Nov. 29, 1932. J. E. BELL 1,888,975

STEAM GENERATING AND SUPERHEATING APPARATUS

Filed Sept. 15, 1924 4 Sheets-Sheet 1

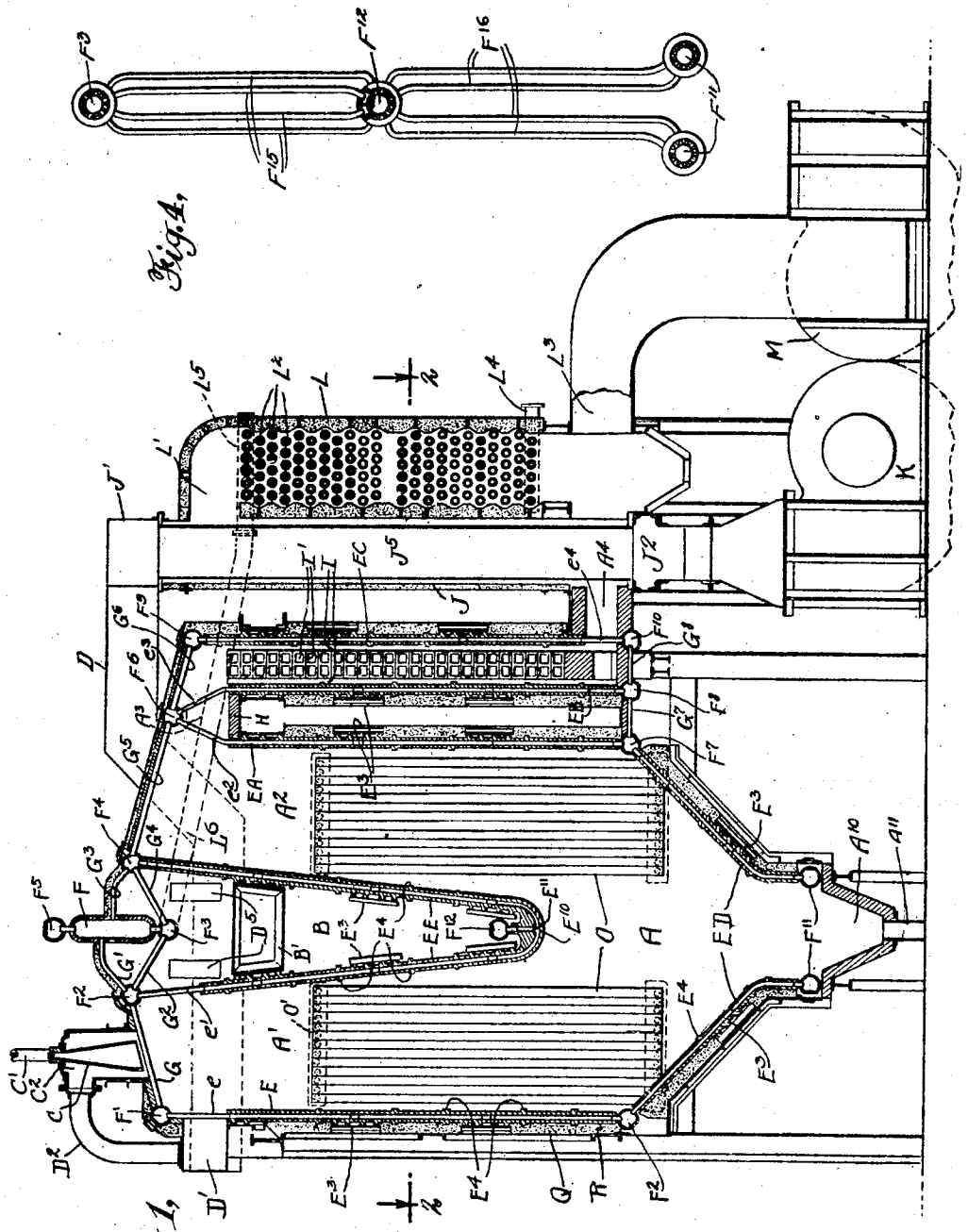


Fig. 4,

Fig. 1,

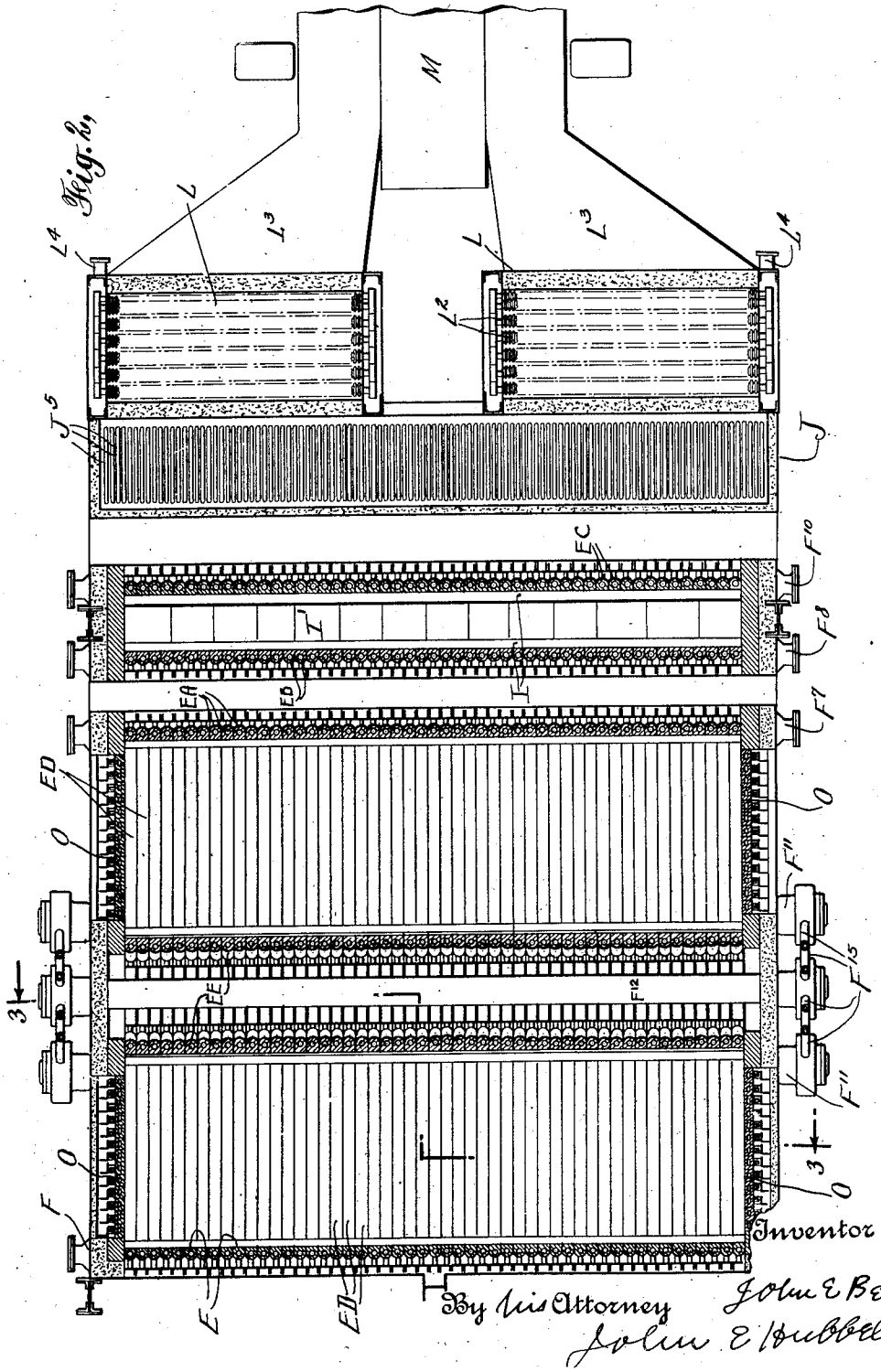
Inventor
John E Bell

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STEAM GENERATING AND SUPERHEATING APPARATUS

Filed Sept. 15, 1924 4 Sheets-Sheet 2

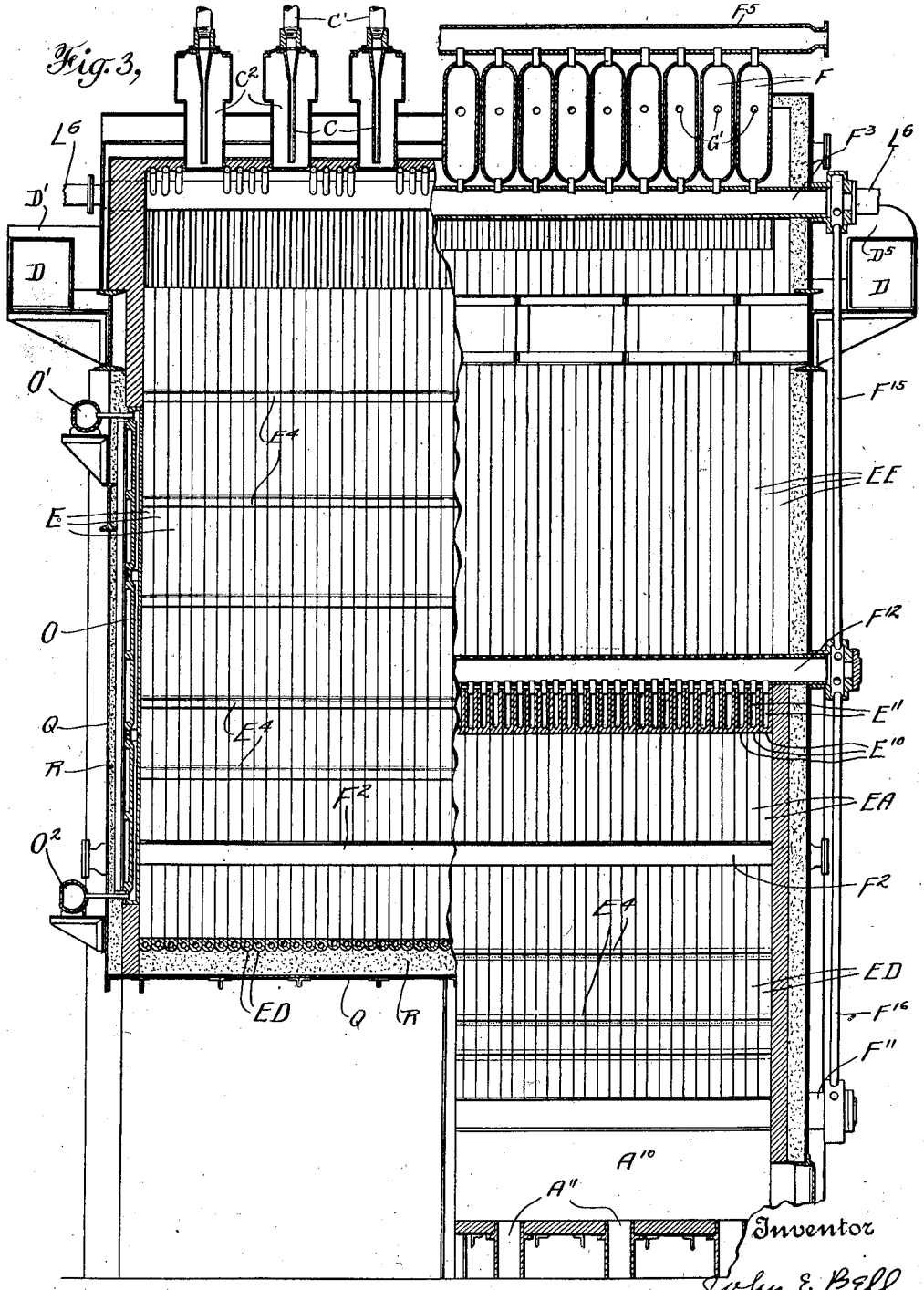


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STEAM GENERATING AND SUPERHEATING APPARATUS

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Fig. 3,




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STEAM GENERATING AND SUPERHEATING APPARATUS

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Fig. 5,

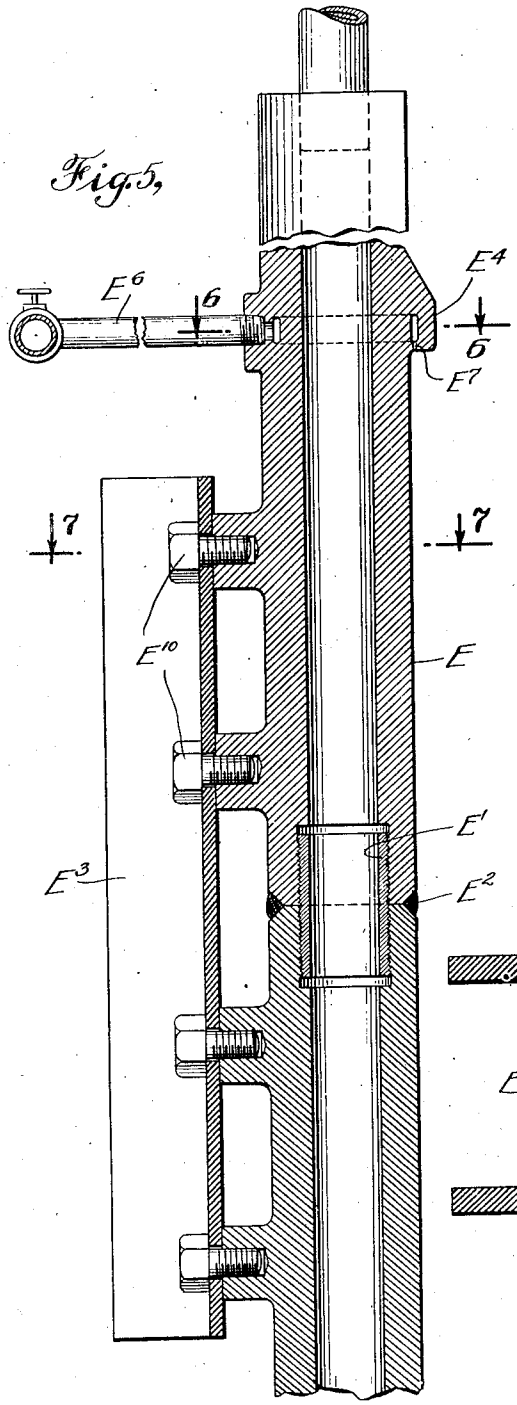



Fig. 6,

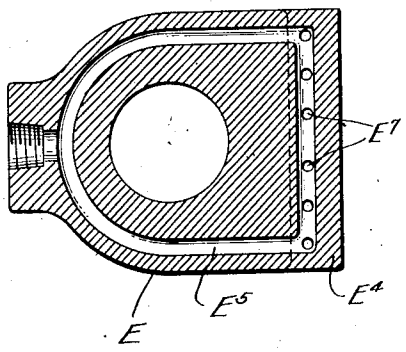
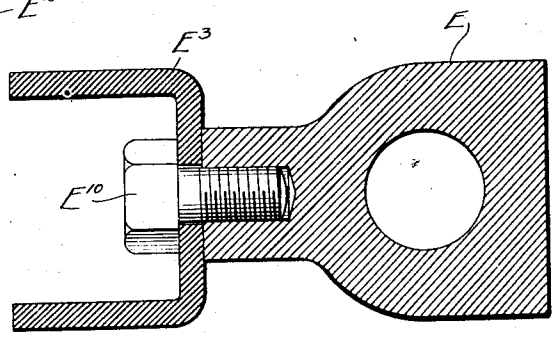



Fig. 7.




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Patented Nov. 29, 1932 1,888,975

# UNITED STATES PATENT OFFICE

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## STEAM GENERATING AND SUPERHEATING APPARATUS

Application filed September 15, 1924. Serial No. 737,706.

The general object of my present invention is to provide an improved steam generator. More specifically, the object of my present invention is to provide improved apparatus for the combustion of powdered fuel and the utilization of the resultant heat in generating steam, and usually also in superheating the steam generated, with provisions for absorbing a large portion of the heat generated by direct radiation to conduits incorporated in or lining the walls of the combustion chamber. My present invention is especially devised and adapted for use in generating steam at such high pressures as 1,000 or 1,200 pounds per square inch, though not necessarily limited to such use, and is characterized by the provisions made for securing the necessary strength and durability required with high steam pressures and to withstand the high temperatures which are obtained when powdered coal is burned with a minimum of excess air for combustion and with that air preheated. The invention is further characterized by the relatively small amount of water holding capacity of the steam generator as a whole in proportion to its steam generating capacity, as is especially desirable with steam generators operating at high pressure, and by the arrangements and provisions whereby a proper water circulation is secured in the steam generator notwithstanding its small water storage capacity and the rapid rate of steam generation in the conduits absorbing heat by direct radiation from the highly heated combustion chamber.

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 advantages and specific objects attained with its use, reference should be had to the accompanying drawings and descriptive matter in which I have illustrated and described a preferred embodiment of my invention.

Of the drawings:

Fig. 1 is an elevation in section;

Fig. 2 is a plan in section on the line 2—2 of Fig. 1;

Fig. 3 is an elevation in section on the broken line 3—3 of Fig. 2;

Fig. 4 is an elevation of a portion of the external piping of the steam generator;

Fig. 5 is a section of a portion of one of the heat absorbing elements;

Fig. 6 is a section on the line 6—6 of Fig. 5; and

Fig. 7 is a section on the line 7—7 of Fig. 5.

The combustion chamber A of the boiler furnace is given a U shape by a hollow baffle B, which depends from the top wall of the combustion chamber. Powdered fuel is passed into the upper end of one leg A′ of the U shaped combustion chamber by nozzles C receiving the powdered fuel and carrier air through pipes C′ from a suitable fuel feeding mechanism (not shown). Additional air for the combustion of the fuel is supplied through chambers $C^2$ one surrounding each of the nozzles C from corresponding pipes $D^2$. The pipes $D^2$ receive air from a horizontal conduit D′ running along the front of the combustion chamber and also supplying air to the upper end of the combustion chamber leg A′ through the front wall of the combustion chamber. The conduit D′ receives air at each end through conduits D at the sides of the combustion chamber, from the outlet chamber J′ of an air preheater J hereinafter described.

The main heat absorbing surface of the boiler proper is formed by heat absorbing elements E, EA, EB, EC, ED, and EE. The elements E line the front wall of the combustion chamber A, the elements EA line the rear wall of the combustion chamber A, the heat absorbing elements EB and EC line the front and rear walls respectively, of a conduit I through which the heating gases pass from the boiler proper into the air preheater J, the elements ED line the front and rear walls of the ash proper bottom portion of the combustion chamber, and the elements EE form the front and rear walls of the hollow baffle B. The elements E are preferably formed of cast steel sections as shown in Figs. 5, 6 and 7 which have flat heat absorbing faces and flat sides and unite to form a smooth heat absorbing surface exposed to the interior of the

combustion chamber. As shown, each element E is formed in three sections, the adjacent ends of adjacent sections being connected by threaded nipples E′ (see Fig. 5) the joints between the connected sections being sealed by welding the ends of the sections together as indicated at $E^2$ in Fig. 5. Each pair of section ends thus connected are advantageously additionally connected by means of a channel bar $E^3$ secured to the section ends by bolts $E^{10}$ tapped into the sections. The channel bars $E^3$ may well form part of the means employed to connect the elements E to supporting means. As shown, the supporting means form part of the skeleton steel frame work of the boiler housing which it is not necessary to describe further than to note that the housing advantageously comprises an external metal casing or shell Q and insulation R between the shell and the heat absorbing elements.

Advantageously, provisions are made for blowing deposits of furnace dust off the heat absorbing surface. These provisions, as illustrated, comprise nozzle lugs $E^4$ formed integrally with the sections at intervals along their lengths and with channels $E^5$ in these lugs and in the side walls of the elements through which steam or other cleaning fluid supplied by a cleaning fluid supply piping $E^6$, is passed to the jet orifices $E^7$ through which it is discharged in jets sweeping the heat absorbing face of the elements. The piping $E^6$ is external to the boiler housing and is shown only in Fig. 5 on account of the small scale of the other figures. The elements EA, EB, EC, ED, and EE may be and are shown as all similar to the elements E in their general construction.

The elements E are connected at their upper ends each by a bare tube *e* into a horizontal header F′ incorporated in the top wall of the combustion chamber. These tubes *e* are separated by spaces through which air passes into the combustion chamber from the conduit D′. At the lower ends the elements E are connected into a horizontal header $F^2$. The header F′ is connected to a parallel header $F^2$ by a set of tubes G which line the roof over the leg portion A′ of the combustion chamber. Preferably, as shown, the header $F^2$ is located at a higher level than the header F′ so that the tubes G are upwardly inclined from the header F′ thus facilitating the boiler circulation. The header $F^2$ is connected by upwardly inclined pipes G′ into a series of small vertically disposed steam and water drums F which are located centrally above the baffle B, the pipes G′ opening into the drums F above the water level in the latter. The front and rear walls of the baffle B are connected some distance below their upper ends by a brace B′ shown as attached to the adjacent sections of the elements EE. At their lower ends the drums F are connected to a horizontal header $F^8$. The header $F^8$ which is located at a level below that of the header $F^2$ is connected to the latter by a row of inclined tubes $G^2$.

At the rear of the drums F is a horizontal header $F^4$ which is parallel to the header $F^2$ and at the same level as the latter. The header $F^4$ is connected to the drum F and to the header $F^8$ by tubes $G^3$ and $G^4$ corresponding to the tubes G′ and $G^2$ as previously described. The heat absorbing elements EE forming the front wall of the baffle B are connected at their upper ends to the header $F^2$ by bare tubes *e′* through the spaces between which flow some of the air supplied to the combustion chamber to support the combustion therein, this air being supplied to the baffle from the conduits D through ports $D^5$ formed in the end walls of the hollow baffle. The elements EE forming the rear wall of the baffle B, extend to the underside of the header $F^4$ into which they are connected by short nipples. Each element EE in the front wall of the baffle is connected to the adjacent element EE in the rear wall of the baffle by a cast metal section $E^{10}$ which forms the lower end of the hollow baffle. Each section $E^{10}$ is formed with a central uprising channel $E^{11}$ connected into a horizontal header $F^{12}$ directly below the header $F^3$.

The elements EA lining the rear wall of the combustion chamber A are connected by bare tubes $e^2$ to a header $F^6$ located in a plane approximately midway between the elements EA and the elements EB, the tubes $e^2$ being bent backward for this purpose. The elements EB have their upper ends connected by forwardly bent bare tubes $e^3$ into the header $F^6$. The heating gases pass from the boiler proper into the upper end of the passage I through the spaces between the bare tubes $e^2$ and $e^3$. The lower ends of the elements EA are connected into a horizontal header $F^7$, and the lower ends of the elements EB are connected into a horizontal header $F^8$. The header $F^6$ is connected to the header $F^4$ by upwardly inclined bare tubes $G^5$ lining the roof of the leg $A^2$ of the combustion chamber. The upper ends of the elements EC extend to, and are connected into a horizontal header $F^9$ which is connected to the header $F^6$ by upwardly inclined bare tubes $G^6$ which line the roof of the conduit between the elements EB and EC. The lower ends of the elements EC are connected to a header $F^{10}$ by bare tubes $e^4$ which are spaced apart to provide ports through which the heating gases pass from the lower end of the conduit I into the inlet passage $A^4$ of the air heater J. The headers $F^7$ and $F^8$ are connected by horizontal circulating pipes $G^7$, and the headers $F^8$ and $F^{10}$ are connected by horizontal circulating pipes $G^8$.

The elements ED forming the front wall of the ash hopper bottom portion of the com-

bustion chamber are connected at their upper ends into the header $F^2$ and are connected at their lower ends into a header $F^{11}$, while the set of elements ED forming the rear wall of the hopper shaped bottom portion of the combustion chamber are connected at their upper ends to the header $F^7$ and are connected at their lower ends to a second header $F^{11}$. The two headers $F^{11}$ are spaced apart and run along the upper edges of a trough shaped ash receiver $A^{10}$ which has outlets $A^{11}$ at its bottom to a screw conveyor (not shown) or other means for handling the ashes. As shown, the lower portions of the elements ED are vertical, but the upper portions of the elements are inclined both to the vertical and to the horizontal. The headers $F^2$, $F^7$, $F^8$, and $F^{10}$ are all shown as arranged at the same level.

Advantageously, as shown, a wall or filler of refractory material is placed centrally in the conduit I to provide a shallow or narrow flow channel between the wall and the heat absorbing faces of the elements EB and a similar channel between the wall and the heat absorbing faces of the elements EC. As shown, this wall is formed by hollow blocks I′ of a suitable refractory material which may be similar in shape to the hollow tile employed in the construction of buildings. With this arrangement, the heating gases which may enter the upper end of the conduit I at a temperature of 2,000° F. or thereabouts, impart their heat at a very rapid rate to the elements EB and EC partly by contact and convection, and partly by direct radiation from the tiles I′ which will be heated to a temperature substantially intermediate that of the gas sweeping over them and that of the elements EB and EC. With this arrangement, a very high rate of heat absorption by the elements EB and EC may be obtained.

The air preheater J, to which the heating gases pass from the lower end of the conduit I, may be of any usual or suitable type, and, as conventionally illustrated, is formed by flattened tubes of metal with spaces between the tubes for the flow of the heating gases. The flattened tubes are connected at their upper ends into the header or conduit J′, which supplies heated air from its ends to the conduits D, and are connected at their lower ends to an inlet chamber $J^2$, to which air is supplied by a blower K.

From the upper end of the air heater the heating gases pass to the inlets L′ of an economizer which may well be, and, as shown, is of the type now in commercial use and known as the Foster economizer, and is formed in two similar sections. Each economizer section L has an inlet L′ at its upper end, and an outlet $L^3$ for heating gases at its lower end. The heating gases pass downward in each economizer section from the inlet L′ to the $L^3$ across a bank of closely spaced horizontally disposed gilled tubes $L^2$. From the economizer outlets $L^3$ the gases pass to a draft creating device, shown as a suction fan M. The water flows successively through the tubes $L^2$ at sucessively higher levels from the economizer inlet headers $L^4$ to the economizer outlet headers $L^5$. The latter are connected into the boiler circulating system by conduits $L^6$ which, as shown, may advantageously be connected into the ends of the header $F^3$.

The headers $F^3$ and $F^{12}$ are connected at each end of the boiler by tubes $F^{15}$ which are outside of the boiler housing, and each end of the header $F^{12}$ is connected by external tubes $F^{16}$ to the corresponding end of each of the headers $F^{11}$. These conduits, being comparatively cool, provide for the rapid downflow of water from the header $F^3$ into the headers $F^{12}$ and $F^{11}$ required to keep the various heat absorbing elements filled with water notwithstanding the very rapid rate at which steam is generated in the various elements.

As shown, two superheater sections are incorporated in or lining each side wall of the combustion chamber A. Each superheater section comprises a row of elements O, which may be generally similar in construction to the elements E. The elements O of each superheater section are connected at their upper ends to a superheater inlet heater O′ and at their lower ends to superheater outlet headers $O^2$. Steam is supplied to the superheater inlet headers from the ends of the boiler steam pipe $F^5$ by pipe connections, which I have not thought it necessary to illustrate.

With the described arrangement, the air supporting combustion is supplied with such distribution and direction of flow and so preheated as to insure rapid and complete combustion of the fuel with a relatively small amount of air in excess of that theoretically required for the complete combustion of the fuel. This tends, of course, to extremely high combustion temperatures, and if the combustion chamber walls were not formed or lined as they are by heat absorbing conduits, it would be practically impossible to prevent the walls from being destroyed by the high temperature in the combustion chamber. With these walls lined as they are by the heat absorbing elements E, EA, ED, EB, O, and by the circulating tubes *e*, *e*′, G, and $G^5$, and also cooled by the air conduits D and D′, the walls of the combustion chamber proper are not subjected to destructive temperatures or to the erosive action of molten slag or non-gaseous residue of the fuel which is cooled by the heat absorbing elements to a temperature below that at which it is molten before coming into contact with any portion of the walls defining the combustion chamber. Because of this fact, the non-gaseous residue of the fuel de-

positing on the inclined portions of the elements ED, as well as upon the side walls of the combustion chamber, is in a form which permits of its ready removal by the cleaning fluid jets discharged through the various cleaning nozzles $E^4$, and the residue finally collecting in the ash trough $A^{10}$, may be readily removed as by means of a screw conveyor (not shown), to the casing of which the lower ends of the ash outlets $A^{11}$ open.

The form of the combustion chamber and the manner in which air supporting combustion is introduced, are in accordance with the best known practices for burning powdered fuel efficiently, and for minimizing the amount of non-gaseous fuel residue swept out of the combustion chamber with the heating gases leaving the latter through the port $A^3$. The shape of the boiler as a whole and the distribution of its heat absorbing surface insure a very high capacity per unit of space, the volume of the boiler proper being but little in excess of that required to provide the proper combustion chamber volume for the efficient combustion of fuel burned. The formation of the boiler heating surface in large part of cast steel elements receiving heat mainly by direct radiation from a radiating source at high temperature, insures a very high rate of heat absorption per unit of heat absorbing surface, with a low construction cost and great security against deterioration under the severe operating conditions to which they are subjected. The rapid absorption of heat by all portions of the boiler heating surface and the consequent rapid generation of steam in all parts of the circulating system absorbing heat, which is characteristic, require a rapid and effective boiler water circulation. This is secured in the boiler illustrated in part by reducing the bends in the water passages to a minimum. The inclination of the tubes $G^5$ and $G^6$ in the roof of the boiler housing and of the upper portion of the elements ED, coupled with the vertical disposition of most of the channels in the boiler heating surface, all contribute to an effective water circulation. The external downcomer pipes $F^{15}$ and $F^{16}$ may be made as numerous and of sufficient size to minimize the downflow resistence to a gravity circulation. The water and steam channels are so shaped and disposed as to avoid the formation of steam pockets which would interfere with the circulation.

The multiplicity of small vertical steam and water drums F provide the necessary steam and water separating space without requiring drums of large diameter which is an advantage from the standpoint of strength for high pressure work and the arrangement as a whole minimizes the amount of water holding space per unit of capacity in the boiler which is especially desirable for high pressure work. The water storage space in the economizer in which the water is heated to or practically to the boiler temperature desirably augments the capacity of the boiler to respond quickly to the heavy increases in boiler load.

While in accordance with the provisions of the statutes I have illustrated and described the best embodiment of my invention now known to me, it will be apparent to those skilled in the art that changes may be made in the form of the apparatus disclosed without departing from the spirit of my invention as set forth in the appended claims.

Having now described my invention what I claim as new and desire to secure by Letters Patent is:

1. In a boiler furnace heated by the combustion of powdered coal, the combination with a combustion chamber having roof portions oppositely inclined from a peak, of a baffle depending from said roof beneath said peak to provide a U-shaped path of flow for the heating gases, steam and water separating means, radiant heat absorbing water containing elements lining the side walls of said chamber, and radiant heat absorbing elements lining the inclined roof portions of said chamber and connecting the first mentioned elements to said means.

2. In a boiler furnace heated by the combustion of powdered coal, the combination with a combustion chamber and a baffle depending from the roof thereof to provide a U-shaped path of flow for the burning gases, of a plurality of small diameter vertically disposed steam and water drums located above said baffle, vertically disposed radiant heat absorbing elements lining the side walls of said combustion chamber, connections between the upper ends of said elements and said drums absorbing radiant heat from the combustion chamber, and connections external to said combustion chamber between the lower ends of said elements and said drums.

3. In a boiler furnace heated by the combustion of powdered coal, the combination with a combustion chamber and a baffle depending from the roof of said chamber to provide a U-shaped path of flow for the burning gases, of a boiler system comprising a set of vertically disposed radiant heat absorbing elements at each side of the baffle, a set of vertically disposed radiant heat absorbing elements lining each side wall of the combustion chamber facing said baffle, a horizontally disposed drum for each set of said elements to which the upper ends of the latter are connected, upwardly inclined connections from the drum at the top of each side wall set of elements to the drum at the top of the adjacent baffle elements, and means providing a steam and water space to which the drums at the tops of the baffle elements are connected.

4. In a boiler furnace heated by the combustion of powdered coal, the combination with a combustion chamber and a baffle depending from the roof of said chamber to provide a U-shaped path of flow for the burning gases, of a boiler system comprising a set of vertically disposed radiant heat absorbing elements at each side of the baffle, a set of vertically disposed radiant heat absorbing elements lining each side wall of the combustion chamber facing said baffle, a horizontally disposed drum for each set of said elements to which the upper ends of the latter are connected, upwardly inclined connections from the drum at the top of each side wall set of elements and the drum at the top of the adjacent baffle elements, a series of small diameter vertically disposed steam and water drums above the baffle, and separate steam and water connections between the drums at the tops of the baffle elements and the steam and water drums.

5. In a boiler furnace heated by the combustion of powdered coal, the combination with a combustion chamber and a baffle depending from the roof thereof to provide a U-shaped path of flow for the burning gases, of a plurality of small diameter vertically disposed steam and water drums located above said baffle, radiant heat absorbing elements lining the sides of said baffle, horizontal drums one at each side of said steam and water drums to which the upper ends of said elements are connected, and connections between said horizontal drums, and said steam and water drums opening to the latter above and below the water level therein.

6. In a boiler furnace, the combination with a combustion chamber, of a hollow baffle extending downward into said chamber, a set of uprising steam generating conduits forming each side of said baffle, and a horizontal drum within the baffle adjacent its lower end to which the lower ends of said elements are connected.

7. In a boiler furnace, the combination with a combustion chamber, of a hollow baffle extending downward into said chamber, a set of uprising steam generating conduits forming each side of said baffle, a horizontal drum within the baffle adjacent its lower end to which the lower ends of said elements are connected, a series of vertical steam and water drums in the upper portion of said baffle, and connections between the upper ends of said elements and said drums.

8. In a boiler furnace, the combination with a combustion chamber, of a baffle extending downward into said chamber, a set of uprising steam generating elements forming each side of said baffle, cast metal elbow conduit sections connecting the lower ends of the elements of one set to the elements of the other set, and a horizontal drum between the two sets of said elements and connections between the latter and said elbow conduit sections.

9. In a boiler furnace comprising a combustion chamber, means for absorbing radiant heat therein, a conduit through which the heating gases pass away from said chamber, said conduit having laterally and longitudinally extended opposing side walls spaced close to one another, heating elements lining one of said walls and the other being formed of refractory material adapted to absorb heat from the heating gases passing through the conduit and radiate it to the last mentioned elements.

10. In a boiler furnace comprising a combustion chamber, means for absorbing radiant heat therein to substantially reduce the temperature of the heating gases leaving the chamber, a conduit through which the heating gases pass away from said chamber, heating elements arranged to provide two extended opposing walls of said conduit and adapted to absorb heat by radiation and convection, and a refractory division member in said conduit spaced away from each of said walls by a comparatively small distance whereby said division absorbs heat from the gases and radiates it against said walls.

11. In a boiler furnace heated by the combustion of powdered coal, the combination with a combustion chamber having an inclined bottom wall and an ash receiving space at the lower edge of the latter, of heat absorbing conduit elements forming a lining for said inclined wall, and soot blowing provisions incorporated in said lining and constructed to discharge cleaning fluid jets directed downwardly along said inclined wall.

12. In a boiler furnace heated by the combustion of powdered coal, the combination with a combustion chamber having oppositely inclined bottom walls leading downward to an ash receiving space between said walls, of radiant heat absorbing conduit elements forming a lining for said inclined walls, and soot blowing provisions incorporated in said lining and constructed to deliver jets of a cleaning fluid downwardly over the latter to move furnace dust accumulating on said linings into said ash receiving space.

13. The combination with the combustion chamber, of a furnace for burning powdered coal, of inclined bottom walls forming a hopper bottom for the discharge of the ash content burned, heat absorbing conduit elements forming a lining for said inclined walls, and soot blowing provisions incorporated in said walls for discharging cleaning jets downwardly along the inner surfaces of said walls.

14. In a boiler furnace heated by the combustion of powdered coal, the combination with a combustion chamber having an inclined bottom wall leading downward to an ash receiving space, of radiant heat absorbing conduit elements lining said bottom wall

and a side wall of said space, and each comprising a lower portion extending upward along the side of said space and an upper portion running upwardly over said inclined bottom wall.

15. In a boiler furnace heated by the combustion of powdered coal, the combination with the walls of a combustion chamber having an upwardly inclined roof portion and having a localized outlet port for the discharge of products of combustion and means for passing streams of powdered coal and combustion supporting air into said combustion chamber, of a steam generating system comprising a steam and water separating space, vertically disposed steam generating elements lining the combustion chamber side walls and forming the major heat absorbing portion of the boiler, and conduit connections between said elements and said space which are inclined to the horizontal upwardly toward said space and line a substantial and correspondingly inclined portion of the roof of the combustion chamber.

16. In a boiler furnace heated by the combustion of powdered coal, the combination with the walls of a combustion chamber having roof portions oppositely inclined from a peak, and having a localized outlet port for the discharge of products of combustion and means for passing streams of powdered coal and combustion supporting air into said chamber, of a steam generating system comprising a steam and water separating space adjacent the roof peak, vertically disposed radiant heat absorbing elements lining the side walls of said chamber, and radiant heat absorbing elements lining a substantial portion of the roof of said chamber and connecting the first mentioned elements to said space.

17. In a boiler furnace, the combination with a heating gas chamber wall formed with a gas port in a relatively cool portion of said wall, of steam generating conduit elements lining said wall and composed of sections having relatively massive metal walls arranged side by side to form a continuous lining for a relatively hot portion of said wall, and a tubular connection to each of said sections having a relatively thin wall and smaller in cross section than the massive walled section of the element, said connections extending across said port and being spaced apart to permit gas flow through the port.

Signed at New York City in the county of New York and State of New York this 12th day of September, A. D. 1924.

JOHN E. BELL.