Nov. 26, 1940. R. M. HARDGROVE 2,222,769

VAPOR GENERATOR

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Fig. 1

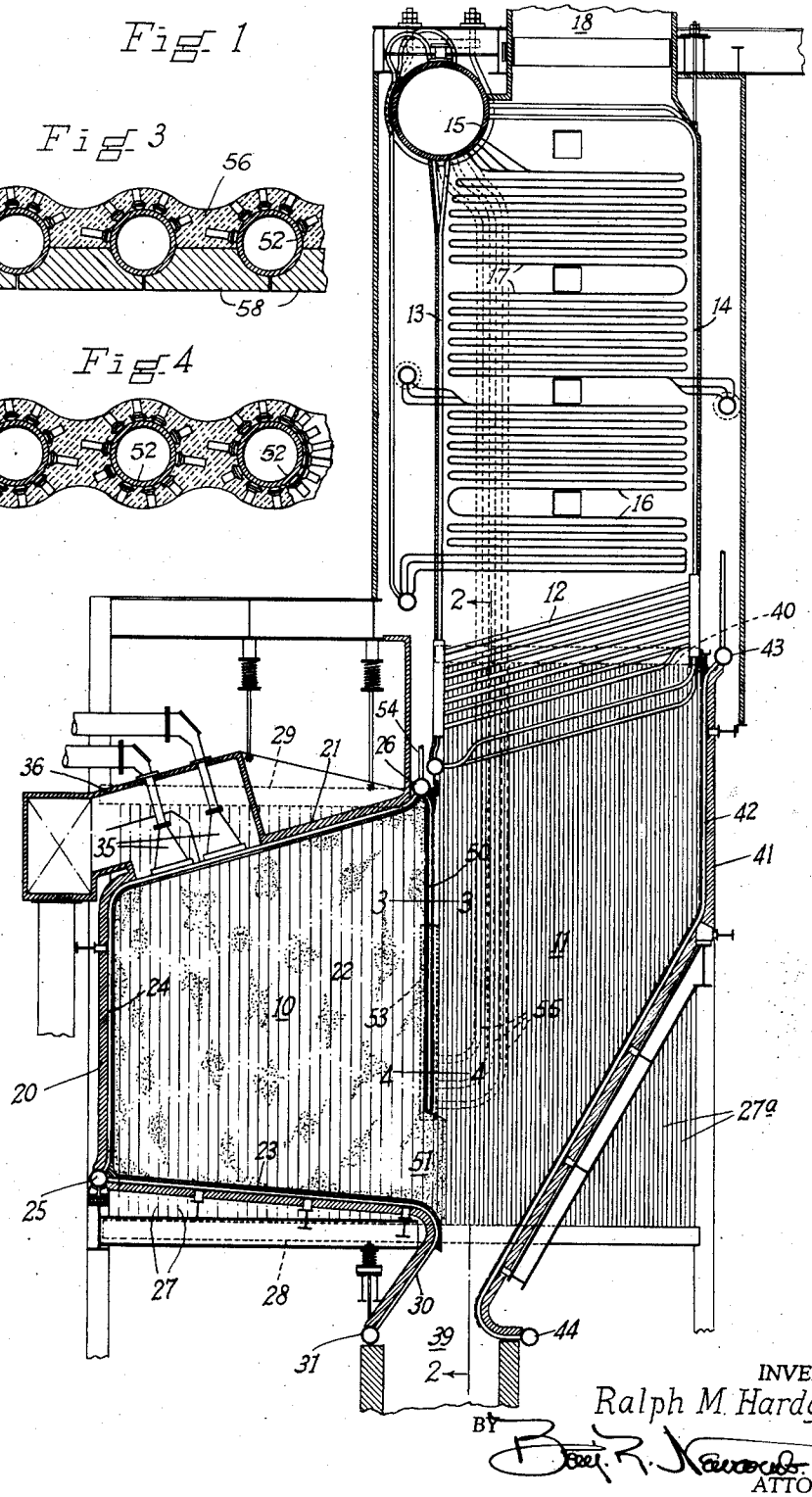


Fig. 3

Fig. 4

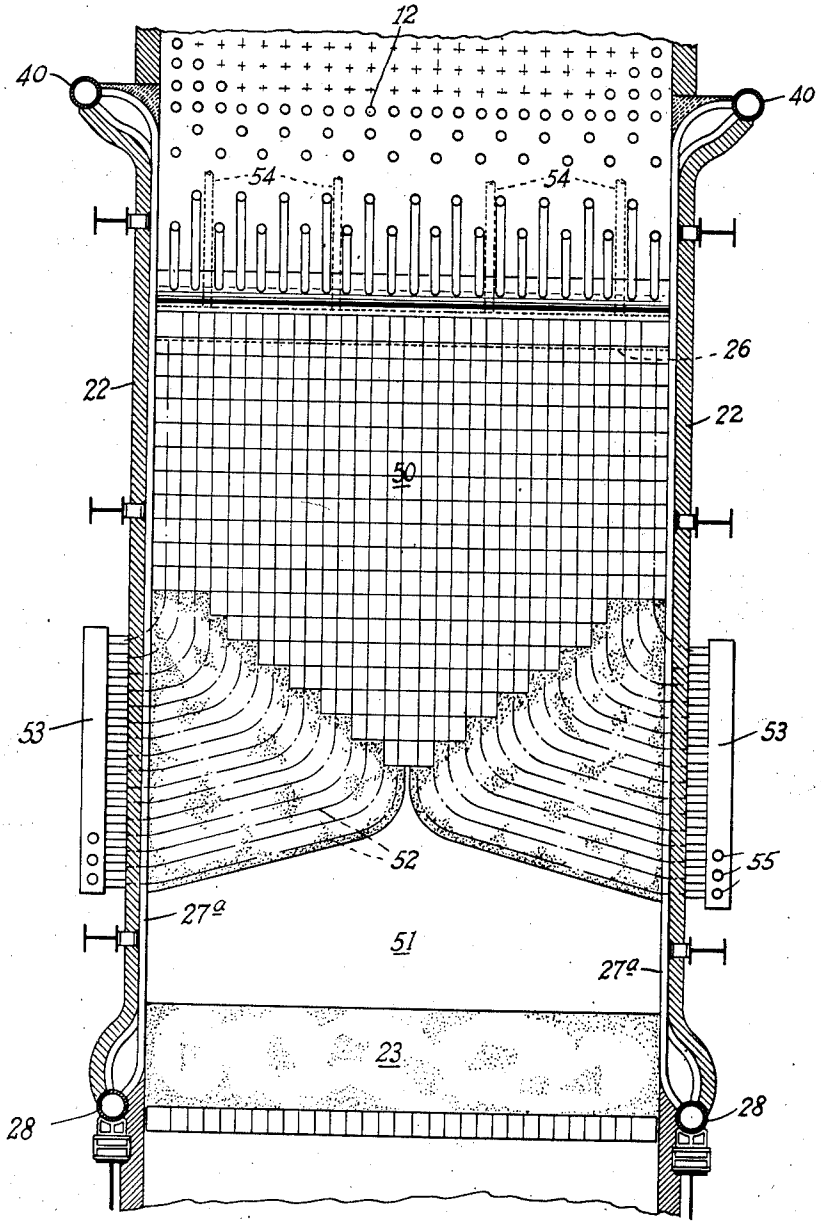
INVENTOR.
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BY
ATTORNEY.

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VAPOR GENERATOR

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Fig. 2



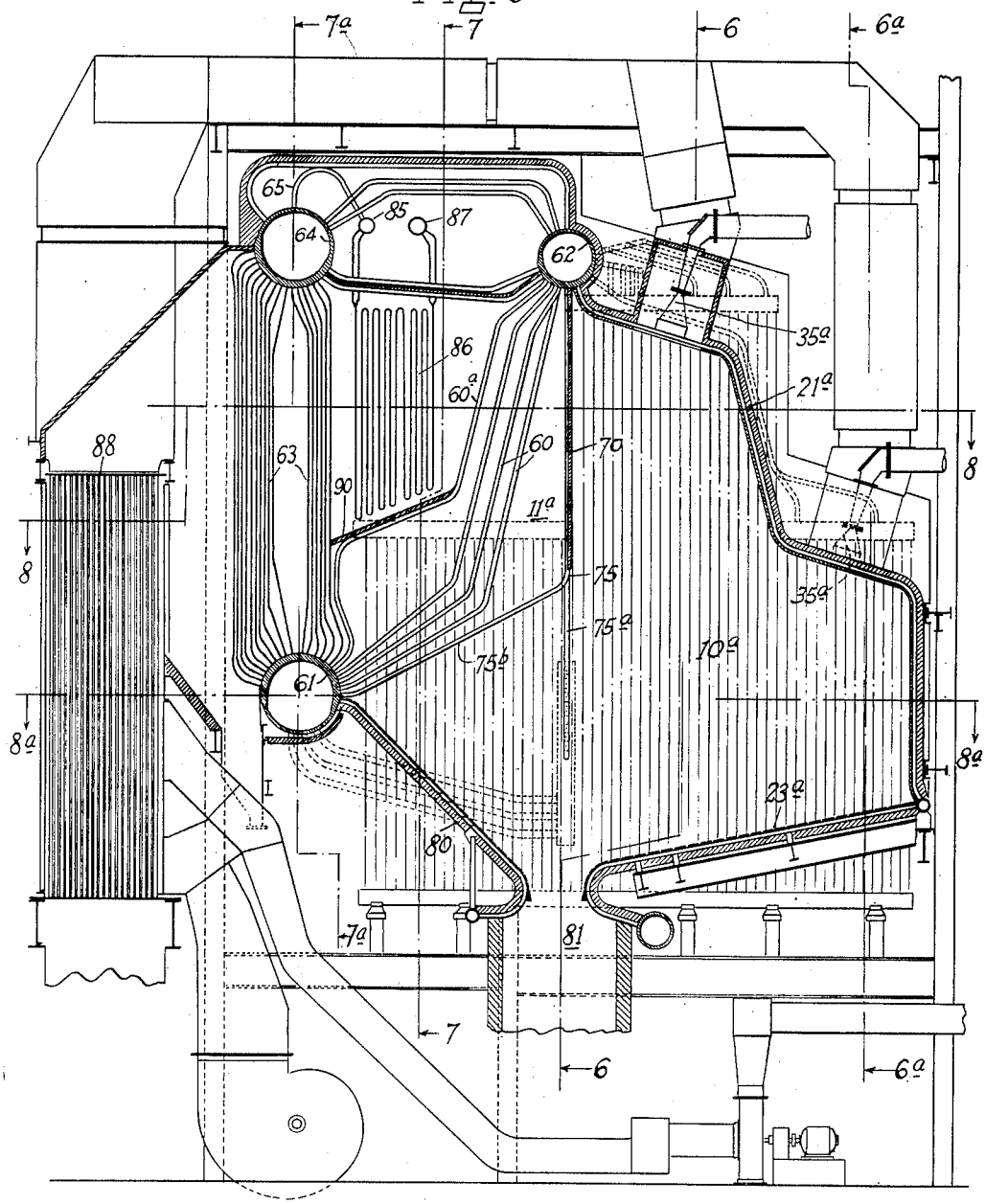
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VAPOR GENERATOR

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Fig. 5



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Ralph M. Hardgrove

BY Basil R. Jaccard

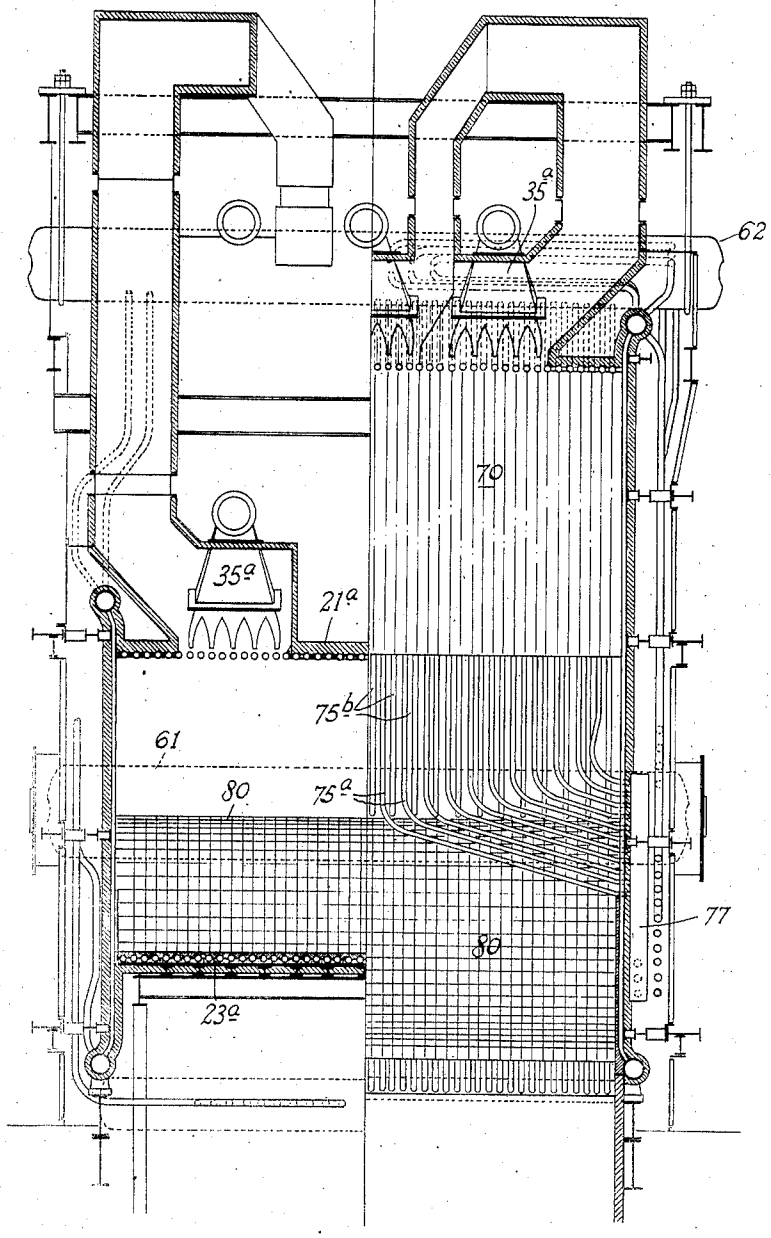
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VAPOR GENERATOR

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Fig. 6



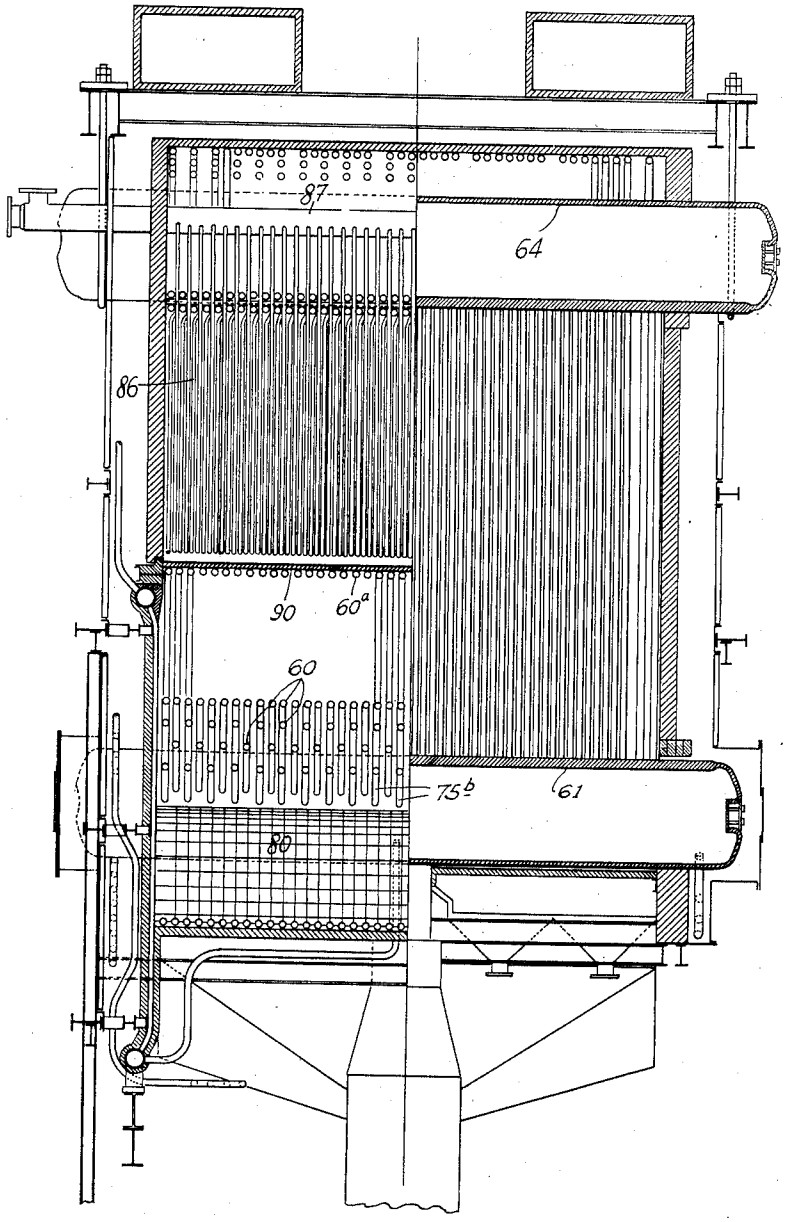
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VAPOR GENERATOR

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Fig. 7



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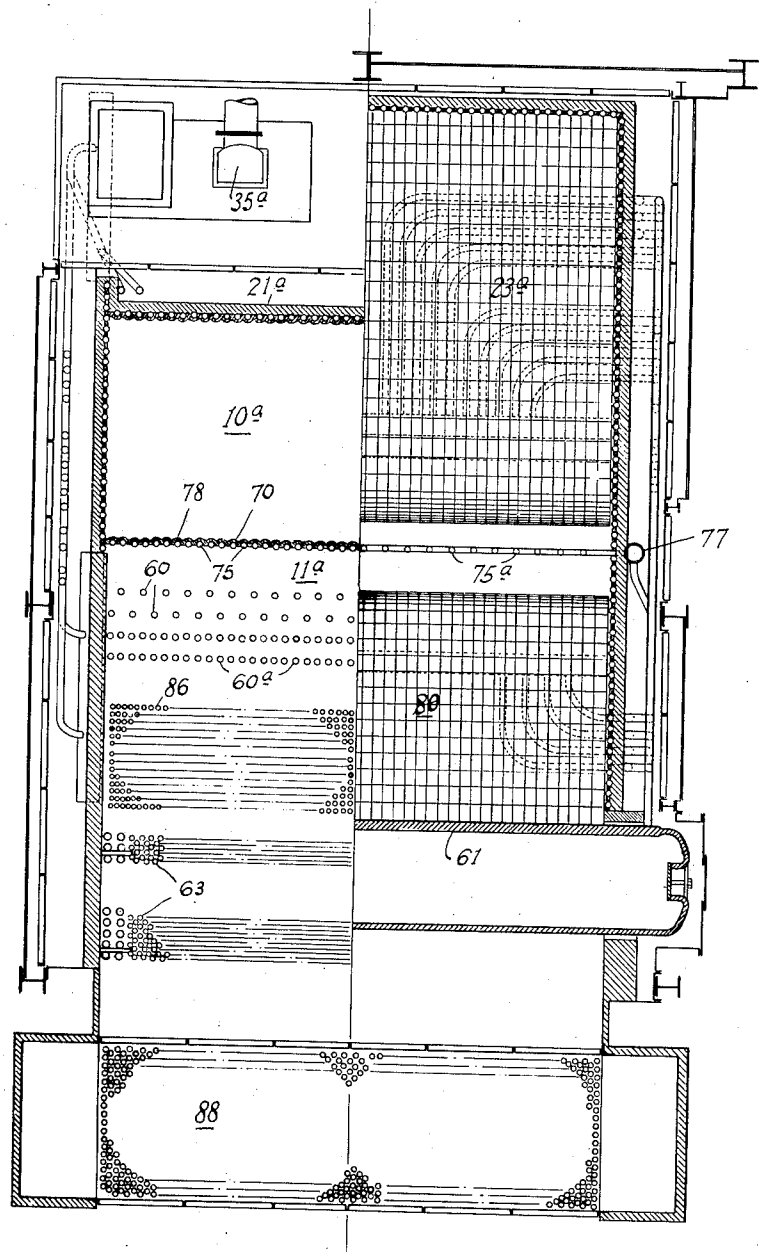


Fig. 8

INVENTOR.

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BY Brady R. Newcomb

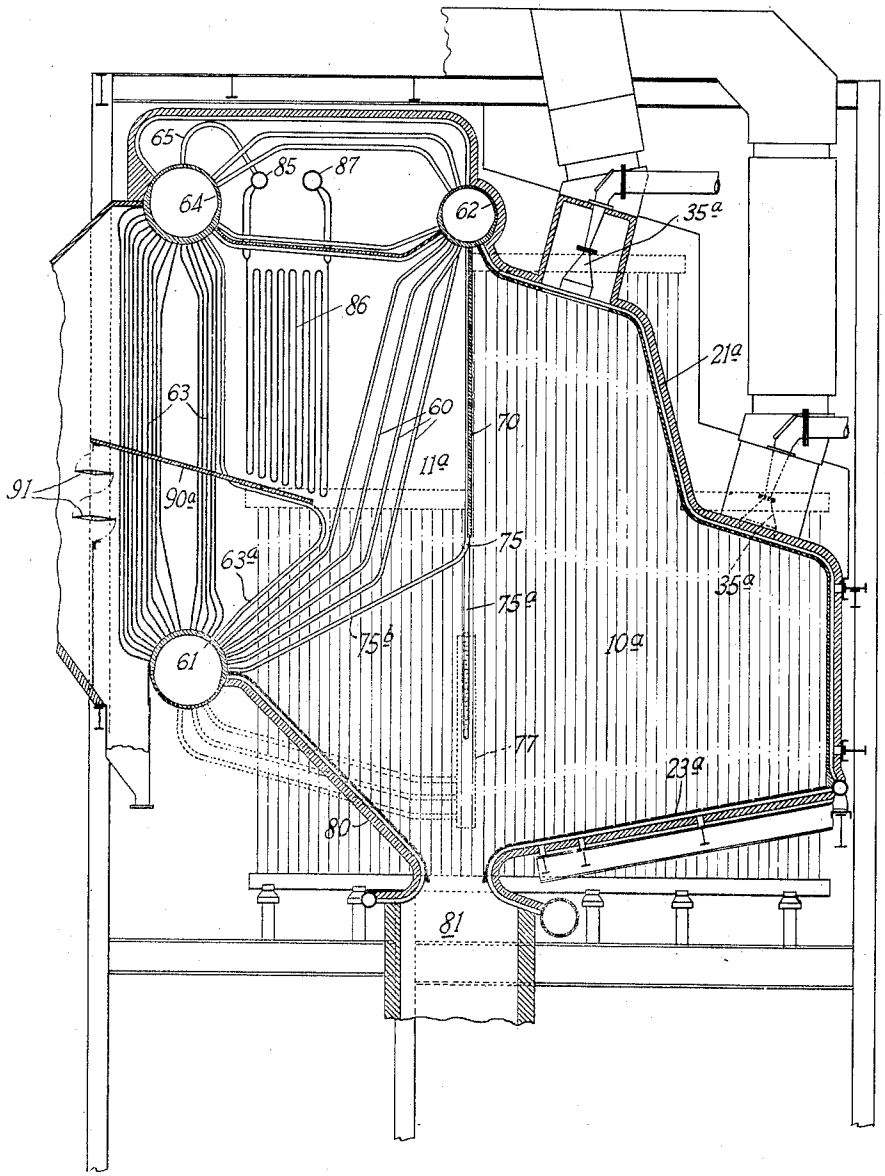
ATTORNEY.

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VAPOR GENERATOR

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Fig. 9



INVENTOR.
Ralph M. Hardgrove
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Patented Nov. 26, 1940

2,222,769

UNITED STATES PATENT OFFICE

2,222,769

VAPOR GENERATOR

Ralph M. Hardgrove, Westfield, N. J., assignor to The Babcock & Wilcox Company, Newark, N. J., a corporation of New Jersey

Application October 14, 1937, Serial No. 168,869

9 Claims. (Cl. 122—235)

The present invention relates in general to the construction and operation of steam generating units, and more particularly, to high capacity steam generating units incorporating a two-stage furnace for burning finely divided solid fuel in suspension. Such furnaces are divided into a primary or high temperature section and a secondary or low temperature section by a fluid cooled screen or partititon. The furnace partition serves to screen the secondary furnace section and the convection heated surface of the unit from radiant heat from the primary furnace section and vice versa. The normal mean operating temperature in the primary furnace section permits the efficient and stabilized combustion of a wide range of pulverized fuels over a wide range of operating load and the separation therein of a high percentage of the fuel ash content. The secondary furnace section is constructed and relatively arranged with respect to the furnace screen and convection heated steam generating surface that the temperature of the furnace gases and suspended ash particles will be reduced by radiant heat transfer therein to a temperature resulting in minimum slagging of the steam generating tubes and separation of ash in the secondary section mainly in a dry condition.

In such furnaces the furnace partition has been heretofore formed by a row of substantially vertical water tubes extending to the furnace floor with closure means for the intertube spaces except adjacent the floor, leaving narrow openings in the lower portion for the passage of the furnace gases and separated ash from the primary furnace section to a hopper located below the secondary section. The lower portions of the partition tubes are usually bent to increase the size of the partition passages, as larger size openings aid in reducing the draft loss and lessen the possibility of the passages becoming clogged by accumulation of separated ash therein.

The main object of my invention is the provision in a steam generating unit of the character described of an improved construction of the furnace partition, whereby the draft loss through the furnace is substantially reduced, ash accumulations in the passage connecting the furnace sections eliminated, and maintenance costs lowered. Another object is the provision of a steam generator unit having simple and effective provisions for regulating steam superheat temperatures.

The various features of novelty which characterize my 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 I have illustrated and described preferred embodiments of my invention.

Of the drawings:

Fig. 1 is a partly diagrammatic sectional elevation of a steam generating unit incorporating my invention;

Fig. 2 is an enlarged vertical section taken on the line 2—2 of Fig. 1;

Figs. 3 and 4 are sectional views taken on the lines 3—3 and 4—4 respectively of Fig. 1;

Fig. 5 is a view similar to Fig. 1 showing a modified form of the invention;

Fig. 6 is a vertical sectional view, the right half being taken on the line 6—6, and the left half on the line 6A—6A, of Fig. 5;

Fig. 7 is a vertical sectional view, the left half being taken on the line 7—7, and the right half on the line 7A—7A of Fig. 5;

Fig. 8 is a horizontal sectional view, the left half being taken on the line 8—8, and the right half on the line 8A—8A of Fig. 5; and

Fig. 9 is a view similar to Fig. 5 illustrating a modification.

The steam generator unit illustrated in Figs. 1 to 4 comprises a pulverized fuel burning furnace divided into a primary or high temperature section 10 and a laterally adjoining secondary or low temperature section 11. The furnace section 11 is positioned directly below a sectional header steam boiler having a high circulation head, and comprising a bank of inclined steam generating tubes 12 extending across the upper end of the furnace section 11. The tube bank 12 is connected at opposite ends by vertically extending circulator tubes 13 and 14 to a transverse steam and water drum 15. The lowermost rows of the tube bank are bent and arranged to form a boiler slag screen. The boiler structure is arranged to provide a direct vertical gas flow from the furnace to the heating gas outlet 18 at the top of the setting. The space above the tube bank and between the circulator rows is utilized for the location of the auxiliary heating surface including a superheater 16 having two superposed sections extending across the gas pass, and an economizer 17, also divided into two superposed sections, above the superheater. Each of the superheater and economizer sections is formed by horizontally extending multiple-looped return bend tubes adapted to have their looped ends supported from the adjacent circulator tubes.

The primary furnace section is defined by a vertical front wall 20, a rearwardly and upwardly inclined arch 21, vertical side walls 22, and a rearwardly and downwardly inclined floor 23, all of which are fluid cooled. For this purpose a row of water tubes 24 extends upwardly along the inner side of the front wall from a bottom header 25, and along the arch 21 to a transverse upper or discharge header 26. A row of water tubes

27 extends vertically along the inner side of each side wall 22 between lower and upper headers 28 and 29 respectively. A row of tubes 30 slopes downwardly along the floor from the header 25 around the rear end of the floor to a parallel transverse header 31 forwardly of the rear end of the floor. The tubes 24, 27 and 30 are studded and covered with refractory to provide refractory faced boundary surfaces for the high temperature furnace section. The tubes 24 along one portion of the arch are uncovered to form a burner port through which a group of staggered pulverized fuel burner nozzles 35 discharge. An air box 36 surrounds the burner port and fuel nozzles and discharges secondary air around the streams of pulverized fuel and primary air discharged by the nozzles. The described construction of the high temperature furnace section and the furnace partition hereinafter described cooperate to define a hot combustion zone wherein pulverized fuel may be burned in suspension at high rates of heat release and a normal mean furnace temperature substantially above the fuel ash fusion temperature maintained. The ash particles separating from the burning fuel stream collect over substantially the entire area of the floor 23 in a molten condition and tend to flow over the rear end of the floor into an ash pit 39 below the secondary furnace section 11.

The secondary or low temperature furnace section 11 is provided with a large amount of cold wall area to permit the maintenance of a normal mean temperature therein below the fuel ash fusion temperature. The side wall tubes 27*a* in this section extend between an extension of the header 28 and an upper header 40. The rear wall 41 of the furnace section 11 has its lower portion inclined downwardly and forwardly to the ash pit 39 and is covered by water tubes 42 extending between upper and lower headers 43 and 44 respectively. The tubes 27*a* and 42 are made either bare, partly studded, or covered with metallic blocks to provide the desired amount of cold wall area.

The rear side of the primary furnace section and the front side of the secondary furnace section are defined by a partition 50 which extends downwardly from the rear end of the arch 21 in a vertical plane. The partition 50 terminates above the rear end of the floor leaving an unobstructed passage 51 therebetween for the flow of heating gases from the primary furnace section to the secondary furnace section and of molten slag from the primary furnace section floor to the pit 39 below the secondary section. The partition 50 is fluid cooled by a row of water tubes 52 uniformly spaced transversely of the furnace chamber and having their upper ends connected to the header 26. The lower portions of the tubes 52 are bent laterally in opposite directions at opposite sides of the furnace center line, as shown in Fig. 2, and extend through the side wall 22 into vertically extending side wall headers 53. The partition tubes 52 are connected into the boiler circulation system by risers 54 extending from the header 26 to the drum 15 and downcomer tubes 55 leading from the water space of the drum to the vertical headers 53. Suitable water supply connections are also provided from the water space of the drum 15 to the headers 26, 31 and 44. As shown in Figs. 1 to 3, the straight upper portions of the tubes 52 are studded and the intertube spaces and front side of the tubes covered with refractory 56 to provide a refractory rear wall surface for the primary furnace section. Metallic wall blocks 58 cover the rear side of the straight portions of the tubes 52 and add to the cold surface of the secondary furnace section. The lower bent portions of the tubes 52 are completely studded as shown in Fig. 4 and the tubes surrounded and the intertube spaces closed by refractory material 56. In view of the parallel arrangement of the bent portions of the tubes 52, the upper side of the passage 51 will have a symmetrical shape converging from the side walls 22 to an apex at the center line of the furnace.

The described partition construction provides an unobstructed passage below its lower end for the high temperature gases and molten slag leaving the primary furnace section. The partition tubes and refractory being out of the direct path of the gas and slag streams leaving the primary section will not be subject to severe erosion conditions and little, if any, maintenance will be required. The burning fuel and heating gases generated pass through a U-shaped path of flow in the furnace, the legs of which are formed by the furnace sections and the connecting portion by the passage 51 below the partition.

In Figs. 5 to 8, a modified two-stage furnace construction is illustrated in connection with a three-drum boiler of the vertical bent tube type. The primary or high temperature furnace section 10*a* is similar to that shown in Figs. 1 to 4, except that the rear portion of the section is extended vertically and the fuel burners 35*a* are divided into two groups discharging downwardly at different elevations in the arch 21*a*. This particular fuel burner arrangement is described and claimed in a copending application of George W. Saathoff, Serial No. 169,361, filed Oct. 16, 1937.

The convection heating surface comprises a front bank of vertically disposed widely spaced bent tubes 60 extending between a lower water drum 61 and a front upper steam and water drum 62 and a divided rear bank of tubes 63 vertically arranged between the drum 61 and a rear upper steam and water drum 64. The upper drums are connected by steam circulators and by water circulators in the usual manner, and the drum 64 provided with steam outlet connections 65 to a superheater hereinafter described.

In this generating unit, a dividing furnace partition 70 extends downwardly from the upper drum 62 in substantially vertical alignment with the rear end of the sloping floor 23*a*. The partition extends through approximately the upper half of the furnace forming the rear wall of the primary section 10*a* and leaving therebelow a gas passage of substantial height between the primary furnace section and a secondary or low temperature furnace section 11*a* at the rear of the partition. As shown, the partition is formed by a transverse row of water tubes 75 having their upper ends connected to the front upper drum 62 and their lower portions bent either downwardly and rearwardly and connected to the lower water drum 61 or laterally in opposite directions and connected to vertically arranged side wall headers 77. As shown, the partition tubes are equally divided, the lower portions of alternate tubes 75*b* being connected to the drum 61 and the intermediate tubes 75*a* connected to the nearer header 77. The vertically extending partition portions of the tubes 75 are studded along their front faces and the studs are covered and intertube spaces closed by refractory material 78. This construction provides a refractory faced rear side for the primary furnace section 10*a* and a substantial

amount of cold wall area for the front side of the secondary furnace section 11*a*. The bare portions 75*a* of the partition tubes are transversely spaced uniformly to form a tube screen across which a substantial portion of the furnace gases from the primary furnace section will flow before entering the secondary furnace section. The bent portions 75*b* also form a tube screen entirely across the furnace through which all of the furnace gases must flow before contacting with the remaining convection heated surface. The bottom of the secondary furnace section is defined by a steeply inclined fluid cooled rear wall 80 with its lower end spaced from the lower rear end of the floor 23*a* to form an opening therebetween into a subjacent ash pit 81. With this arrangement the ash pit will receive ash separating in the primary section either in a molten or dry condition depending upon the furnace conditions therein, and dry ash separating in the secondary furnace section 11*a*.

The steam outlet connections 65 from the drum 64 are connected to an inlet header 85 of a steam superheater formed by multiple-looped flat coils 86 arranged side-by-side the full width of the boiler, and having their opposite ends connected to the inlet header 85 and an outlet header 87. The superheater tube coils 86 extend downwardly from the top of the setting and terminate a substantial distance above the level of the drum 61. The steam boiler convection surface is of the single pass type, no flow directing baffles being associated with the tube banks. The arrangement of the tube bank 60 and the location of the gas exit from the primary furnace section at the lower rear side thereof forms in effect a vertical gas pass through which the hot furnace gases tend to rise by reason of their low density. Under light load conditions most of the furnace gases will pass vertically upward at the rear side of the partition 70, and then substantially horizontally across the tubes 60, the superheater 86, and tube bank 63 to a stack connection in which a tubular air heater 88 is located. As the boiler load increases, and consequently the volume of furnace gases, a more uniform distribution of the gas flow will occur throughout the height of the horizontal path across the convection surface. The boiler is proportioned so that at full load substantially all of the heating surface is equally active across the horizontal portion of the gas pass throughout its height, while at light loads the part near the top will be subjected to a greater gas flow than the bottom portion. This inherent variation in gas distribution in this portion of the boiler is utilized with the described arrangement of superheater tubes to limit the range of variations in superheat temperatures. The portion between the lower end of the superheater and the bottom drum 61 will receive a larger percentage of the gases at high loads than at low loads and cause a corresponding decrease in the percentage of the gases contacting with the superheater surface.

To aid this natural selection of gas flow path, the tubes in the rearmost row 60*a* of the front boiler bank are bent to provide a horizontally inclined portion directly below the superheater for supporting a baffle 90. By this arrangement the heating gases will either follow the portion of the flow path upwardly between the baffle 90 and partition 70 and across the superheater 86 or pass below the baffle 90 across the lower portion of the rear tube bank 63.

If desired, a more positive control of the portion of the heating gases by-passing the superheater may be effected by reversing the inclination of the superheater baffle and extending it rearwardly, as indicated at 90*a* in the modified construction shown in Fig. 9, and controlling the passage between the baffle and the drum 60 by control dampers 91. With such an arrangement the baffle is preferably supported by the front row of tubes 63*a* of the rear bank. When the control dampers are in their fully open position, the superheat temperature control will be entirely inherent, while with the dampers partly closed a supplementary superheat control lessening the amount of by-passed gases will be effected.

While in accordance with the provisions of the statutes I have illustrated and described herein the best forms of my invention now known to me, 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 my claims, and that certain features of my invention may sometimes be used to advantage without a corresponding use of other features.

I claim:

1. A furnace for burning finely divided solid fuel comprising vertically disposed front, rear and side walls defining a furnace chamber, an arch extending rearwardly from said front wall over the front section of said furnace chamber, means forming a transverse partition extending downwardly from said arch and terminating above the furnace bottom to separate a high temperature section and a low temperature section communicating at their lower ends, means in said arch for introducing a stream of finely divided solid fuel into the upper end of and burning the same in suspension in said high temperature section, heat absorbing means lining the boundary surfaces of said high temperature section and constructed to maintain a normal mean temperature therein above the fuel ash fusion temperature including a rearwardly sloping closed floor constructed to receive a layer of ash particles in a molten condition, a hopper below said low temperature section constructed to receive molten ash flowing over the rear end of said floor, said partition-forming means comprising a transverse row of water tubes having laterally bent lower portions extending to opposite side walls of said furnace and leaving an unobstructed gas flow space between the lower end of said partition and said floor, and means providing a fluid circulation through said partition tubes.

2. A furnace for burning finely divided solid fuel comprising vertically disposed front, rear and side walls defining a furnace chamber, an arch extending rearwardly from said front wall over the front section of said furnace chamber, means forming a transverse partition extending downwardly from said arch and terminating above the furnace bottom to separate a front high temperature section and a rear low temperature section communicating at their lower ends, means in said arch for introducing a stream of finely divided solid fuel into the upper end of and burning the same in suspension in said high temperature section, heat absorbing means lining the boundary surfaces of said high temperature section and constructed to maintain a normal mean temperature therein above the fuel ash fusion temperature including a rearwardly sloping closed fluid cooled floor constructed to receive a layer of ash particles in a molten condition, heat absorbing means lining the boundary sur-

faces of said low temperature section and constructed to maintain a normal mean temperature therein below the fuel ash fusion temperature, a hopper below said low temperature section constructed to receive dry ash separating in said low temperature section and molten ash flowing over the rear end of said floor, said partition-forming means comprising a transverse row of water tubes having laterally bent lower portions extending to opposite side walls of said furnace and leaving an unobstructed gas flow space between the lower end of said partition and said floor, and means providing a fluid circulation through said partition tubes.

3. A steam generator comprising upper and lower drums, a bank of steam generating tubes connecting said upper drum to said lower drum, a furnace chamber, means forming a transverse partition extending downwardly in said furnace chamber and terminating a substantial distance above the bottom of said furnace chamber, said partition means including a row of water tubes having their upper ends connected to said upper drum, the lower ends of some of said tubes being bent laterally and extending to one of the side walls of said furnace chamber, means providing a fluid circulation through said last mentioned tubes, and the lower ends of other partition tubes being bent rearwardly and connected to said lower drum and arranged to form a tube screen for said tube bank.

4. A steam generator comprising upper and lower drums, a bank of steam generating tubes connecting said upper drum to said lower drum, a furnace chamber, means forming a transverse partition extending downwardly in said furnace chamber and terminating a substantial distance above the bottom of said furnace chamber, said partition means including a row of water tubes having their upper ends connected to said upper drum, the lower ends of alternate partition tubes being bent laterally and extending to the opposite side walls of said furnace chamber, means providing a fluid circulation through said last mentioned tubes, and the lower ends of the remaining partition tubes being bent rearwardly and connected to said lower drum and arranged to form a tube screen for said tube bank.

5. A steam generator comprising a furnace chamber, a partition arranged to divide said furnace chamber into front and rear sections serially connected below said partition, convection heated steam generating and superheating surface at the rear side of said partition receiving furnace gases from said rear furnace section including a plurality of transverse upper drums, a transverse lower drum, vertically disposed front and rear banks of water tubes connecting said upper drums to said lower drum, said partition comprising a row of tubes having their ends connected to the front upper drum and said lower drum, a steam superheater positioned between said water tube banks and having its lower end spaced from said lower drum, a horizontally arranged baffle extending below said superheater and arranged to define the upper side of a gas by-pass from said rear furnace section between the lower end of said superheater and said lower drum, and water tubes in said front bank bent to support said baffle.

6. A steam generator comprising walls defining a furnace chamber, a bank of steam generating tubes arranged to receive heating gases from said furnace chamber, means for burning a slag-forming fuel in said furnace chamber, means forming a transverse partition extending downwardly in said furnace chamber and terminating a substantial distance above the bottom of said furnace chamber, said partition means including a row of transversely spaced tubes having vertical upper portions and parallel lower portions bent laterally in the plane of said partition towards one side of said furnace chamber and means for closing the intertube spaces of the upper portions of said partition tubes, said laterally bent lower tube portions being spaced apart and arranged to form a tube screen across the path of the heating gases to said steam generating bank, and means providing a fluid circulation through said partition tubes.

7. A steam generator comprising walls defining a furnace chamber, a bank of steam generating tubes arranged to receive heating gases from said furnace chamber, means for burning a slag-forming fuel in said furnace chamber, means forming a transverse partition extending downwardly in said furnace chamber and terminating a substantial distance above the bottom of said furnace chamber, said partition means including a row of transversely spaced tubes having vertical upper portions and parallel lower portions bent downwardly and laterally in the plane of said partition towards opposite sides of said furnace chamber and means for closing the intertube spaces of the upper portions of said partition tubes, said laterally bent lower tube portions being spaced apart and arranged to form a tube screen across the path of the heating gases to said steam generating bank, and means providing a fluid circulation through said partition tubes.

8. A steam generator comprising a furnace chamber, a plurality of transverse upper drums, a transverse lower drum, vertically disposed front and rear banks of steam generating tubes connecting said upper drums to said lower drum, a steam superheater positioned between said tube banks and having its lower end spaced from said lower drum, said tube banks and superheater being constructed and arranged for a single pass flow thereacross for the heating gases from the furnace chamber to the gas outlet side of said tube banks, and a horizontally inclined baffle arranged directly below said superheater and arranged to define the upper side of a gas by-pass from said furnace chamber across the lower part of said front and rear tube banks.

9. A steam generator comprising a furnace chamber, a plurality of transverse upper drums, a transverse lower drum, vertically disposed front and rear banks of steam generating tubes connecting said upper drums to said lower drum, a steam superheater positioned between said tube banks and having its lower end spaced from said lower drum, said tube banks and superheater being constructed and arranged for a single pass flow thereacross for the heating gases from the furnace chamber to the gas outlet side of said tube banks, a horizontally inclined baffle arranged directly below said superheater and arranged to define the upper side of a gas by-pass from said furnace chamber across the lower part of said front and rear tube banks, and a row of water tubes in one of said tube banks bent laterally to support said baffle, and control dampers for regulating the heating gas flow through said by-pass.

RALPH M. HARDGROVE.