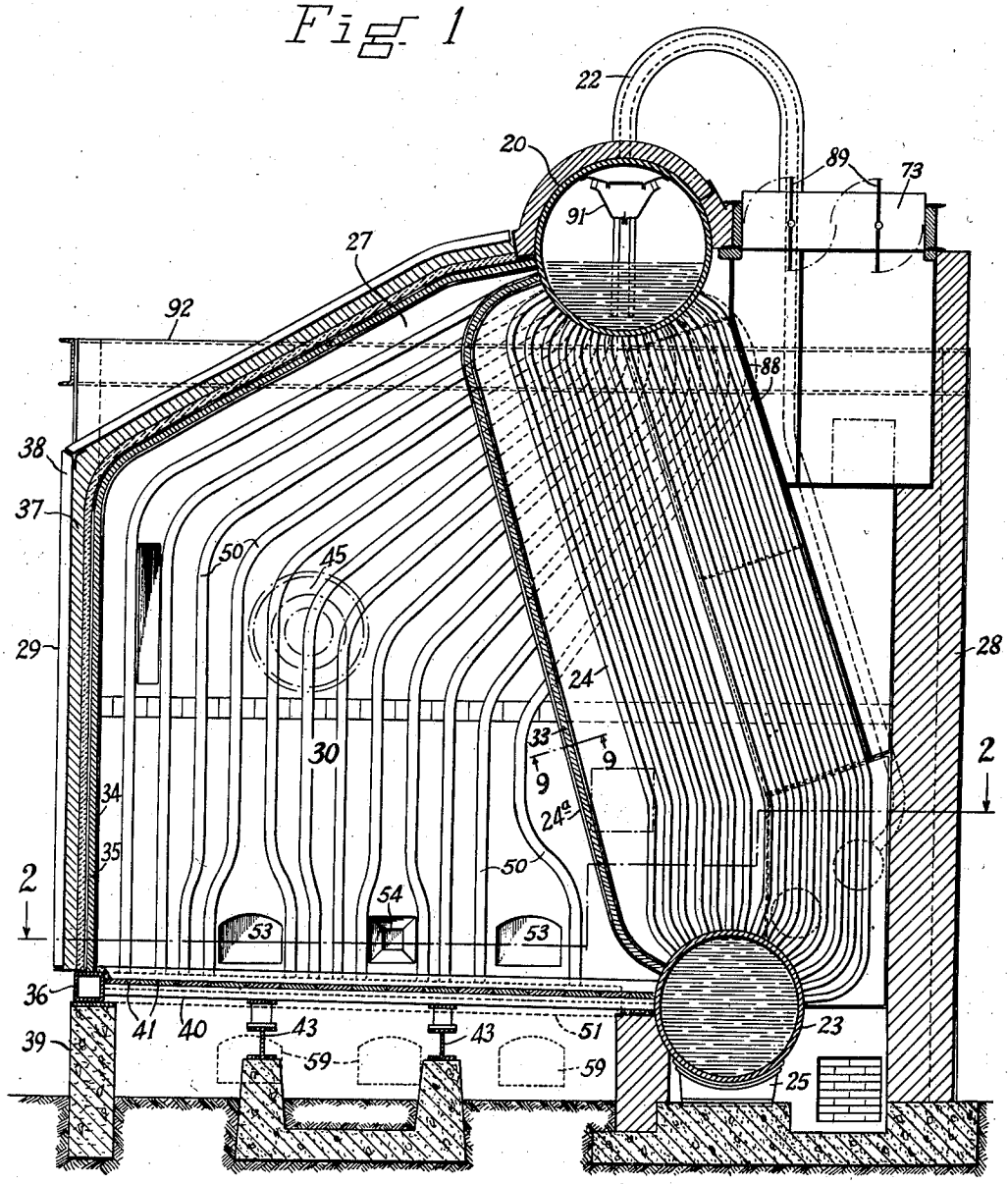
April 30, 1935. E. G. BAILEY ET AL 1,999,984

STEAM BOILER

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Fig. 1



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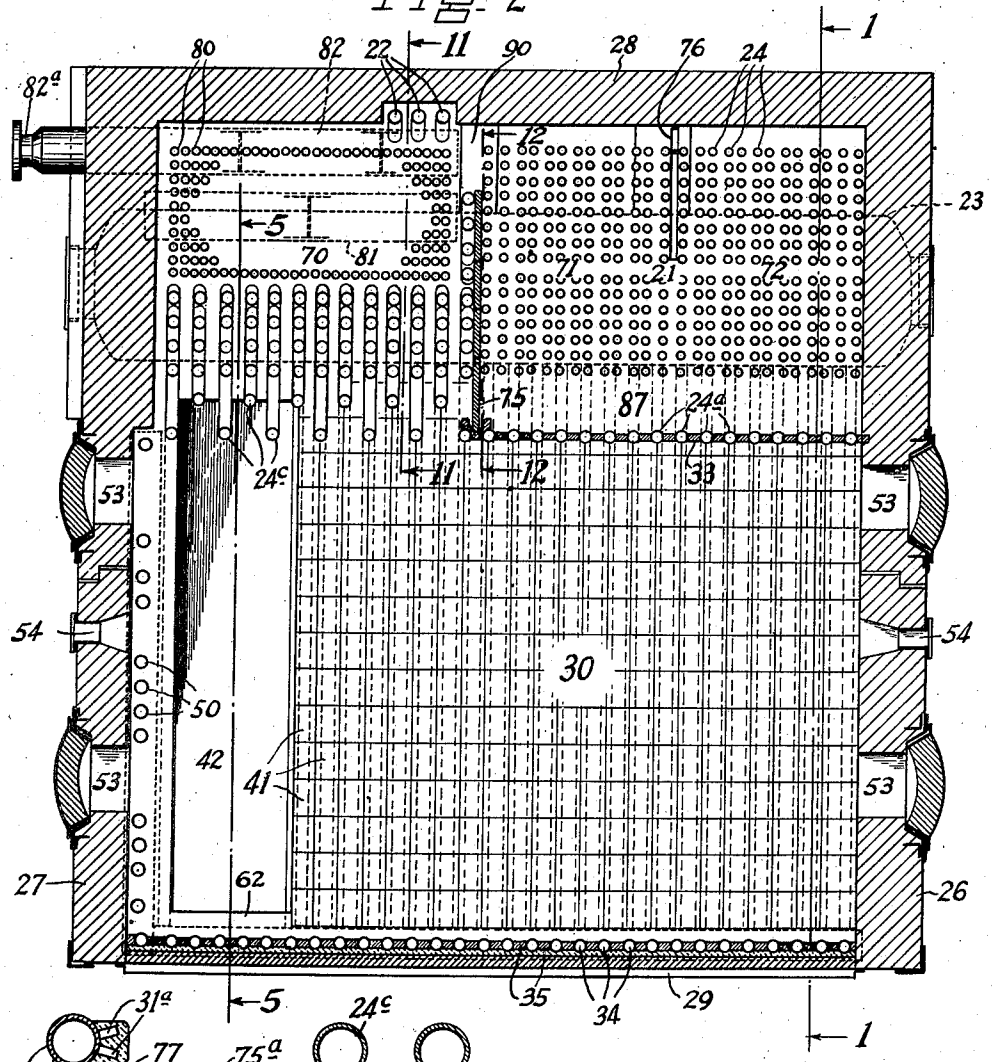
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STEAM BOILER

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Fig. 2



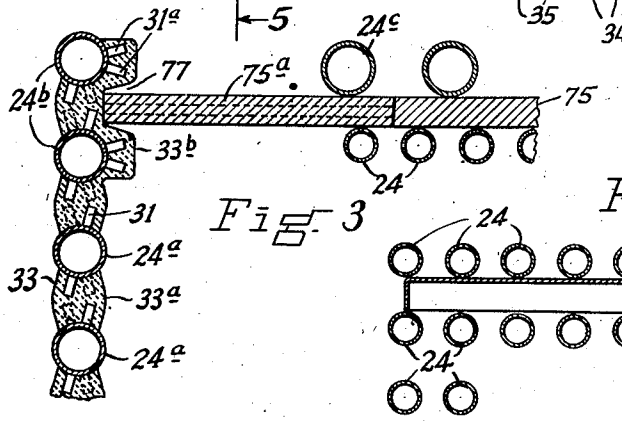
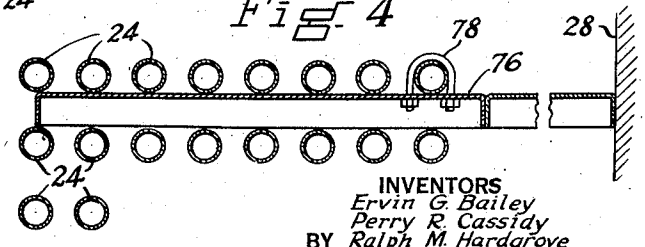


Fig. 3

Fig. 4



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STEAM BOILER

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Fig. 5

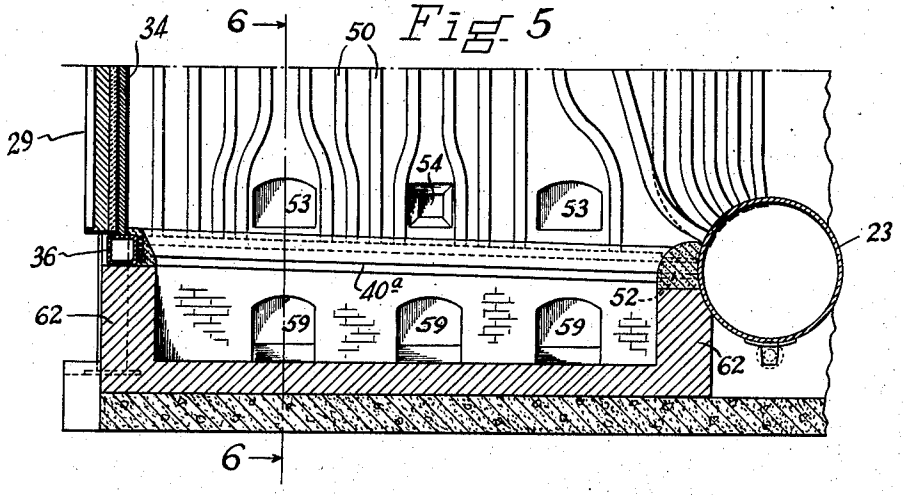


Fig. 6

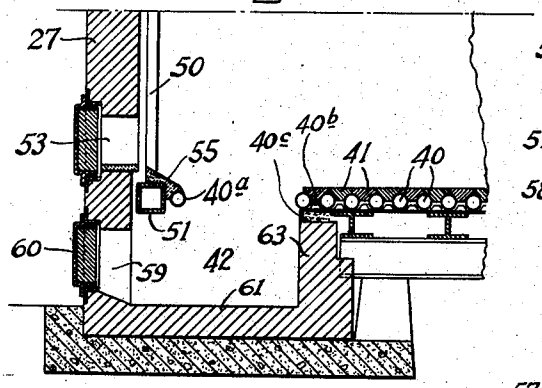


Fig. 7

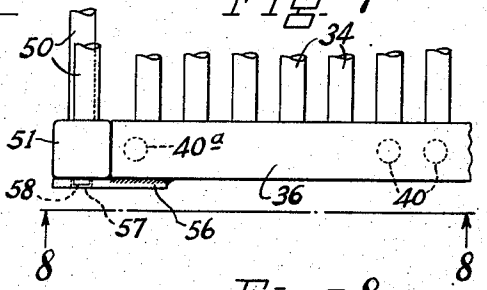


Fig. 8

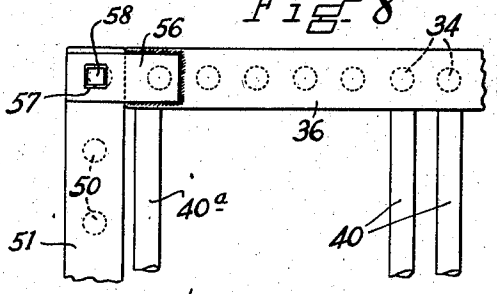


Fig. 10

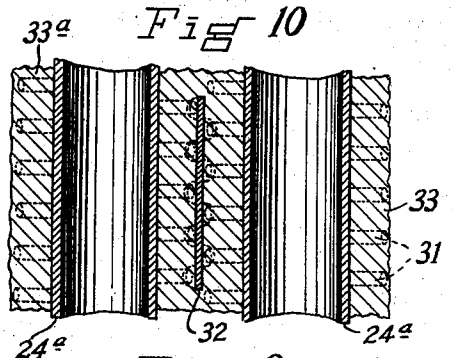


Fig. 9

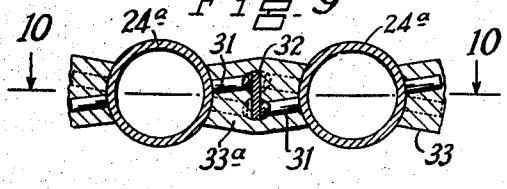
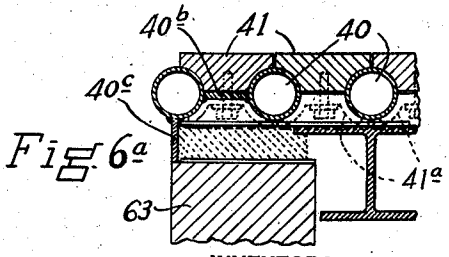


Fig. 6a



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STEAM BOILER

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Fig. 11

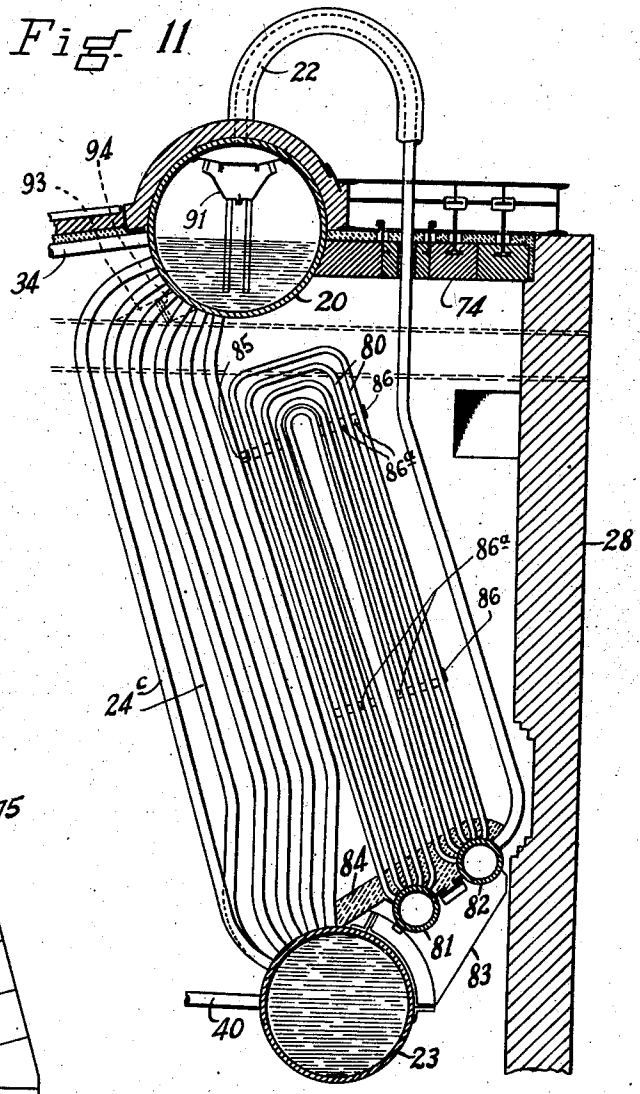


Fig. 12

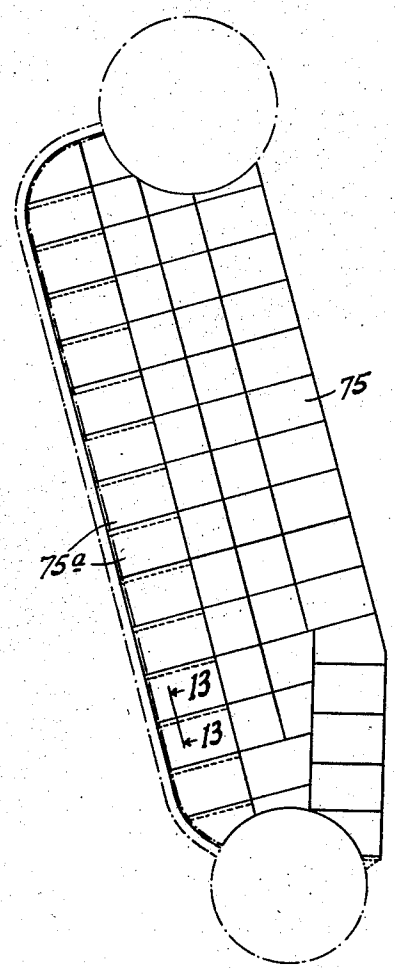
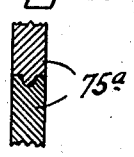


Fig. 13



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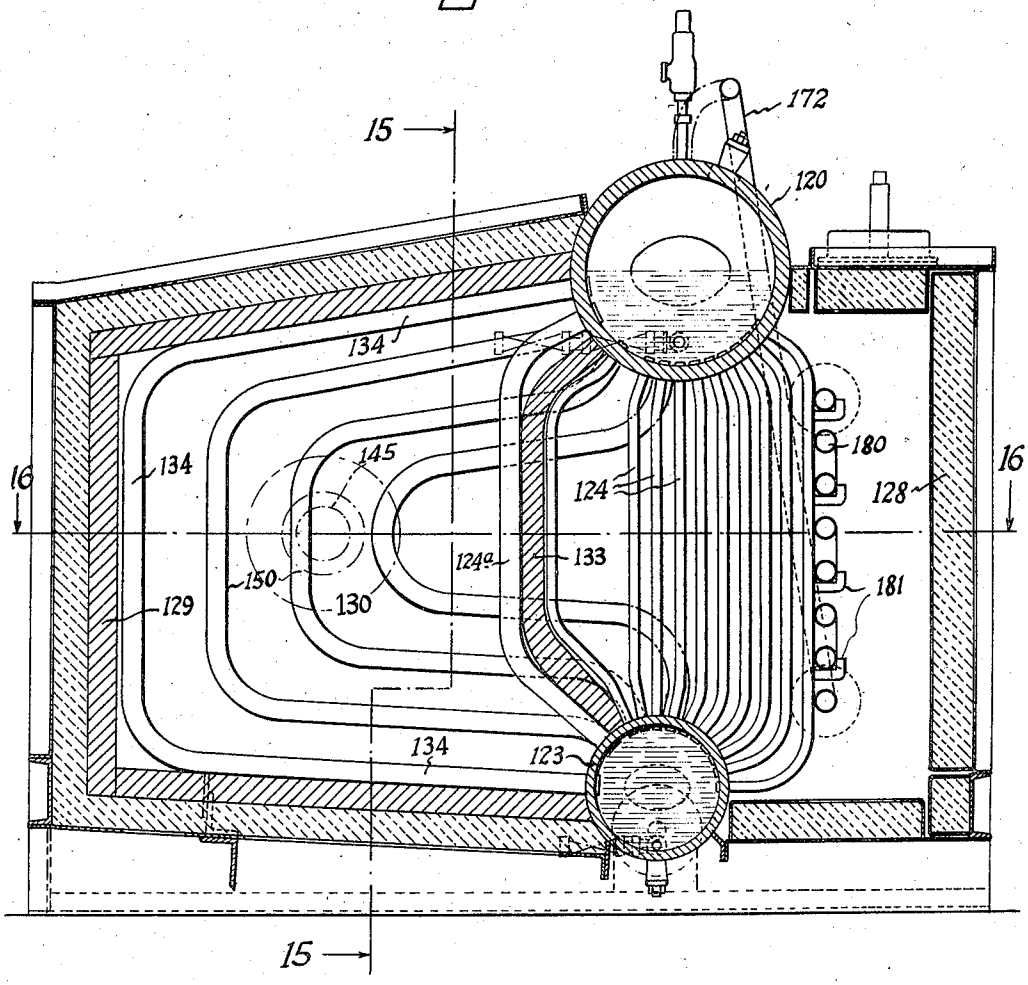
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STEAM BOILER

Filed Dec. 8, 1933 7 Sheets-Sheet 5

Fig. 14



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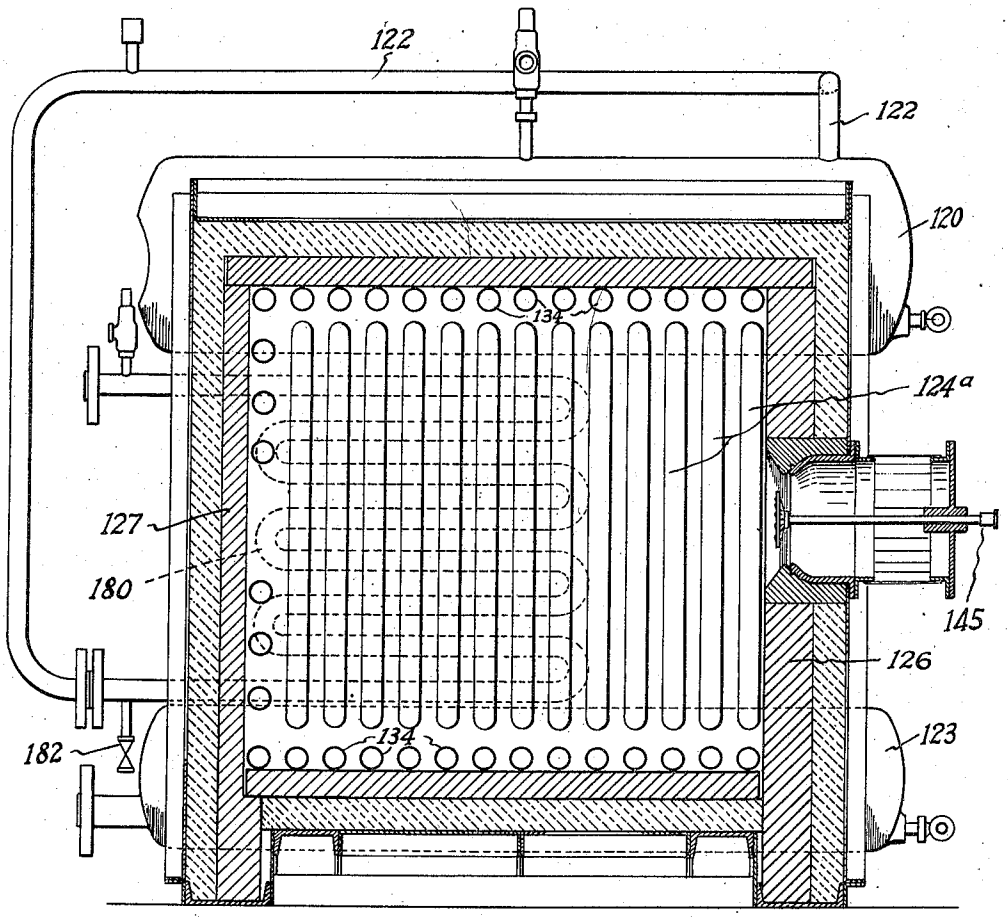
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STEAM BOILER

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Fig. 15



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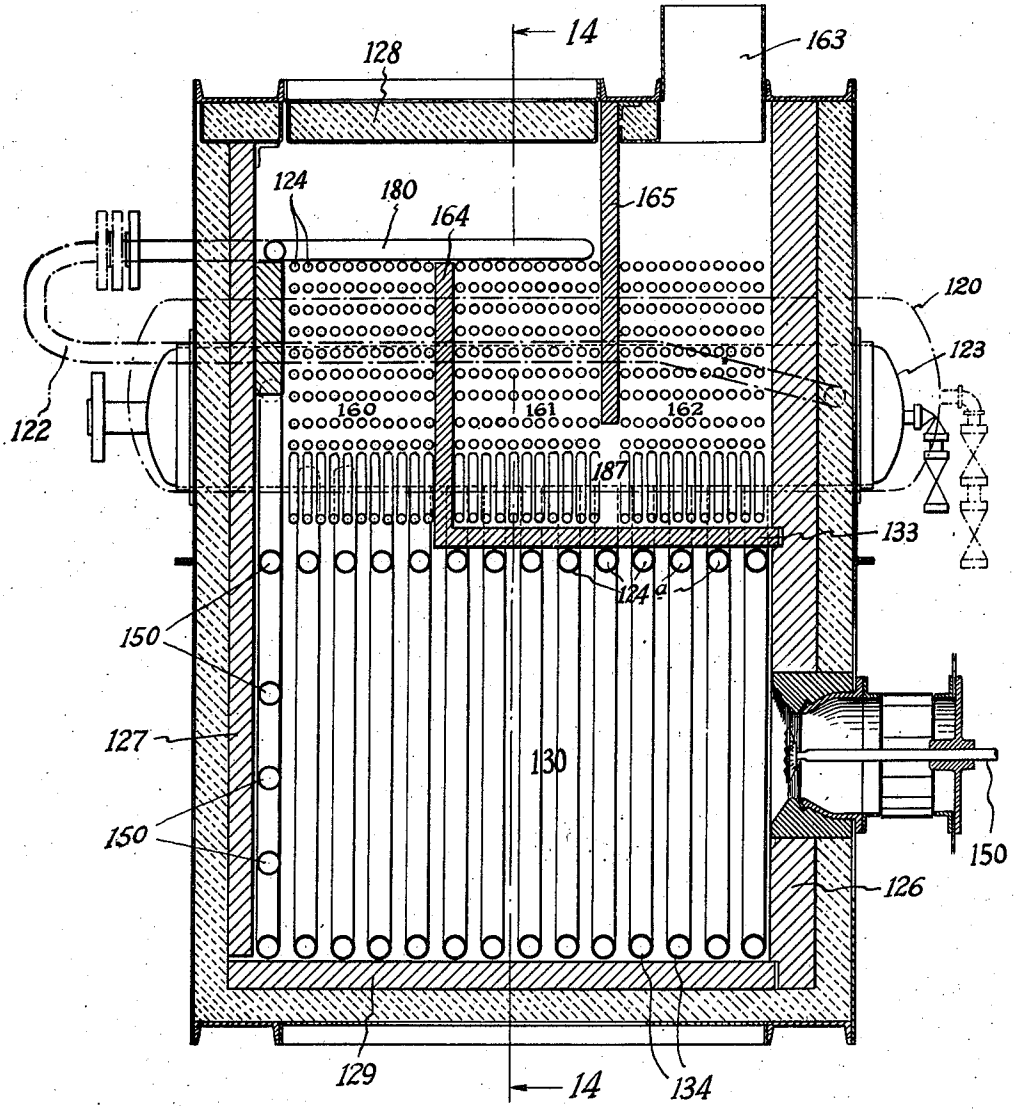
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STEAM BOILER

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Fig. 16



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Patented Apr. 30, 1935 1,999,984

UNITED STATES PATENT OFFICE

1,999,984

STEAM BOILER

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Application December 8, 1933, Serial No. 701,426

29 Claims. (Cl. 122—336)

The present invention relates to the construction and operation of water tube steam boilers, which due to their compactness, low head-room requirements and relatively small steaming capacity are particularly applicable to industrial plants and marine installations.

The general object of our invention is the provision of a steam boiler of the character described which is further characterized by a substantial reduction in the head-room requirements, a relatively low cost of construction, and a capacity for operation at high ratings with a low draft loss, good efficiency and high superheat temperatures. A further object is the provision of a furnace construction and arrangement in a steam boiler of the character described which is adapted for the burning of fuel at high efficiencies, and particularly of a fluid fuel, such as pulverized coal, oil or gas, in suspension. A further object is the provision of a two drum steam boiler of the character described having a highly compact and thermally effective arrangement of the fluid heating surface thereof relative to the boiler furnace and the flow of heating gases from the furnace. A still further object is the provision of a two drum steam boiler construction which is adapted for standardization in a series of sizes or classes of different horse power capacities with little or no variation in the draft loss and exit gas temperature throughout the series. A further object is an improved superheater construction and arrangement in a boiler of the character described in which slagging of the superheater tubes is minimized, high steam temperatures obtained with a minimum of superheater surface, superheater tube temperatures maintained within safe limits, and a relatively flat superheat curve attained. A further specific object is the provision of a low cost fluid cooled furnace shaped to provide an effective utilization of its volume for burning the fuel, and constructed to simplify the boiler supporting structure, facilitate the removal of the fuel residue, whether in the form of dry ash or molten slag, and expedite the fluid circulation through the wall cooling tubes.

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 preferred embodiments of our invention.

Of the drawings:

Fig. 1 is a sectional elevation taken on the line 1—1 of Fig. 2 and illustrating one embodiment of our invention; Fig. 2 is a plan section taken on the line 2—2 of Fig. 1; Figs. 3 and 4 are enlarged views of the tube bank baffles shown in Fig. 2; Fig. 5 is a vertical section taken on the line 5—5 of Fig. 2; Fig. 6 is a vertical section taken on the line 6—6 of Fig. 5; Fig. 6A is an enlarged view of a portion of the furnace floor; Figs. 7 and 8 are elevation and bottom views respectively of the header connection; Fig. 9 is an enlarged detail of the partition taken on the line 9—9 of Fig. 1; Fig. 10 is a vertical section taken on the line 10—10 of Fig. 9; Fig. 11 is a vertical section taken on the line 11—11 of Fig. 2; Fig. 12 is a vertical section taken on the line 12—12 of Fig. 2; Fig. 13 is a vertical section taken on the line 13—13 of Fig. 12; Fig. 14 is a sectional elevation of a modified boiler construction taken on the line 14—14 of Fig. 16; Fig. 15 is a vertical section taken on the line 15—15 of Fig. 14; and Fig. 16 is a plan section taken on the line 16—16 of Fig. 14.

In the steam boiler embodying our invention illustrated in Figs. 1 to 13 of the drawings, 20 designates an upper horizontally arranged longitudinally extending steam and water drum having a submerged feed water supply connection and steam outlets 22 adjacent one end. The drum 20 is connected to a similarly arranged lower water drum 23 by a vertically inclined bank of bent tubes 24 extending between and connected to the drums substantially throughout the length thereof. The drum 23 is supported on longitudinally spaced cradles 25 and anchored at its front end for relatively free longitudinal expansion and contraction rearwardly. The drums 20 and 23 and tube bank 24 constitute the main steam generating section of the boiler, the weight of these parts being almost wholly supported by the cradles 25. The drums 20 and 23 and tube bank 24 are positioned in a housing having vertical refractory front and rear walls 26 and 27 respectively, and a side wall 28 at the outer side of the tube bank relative to the furnace. The opposite side wall 29 is laterally spaced a substantial distance from the inner side of the tube bank and constructed as hereinafter described. The walls 26, 27, 28 and 29 thus form a boiler housing substantially rectangular in horizontal cross section, as shown in Fig. 2.

The space between the inner side of the tube

bank 24 and the walls 26, 27 and 29 is utilized for the boiler furnace or combustion chamber 30 and is arranged to communicate at its rear end with the rear end of the space 21 occupied by the tube bank 24. The inner side wall 33 of the furnace chamber terminates short of the rear wall 27, and is advantageously formed by a partition comprising a row of longitudinally spaced vertical tubes 24a having their upper and lower ends connected to the drums 20 and 23 respectively, and forming the innermost row of the tube bank 24. The tubes 24a are preferably of larger diameter than the tubes 24 in the remaining rows and spaced from the adjacent row a greater distance transversely of the tube bank than the transverse spacing between the remaining rows in the tube bank. The tubes 24a, as shown in detail in Figs. 9 and 10, have vertical rows of staggered metallic studs 31 extending along opposite sides thereof and projecting into the intertube spaces. To prevent spreading of the tubes 24a the studs 31 on adjacent tubes are advantageously tied together at points spaced along the tubes. At each of these points the studs on adjacent tubes are welded by jump welds to a vertical plate 32 positioned between the stud rows. The use of the plates 32 facilitates the manufacture and assembly of the stud tubes. The intertube spaces containing the studs 31 are closed by suitable refractory material 33a applied in an initially plastic state and allowed to set. The partition or wall 33 so formed extends only a portion of the length of the tube bank, leaving a space between its rear end and the rear wall 27 through which the furnace chamber and the tube space communicate. The tubes 24a receive heat on one side by radiation from the furnace chamber and on the opposite side by convection from the tube space.

The outer side wall 29 of the furnace chamber 30 has its inner portion formed in substantially the same manner as the inner wall 33 by a row of vertically arranged radiantly heated stud tubes 34 uniformly spaced throughout the length of the furnace chamber and refractory material 35 closing the intertube spaces and supported by the tube studs, as in Figs. 9 and 10. The tubes 34 have their lower ends connected to a substantially horizontal header 36 extending longitudinally of the furnace chamber slightly above the level of the axis of the mud drum 23 and supported on longitudinally spaced piers 39. The upper portions of the tubes 34 are similarly curved and inclined toward the tube bank 24 and connected into the drum 20 above the level of the tubes 24a and at or below the normal water level in the drum. The tubes 34 thus define the outer side wall and roof of the furnace chamber 30. One or more layers 37 of insulating material are arranged between the outer side of the tubes 34 and an outer metallic casing 38.

The floor of the furnace chamber is defined by a row of horizontally inclined radiantly heated water tubes 40 connecting the drum 23 to the header 36. The tubes 40, 24a and 34 are substantially similarly spaced throughout most of the length of the furnace chamber and the tubes 40 are covered and the spaces therebetween closed by heat resistant blocks 41, the flat upper surfaces of which constitute a smooth floor extending from the front wall 26 to an ash pit 42 at the rear end of the furnace chamber. The blocks 41 are preferably secured to the tubes 40 by clamps 41a bridging adjacent tubes and connected to the blocks 41, as shown in Fig. 6a. The furnace floor is supported at transversely spaced intermediate points by I-beams 43 extending longitudinally thereof.

The combustion chamber 30 with its sides thus defined by the tubes 24a, 34 and 40 permits the use of a small size furnace and the burning of fuel at a relatively high rate of heat release per unit of furnace volume. The fuel burning provisions conventionally indicated in Fig. 1 consist of a combination fuel burner 45, adapted to burn one or more fluid fuels, such as pulverized coal, oil or gas, simultaneously or independently. The fuel burner is symmetrically arranged in the front wall 26 to discharge a stream of fuel horizontally through the furnace chamber toward its rear wall 27.

The stream of fuel directed toward the rear wall of the furnace chamber might cause that wall to rapidly erode at high rates of operation or when a fuel having a low fusion ash is burned, and in the present construction the inner face of the rear wall is advantageously protected by a row of transversely spaced vertical cooling tubes 50, arranged as shown in Figs. 1, 2 and 5. The tubes 50 have their lower ends connected to a horizontally inclined header 51 having its axis in horizontal alignment with the axes of the floor tubes 40 and with the header end adjacent the drum 23 connected thereto by a nipple 52. The upper portions of the tubes 50 are bent substantially parallel to the tubes 34 and connected in a circumferential row to the steam and water drum 20. The lower ends of certain rear wall tubes 50 are bent oppositely at opposite sides of clean-out openings 53 and inspection or lance openings 54. Similar openings are also made in the refractory front wall 26. The tubes 50 and header 51 are slightly spaced from the rear wall to permit rearward movement thereof on expansion of the boiler drums and/or header 36.

In order to facilitate closing the corner of the furnace between the walls 27 and 29, an additional floor tube 40a is provided alongside the header 51. The upper surfaces of the header 51 and tube 40a are protected by a layer of refractory 55. In operation, the floor tubes tend to expand axially and move the header 36 laterally. The tube 40a being widely spaced from the adjacent tube 40 would have little effect on the corresponding portion of the header 36. To prevent deformation of the tube 40a on expansion thereof and to provide simultaneously movement of the headers 51 and 36 on elongation of the latter, a plate 56 is welded to the underside of the header 36 and provided with an opening 57 in a portion thereof below the header 51 into which a lug 58 on the underside of the header 51 fits.

The ash pit 42 in the furnace illustrated extends across the rear end of the furnace chamber in front of the rear wall 27, in which is formed a series of spaced clean-out openings 59 closed by doors 60. The ash pit has a refractory floor 61, side walls 62, and a vertical front wall 63, which has a seal joint permitting relative longitudinal expansion of the furnace floor. The last pair of floor tubes 40 are connected by a spacer bar 40b welded thereto, as shown in Fig. 6A. A seal plate 40c extends downwardly from the lower side of the last tube 40. The joints between the ash pit walls 62 and the header 36 and drum 23 are protected by a refractory layer, the rear portion of the header 36 being studded as shown in Fig. 5, to hold the refractory in position. The furnace floor may be cleaned by tools inserted

through the openings 53 and the fuel residue collected removed from the ash pit through the openings 59 at the boiler room floor level. The floor and ash pit construction may be changed or the ash pit omitted depending upon the character of the fuel burned and the condition of the fuel residue deposited on the furnace floor. Where, for example, the fuel burning provisions are not intended for burning an ash-forming fuel, the ash pit may be omitted and the furnace floor continued to the rear wall 27.

In prior two-drum boiler constructions of the general character described, it has been customary to cause the heating gases to flow horizontally through a single pass longitudinally of the convection heated tube bank. Such a construction is not practical for the basis of a commercial line of boilers having different maximum steam generating capacities while maintaining substantially the same draft loss and exit gas temperature. The addition of steam generating surface in such boilers results either in an undesirable change in the furnace shape, an undesirable decrease in the drum ligament strength, or an increase in the draft loss. The single pass arrangement is further disadvantageous as it offers substantially no flexibility of control of the mass flow of heating gases over the tube bank. With the present construction, a series of boiler sizes with similar tube spacings may be obtained while maintaining substantially the same draft loss and without changing the furnace transverse cross-sectional area and shape, by merely changing the total number of transverse rows of tubes and correspondingly changing the number of transverse rows of tubes in each gas pass.

In the present construction, as shown in Fig. 2, the tube bank space 21 is advantageously divided into a plurality of serially connected gas passes 70, 71 and 72, extending transversely of the tube bank and through which a substantially horizontal flow of heating gases is maintained from the furnace chamber to a gas outlet 73 in the front end of a flat arch 74 extending between the drum 20 and housing wall 28. Sloping baffles 75 and 76 separate the gas passes 70, 71 and 72. As shown in Figs. 2, 3, 12 and 13, the baffle 75 extends between the drums from the inner furnace chamber wall 33 toward the housing wall 28 terminating short of the latter to permit communication between the gas passes 70 and 71. A pair of tubes 24b at the rear end of the chamber wall have studs 31a on their outer sides which support a layer of refractory material 33b in which a notch 77 is formed to receive the inner end of the baffle 75. The baffle 75 is formed by superposed rows of tile, as shown in Fig. 12, which are held between the last transverse row of tubes 24 and a transverse row of large diameter tubes 24c hereinafter described. The superposed tile 75a adjacent the furnace chamber wall 33 are provided with tongue and groove joints, as shown in Fig. 13, to insure a gas-tight wall. The baffle 76 extends from the housing wall toward the inner chamber wall, terminating short of the latter to permit communication between the gas passes 71 and 72. The metallic plates forming the baffle 76 are held in position between transverse tubes 24 by U-clamps 78 secured to adjacent tubes 24. The mass flow conditions in the tube space may be varied by shifting the baffle 76 to form gas passes of successively smaller effective flow areas.

The steam generating tubes 24c in the first gas pass 70 are fewer in number but of greater diameter than the tubes in the second and third passes 71 and 72. The tubes of the innermost rows in the first pass are bent and staggered, as shown in Figs. 2 and 11, to form a slag screen across the entrance end of the first pass. The remaining steam generating tubes 24c are arranged in longitudinal rows occupying only about one-half of the available space in the first pass. The tubes 24c serve as a water screen for a steam superheater positioned in the first pass between the tubes 24c and the wall 28.

The steam superheater is formed by a series of nested single looped tubes 80 arranged substantially parallel to the tubes 24c with their looped portions adjacent the drum 20 and their lower ends connected to a pair of longitudinally extending horizontal headers 81 and 82 between the drum 23 and wall 28. The headers 81 and 82 are partitioned, as indicated in Fig. 2, to divide the superheater into passes for the serial flow of the steam therethrough. The header 82 receives the steam to be superheated at its forward end through the tubes 22 and has an outlet 82a formed on its rear end for the discharge of the superheated steam. The superheater is supported entirely by the drum 23 through longitudinally spaced cantilever beams 83 in which the superheater headers are cradled. The superheater tube connections and lower supports are protected by a layer of refractory 84, as shown in Fig. 11. The horizontal load of the upper end of the superheater is carried by the boiler tubes 24c through lugs 85 welded to the boiler tubes and opposite the superheater tubes, and transverse spacers 86a and longitudinal spacers 86 for holding the superheater tubes in spaced relation.

The amount of steam generating surface in the first pass is limited to that required to remove the slag from the furnace gases and to reduce the gas temperature to a value at which safe superheater tube temperatures result. With only this amount of steam generating surface contacting with the furnace gases prior to their reaching the superheater, only a relatively small amount of superheater surface will be required to obtain a given steam superheat temperature and a less varying superheat curve will result. The use of large diameter tubes in the first pass is desirable with the high gas temperatures present. The use of small diameter superheater tubes in the first pass and steam generating tubes in the second and third passes reduces the cost and space requirements and increases the boiler efficiency for a given amount of heating surface. The boiler and superheater tubes in the first pass can be easily removed and replaced from the furnace chamber.

With the boiler construction described, feed water enters the drum 20 and flows downwardly through substantially all of the tubes 24 in the gas passes 71 and 72. A considerable portion of the steam is generated in the furnace tubes 24a, 40 and 34 and the tubes 24c in the first pass. Fuel is preferably introduced through the front wall into the furnace chamber in a horizontal stream and is rapidly ignited and burned in suspension. The heating gases pass rearwardly through the furnace chamber and then transversely across the slag and water screen tubes 24c in the gas pass 70. The gases then contact with the superheater tubes 80 and turn around the baffle 75 into the gas pass 71. After passing across the tubes 24 in the gas pass 71, the gases turn through the space 87 between the innermost row of small diameter tubes 24 and the inner furnace wall 33, the space 87 insuring proper distribution

of the heating gases in the passes 71 and 72 and minimizing the amount of tube surface therein short-circuited. The heating gases tend to rise during their passage through the gas passes and to prevent by-passing of the lower portions of the tubes in the third pass 72, spaced metal strip baffles 88 are mounted on the outermost tubes 24 in that pass, as shown in Fig. 1, to cause most of the gases to turn downwardly below the baffled section before reaching the boiler gas outlet 73. Dampers 89 control the gas outlet 73. A brick wall 90 is constructed at the front end of the refractory layer 84 to prevent the heating gases entering the space containing the superheater supports. The fluid heating surface in the furnace shown is preferably proportioned in amount and exposure to maintain a furnace temperature such that when a slag-forming fuel is burned in suspension, a substantial portion of the particles of fuel residue deposited on the furnace floor will be cooled sufficiently to permit their removal in a "dry" form.

The steam and water drum 20 contains suitable steam and water separating provisons 91 for insuring the delivery of substantially dry steam to the superheater. The separator is preferably of the type disclosed and claimed in a pending application of James Fletcher, Serial No. 678,374, filed June 30, 1933.

While the whole vertical load of the drums and tube bank is carried by the supports for the mud drum, the vertically inclined arrangement of the tube bank and offsetting of the drums causes a horizontal load which is partly supported by the tubes 34 and the floor supports and partly by end horizontal beams 92 each having an inclined bracket 93 in contact with a similar bracket 94 on the drum, as shown in Fig. 11.

In the modification illustrated in Figs. 14 to 16 the upper and lower drums 120 and 123 have their axes substantially in vertical alignment and the connecting tubes 124 upright. The inner wall of the furnace 130 is formed by a refractory baffle 133 supported between the innermost row of small diameter tubes 124 and a row of large diameter tubes 124a. The innermost row of tubes 124 is laterally spaced from the remaining tube rows a substantial distance to provide a gas turning space 187 therebetween. The floor, outer side wall 129, and roof of the furnace are defined by a row of longitudinally spaced continuous U-shaped tubes 134 having their opposite ends connected to drums 120 and 123 respectively. The tubes 134 line the inner surfaces of the refractory forming the floor, outer side wall, and roof. The rear wall 127 is also lined with continuous U-shaped tubes 150 connected directly to the drums 120 and 123. The furnace construction described, due to the large amount of exposed wall cooling surface, is especially adapted for the burning of oil and other hydrocarbons at extremely high rates of heat release per unit of furnace volume, and a suitable oil burner 145 is centrally mounted in the front wall 126 of the furnace for supplying the fluid fuel.

The space containing the tube bank 124 is also divided into serially connected transverse gas passes 160, 161, and 162 by refractory baffles 164 and 165. The baffle 164 forms a perpendicular extension of the rear end of the baffle 133, while the baffle 165 extends from the housing wall 128 towards, but terminating short of, the baffle wall 133. The tubes 124a at the outer side of the baffle 133 are uniformly spaced throughout the length of the furnace, extending across the entrance to the gas pass 160. The tubes 124 are similarly distributed and arranged in all of the gas passes, and those in the gas pass 160 provide a water screen for the superheater 180. The superheater is formed by one or more large diameter looped tubes extending horizontally along the outer side of the tube bank in the gas passes 160 and 161, with the inter-loop portions thereof supported on a series of brackets 181 welded on the outermost row of tubes 124. The lowermost loop of the superheater is connected to the steam outlet tube 122 of the drum 120, and provided with a drain connection 182 at its lowermost point to make the superheater self-draining.

With the above construction a stream of fluid fuel is projected horizontally toward the rear wall of the furnace, and the products of combustion pass rearwardly around the rear end of the baffle wall 133 and successively through the heating gas passes 160, 161 and 162 to the heating gas outlet 163. The fluid flow in the boiler circulation system will be substantially the same as that described in the embodiment illustrated in Figs. 1 to 13, the flow through the radiant heat absorbing furnace tubes and the steam generating tubes in the gas pass 160 being upward, while the flow through the tubes located in the passes 161 and 162 is generally downward. A considerable portion of the steam generated in the tube bank will be in the tubes located in the gas pass 160, and the steam outlet 122 from the drum 120 is located at the front end of the drum.

While in accordance with the provisions of the statutes we have illustrated and described herein the best forms of our invention now known to us, those skilled in the art will understand that changes may be made in the form of the boiler, furnace and fuel burning provisions 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.

We claim:

1. A steam boiler having an upper steam and water drum, a lower water drum, a vertically disposed convection heated bank of steam generating tubes extending between and connected to said drums along the length thereof, means forming a furnace chamber laterally adjoining the space containing said tube bank and communicating therewith at only one end, baffle means extending transversely of said tube space and arranged to divide said tube space into a plurality of serially connected gas passes extending transversely of said tube bank, and means at the opposite end of said furnace chamber for burning fuel in said furnace chamber and effecting a substantially horizontal flow of heating gases longitudinally through said furnace chamber and reversely through said serially connected gas passes.

2. A steam boiler having an upper steam and water drum, a lower water drum, a vertically disposed convection heated bank of steam generating tubes extending between and connected to said drums along the length thereof, means forming a fluid cooled furnace chamber laterally adjoining the space containing said tube bank and communicating therewith only at one end, means at the opposite end of said furnace chamber for burning fuel in suspension in said furnace chamber and effecting a substantially horizontal flow of heating gases longitudinally through said furnace chamber and reversely through said tube space, and transversely extending baffle means

arranged to divide said tube space into a plurality of serially connected gas passes extending transversely of said tube bank.

3. A steam boiler having a substantially rectangular housing, an upper steam and water drum, an offset lower water drum, a vertically inclined convection heated bank of closely spaced steam generating tubes extending between and connected to said drums substantially throughout the length thereof, a baffle wall separating a laterally adjoining furnace chamber from the space containing said tube bank and terminating at its rear end short of the rear wall of said housing to provide communication therebetween at their rear ends only, a row of water tubes connected to said drums and in thermal contact with said partition, another row of water tubes connected to said drums and laterally spaced from said tube bank and extending along the outer side wall of said furnace chamber, means at the front end of said furnace chamber for burning fuel in suspension in said furnace chamber and effecting a substantially horizontal flow of heating gases longitudinally through said furnace chamber and reversely through said tube space, transversely extending baffle means arranged to divide said tube space into a plurality of serially connected gas passes extending transversely of said tube bank, and said partition and partition cooling tubes being spaced from the adjacent tube bank row of tubes a transverse distance greater than the transverse distance between the longitudinal tube rows in the gas passes laterally adjoining said partition.

4. A steam boiler having an upper steam and water drum, a lower water drum, a vertically disposed convection heated bank of steam generating tubes extending between and connected to said drums along the length thereof, a partition defining the inner side wall of a furnace chamber laterally adjoining the space containing said tube bank and communicating therewith at one end, fuel burning means at the opposite end of said furnace chamber, means effecting a substantially horizontal flow of heating gases longitudinally through said furnace chamber and reversely through said tube space, transversely extending baffle means arranged to divide said tube space into a plurality of serially connected gas passes extending transversely of said tube bank, and the tubes of said tube bank in the gas pass opening to said furnace chamber being of larger diameter than the tubes in the subsequent gas passes.

5. A steam boiler having an upper steam and water drum, a lower water drum, a vertically disposed convection heated bank of steam generating tubes extending between and connected to said drums along the length thereof, means forming a fluid cooled furnace chamber laterally adjoining the space containing said tube bank and communicating therewith at one end, said means including a row of vertically disposed water tubes laterally spaced from said tube bank and having their upper ends connected to said steam and water drum, integral projections on said water tubes, refractory material carried by said tube projections and defining the outer side wall of said furnace chamber, tubes connecting the lower ends of said side wall tubes to said lower drum, and means at the opposite end of said furnace chamber for burning fuel in suspension in said furnace chamber and effecting a substantially horizontal flow of heating gases longitudinally through said furnace chamber and reversely through said tube space and in thermal contact with the tubes therein.

6. A steam boiler having an upper steam and water drum, a lower water drum, a vertically disposed convection heated bank of steam generating tubes extending between and connected to said drums along the length thereof, means forming a fluid cooled furnace chamber laterally adjoining the space containing said tube bank and communicating therewith at one end, said means including a row of vertically disposed water tubes laterally spaced from said tube bank and having their upper ends connected to said steam and water drum, refractory material closing the spaces between said water tubes and defining the outer side wall of said furnace chamber, a header connected to the lower ends of said water tubes, a row of tubes connecting said header to said lower drum, heat resistant material covering and closing the spaces between said last named tubes to define the floor of said furnace chamber, and means at the opposite end of said furnace chamber for burning fuel in suspension in said furnace chamber and effecting a substantially horizontal flow of heating gases longitudinally through said furnace chamber and thence through said tube space and in thermal contact with the tubes therein.

7. A steam boiler having an upper steam and water drum, a lower water drum, a vertically disposed convection heated bank of steam generating tubes extending between and connected to said drums along the length thereof, means forming a fluid cooled furnace chamber laterally adjoining the space containing said tube bank and communicating therewith at one end, said means including a row of vertically disposed water tubes laterally spaced from said tube bank and having their upper ends directly connected to said steam and water drum, refractory material closing the spaces between said water tubes and defining the outer side wall and roof of said furnace chamber, a header connected to the lower ends of said water tubes, a row of tubes connecting said header to said lower drum, refractory means closing the spaces between and covering said last named tubes to define the floor of said furnace chamber, a fluid cooled partition extending between said drums adjacent the forward portion of said tube bank and defining the inner side wall of said furnace chamber, and means at the opposite end of said furnace chamber for burning fuel in suspension in said combustion chamber and effecting a substantially horizontal flow of heating gases longitudinally through said furnace chamber and reversely through said tube space and in thermal contact with the tubes therein.

8. A steam boiler having an upper steam and water drum, a lower water drum, a vertically disposed convection heated bank of steam generating tubes extending between and connected to said drums along the length thereof, a partition defining the inner side wall of a furnace chamber laterally adjoining the space containing said tube bank and communicating therewith at its rear end, means at the front end of said boiler for burning a slag-forming fuel in said furnace chamber and effecting a substantially horizontal flow of heating gases rearwardly through said furnace chamber and thence through said tube space and in thermal contact with the tubes therein, and means adjacent the rear end of said furnace chamber forming a slag screen across the path of flow of the heating gases.

9. A steam boiler having an upper steam and

water drum, a lower water drum, a vertically disposed convection heated bank of steam generating tubes extending between and connected to said drums along the length thereof, a partition defining the inner side wall of a furnace chamber laterally adjoining the space containing said tube bank and communicating therewith at one end, a row of water tubes connected to said drums and laterally spaced from said tube bank and extending along the outer side wall of said furnace chamber, a horizontal header connected to the lower ends of said side wall tubes, means at the opposite end of said furnace chamber for burning fuel in suspension in said furnace chamber and effecting a substantially horizontal flow of heating gases longitudinally through said furnace chamber and reversely through said tube space, a horizontally extending header along the rear wall of said furnace chamber and connected to said lower water drum, a row of tubes connecting said rear wall header and steam and water drum and cooling the rear wall of said furnace chamber, and means forming a direct structural connection between said side and rear wall headers.

10. In a furnace, a wall comprising a row of spaced tubes, a multiplicity of metallic studs mounted on opposite sides of said tubes and projecting into the inter-tube spaces, refractory material carried by said studs and closing the inter-tube spaces, and means for tying adjacent tubes together at a point intermediate their length comprising means forming a welded connection between studs on adjacent tubes.

11. In a furnace, a wall comprising a row of spaced tubes, a multiplicity of metallic studs mounted on opposite sides of said tubes and projecting into the inter-tube spaces, refractory material carried by said studs and closing the inter-tube spaces, and means for tying adjacent tubes together intermediate their length comprising a plate extending vertically between the studs on adjacent tubes and welds integrally connecting said plate to studs on adjacent tubes.

12. In a tubular heat exchanger adapted as a part of a furnace wall to transmit to a contained fluid the heat received radiantly from fuel burning in the furnace; said tubular heat exchanger having a metallic inner part in contact with the contained fluid; and a composite outer structure exposed to radiant heat from the burning fuel; said outer structure comprising metallic projections extending outwardly from the inner part, and refractory material contacting with the inner part and located between the projections, said refractory material being of greater thermal resistance than the material of the remaining structure, thereby preventing overheating of the exchanger metal and contributing to higher furnace temperatures, and means for integrally connecting the metallic projections on adjacent tubes.

13. A steam boiler having an upper steam and water drum, a lower water drum, a vertically disposed convection heated bank of steam generating tubes extending between and connected to said drums along the length thereof, a partition defining the inner side wall of a furnace chamber laterally adjoining the space containing said tube bank and communicating therewith at one end, means defining the remaining walls of said furnace chamber and tube space, means at the opposite end of said furnace chamber for burning fuel in said furnace chamber and effecting a substantially horizontal flow of heating gases longitudinally through said furnace chamber and reversely through said tube space and in thermal contact with the tubes therein, baffle means arranged to divide said tube space into a plurality of serially connected gas passes extending transversely of said tube bank, and a steam superheater positioned in the gas pass opening to said furnace chamber.

14. A steam boiler having an upper steam and water drum, a lower water drum, a vertically disposed convection heated bank of steam generating tubes extending between and connected to said drums along the length thereof, a partition defining the inner side wall of a furnace chamber laterally adjoining the space containing said tube bank and communicating therewith only at one end, means defining the remaining walls of said furnace chamber and tube space, means at the opposite end of said furnace chamber for burning fuel in said furnace chamber and effecting a substantially horizontal flow of heating gases longitudinally through said furnace chamber and reversely through said tube space and in thermal contact with the tubes therein, baffle means arranged to divide said tube space into a plurality of serially connected gas passes extending transversely of said tube bank, a steam superheater positioned in the gas pass opening to said furnace chamber, and water tubes in said last mentioned gas pass arranged to form a screen between said superheater and said furnace chamber.

15. A steam boiler having an upper steam and water drum, a lower water drum, a vertically disposed convection heated bank of steam generating tubes extending between and connected to said drums along the length thereof, a partition defining the inner side wall of a fluid cooled furnace chamber laterally adjoining the space containing said tube bank and communicating therewith only at one end, a row of spaced vertically disposed water tubes laterally spaced from said tube bank and connected to said steam and water drum, refractory material closing the spaces between said water tubes and defining the outer side wall of said furnace chamber, a header connected to the lower end of said water tubes, a row of tubes connecting said header to said lower drum, means closing the spaces between said last named tubes and defining the floor of said furnace chamber, means at the opposite end of said furnace chamber for burning fuel in suspension in said furnace chamber and effecting a substantially horizontal flow of heating gases longitudinally through said furnace chamber and thence through said tube space and in thermal contact with the tubes therein, and an ash receiving opening extending transversely of said furnace chamber at the rear of said floor tubes.

16. A steam boiler having an upper steam and water drum, a lower water drum, a vertically disposed convection heated bank of steam generating tubes extending between and connected to said drums along the length thereof, a bottom support for said drums and tube bank, means forming a furnace chamber laterally adjoining the space containing said tube bank and communicating therewith at its rear end, means at the front end of said furnace chamber for burning fuel in said furnace chamber and effecting a substantially horizontal flow of heating gases rearwardly through said furnace chamber and forwardly through said tube space, a superheater at the outer side of said tube bank having a pair of headers arranged parallel to said lower water drum and looped tubes connecting said headers arranged adjacent said tube bank, means for supporting said headers from said lower water

drum, and means for laterally supporting said looped tubes from said tube bank.

17. A steam boiler having an upper steam and water drum, a lower water drum, a vertically disposed convection heated bank of steam generating tubes extending between and connected to said drums along the length thereof, means defining a furnace chamber laterally adjoining the space containing said tube bank and including a row of tubes having one end connected to said lower drum and extending laterally from said tube bank, a horizontal side wall header connected to the other end of said laterally extending tubes, means for burning fuel in said furnace chamber, a header extending along an end wall of said furnace chamber substantially parallel to said laterally extending tubes and connected to said lower drum, a row of tubes connecting said end wall header to said upper drum, and means forming a direct structural connection between said side and end wall headers.

18. A steam boiler having an upper steam and water drum, a lower water drum, a vertically disposed convection heated bank of steam generating tubes extending between and connected to said drums along the length thereof, a partition defining the inner side wall of a furnace chamber laterally adjoining the space containing said tube bank and communicating therewith at its rear end only, means defining the remaining walls of said furnace chamber and tube space, a row of tubes connected to said upper drum and laterally spaced from said tube bank and extending along the outer side wall of said furnace chamber, a horizontal header connected to the lower ends of said side wall tubes, a row of tubes extending laterally from said lower drum and connecting said lower drum to said side wall header, means at the front end of said furnace chamber for burning fuel in suspension therein and effecting a substantially horizontal flow of heating gases rearwardly through said furnace chamber and thence through said tube space, a horizontally extending header along the rear wall of said furnace chamber and connected to said lower water drum, and a row of spaced tubes connecting said rear wall header to said upper drum and arranged to cool the rear wall of said furnace chamber.

19. A steam boiler having an upper steam and water drum, a lower water drum, a vertically disposed convection heated bank of steam generating tubes extending between and connected to said drums along the length thereof, means defining a furnace chamber laterally adjoining the space containing said tube bank and including a row of spaced tubes extending laterally from and connected to said lower drum, means closing the spaces between said laterally extending tubes and defining the floor of said furnace chamber, means at the front end of said furnace chamber for burning fuel in suspension therein, and an ash receiving opening extending transversely of said furnace chamber at the rear end thereof.

20. A steam boiler having an upper steam and water drum, a lower water drum, a bank of steam generating tubes extending between and connected to said drums along the length thereof, means forming a furnace chamber laterally adjoining the space containing said tube bank and communicating therewith at its rear end, means at the front end of said furnace chamber for burning fuel in said furnace chamber and effecting a substantially horizontal flow of heating gases rearwardly through said furnace chamber and thence through said tube space, baffle means extending transversely of said tube space and arranged to divide said tube space into a plurality of serially connected gas passes extending transversely of said tube bank, steam superheating tubes positioned in the gas pass opening to said furnace chamber and at the outer side of said tube bank, and means for supporting said superheating tubes from said tube bank.

21. A steam boiler comprising an upper steam and water drum, a lower water drum, a vertically disposed convection heated bank of steam generating tubes extending between and connected to said drums along the length thereof, a partition forming the inner side of a furnace chamber and separating the same from a laterally adjoining space containing said tube bank, means defining the remaining sides of said furnace chamber and tube space, said furnace chamber and tube space communicating at their rear ends only, means at the front end of said furnace chamber for burning fuel and effecting a substantially horizontal flow of heating gases rearwardly through said furnace chamber and thence through said tube space, and the tubes in the tube rows at the rear end of said bank nearest said furnace chamber being spaced apart a greater distance than the tubes in the remaining rows of said bank to form a slag screen between the tubes in the remaining rows and said furnace chamber.

22. A steam boiler comprising an upper steam and water drum, a lower water drum, a vertically disposed convection heated bank of steam generating tubes extending between and connected to said drums along the length thereof, a partition forming the inner side of a furnace chamber and separating the same from a laterally adjoining space containing said tube bank, means defining the remaining sides of said furnace chamber and tube space, said furnace chamber and tube space communicating at their rear ends only, means at the front end of said furnace chamber for burning fuel and effecting a substantially horizontal flow of heating gases rearwardly through said furnace chamber and thence through said tube space, the tubes in the tube rows at the rear end of said bank nearest said furnace chamber being spaced apart a greater distance than the tubes in the remaining rows of said bank to form a slag screen between the tubes in the remaining rows and said furnace chamber, and a steam superheater positioned in said tube space at the opposite side of said tube bank from said furnace chamber.

23. A steam boiler having an upper steam and water drum, a lower water drum, a vertically disposed convection heated bank of steam generating tubes extending between and connected to said drums along the length thereof and disposed at both sides of the plane including the longitudinal axes of said drums, a partition forming one side of a furnace chamber substantially wholly at one side of the said axial plane and separating the same from a laterally adjoining space communicating therewith at only one end and containing said tube bank, means defining the remaining sides of said furnace chamber and tube space, means at the other end of said furnace chamber for burning fuel and effecting a substantially horizontal flow of heating gases longitudinally through said furnace chamber and thence through said tube space, and a steam superheater positioned in said tube space on the side of said axial plane opposite said furnace chamber.

24. A steam boiler comprising an upper steam and water drum, a lower water drum, a vertically

disposed convection heated bank of steam generating tubes extending between and connected to said drums along the length thereof, a partition forming the inner side of a furnace chamber and separating the same from a laterally adjoining space containing said tube bank, means defining the remaining sides of said furnace chamber and tube space, said furnace chamber and tube space communicating at their rear ends only, a row of tubes connected to said drums and laterally spaced from said partition and extending along the outer side of said furnace chamber, means at the front end of said furnace chamber for burning fuel and effecting a substantially horizontal flow of heating gases rearwardly through said furnace chamber and thence through said tube space, and vertical baffle means extending from said upper drum to said lower drum and arranged transversely of said tube bank to divide said tube space into a plurality of serially connected gas passes having a substantially horizontal flow of heating gases therein in thermal contact with said tube bank.

25. In a fluid heater, a furnace boundary structure adapted to be exposed in operation to high temperatures and comprising a row of spaced fluid heating tubes, a series of metallic projections mounted on said tubes and arranged to project into the intertube spaces, refractory material between said projections in contact with said tubes and arranged to close the intertube spaces, and means for connecting projections on adjacent tubes.

26. In a fluid heater, a separating wall having opposite sides adapted to be exposed in operation to high temperatures and comprising a row of vertically disposed spaced fluid heating tubes, a series of metallic projections mounted on said tubes and arranged to project into the intertube spaces, refractory material between said projections in contact with said tubes and arranged to close the intertube spaces, and means for integrally connecting projections on adjacent tubes.

27. In a fluid heater, a row of spaced fluid heating tubes having a series of metallic projections mounted on and spaced along opposite sides of said tubes, and arranged to project into the inter-tube spaces, and connecting means between projections on adjacent tubes to tie said tubes together along their length.

28. A steam boiler having a pair of horizontally disposed upper and lower drums, a bank of vertically disposed water tubes extending between and connected to said drums along the length thereof, means forming a longitudinally extending combustion lane and a heating lane laterally adjoining said combustion lane and containing said tube bank and communicating with said combustion lane at one end thereof, said means including a vertically disposed partition extending along one side of said heating lane and having tubes provided with refractory-supporting metallic projections at the heating lane side thereof arranged to form a vertically extending recess, a vertically disposed baffle extending transversely of said heating lane and fitting into the recess in said partition, and means for burning fuel in said combustion lane and arranged to permit a serial flow of heating gases through said combustion and heating lanes.

29. A steam boiler having a pair of horizontally disposed upper and lower drums, a bank of vertically disposed water tubes extending between and connected to said drums along the length thereof, means forming a longitudinally extending combustion lane and a heating lane laterally adjoining said combustion lane and containing said tube bank and communicating with said combustion lane at one end thereof, said means including a row of tubes with refractory material therebetween and forming a vertically disposed longitudinally extending partition separating and forming one side of said combustion and heating lanes, means for burning fuel in said combustion lane and arranged to permit a serial flow of heating gases through said combustion and heating lanes, and said partition and partition-forming tubes being spaced a substantial distance from the laterally adjacent tubes of said tube bank to provide a heating gas distribution space between said partition and tube bank.

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CERTIFICATE OF CORRECTION.

Patent No. 1,999,984. April 30, 1935.

ERVIN G. BAILEY, ET AL.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 2, second column, line 52, for "simultaneously" read simultaneous; page 5, first column, line 10, claim 3, for "baffle wall" read partition; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 16th day of July, A. D. 1935.

Leslie Frazer

(Seal) Acting Commissioner of Patents.