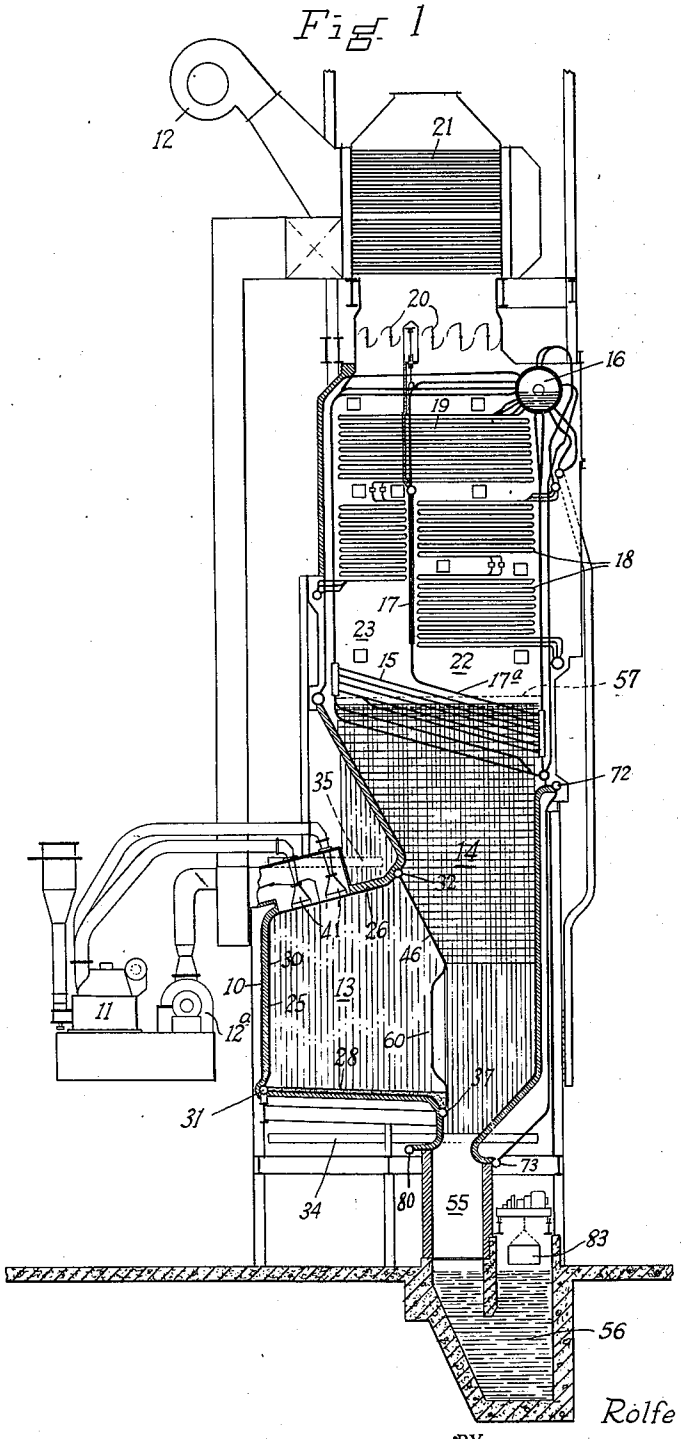
May 20, 1941. R. SHELLENBERGER 2,242,762

FURNACE

Original Filed April 16, 1937 6 Sheets-Sheet 1

Fig. 1



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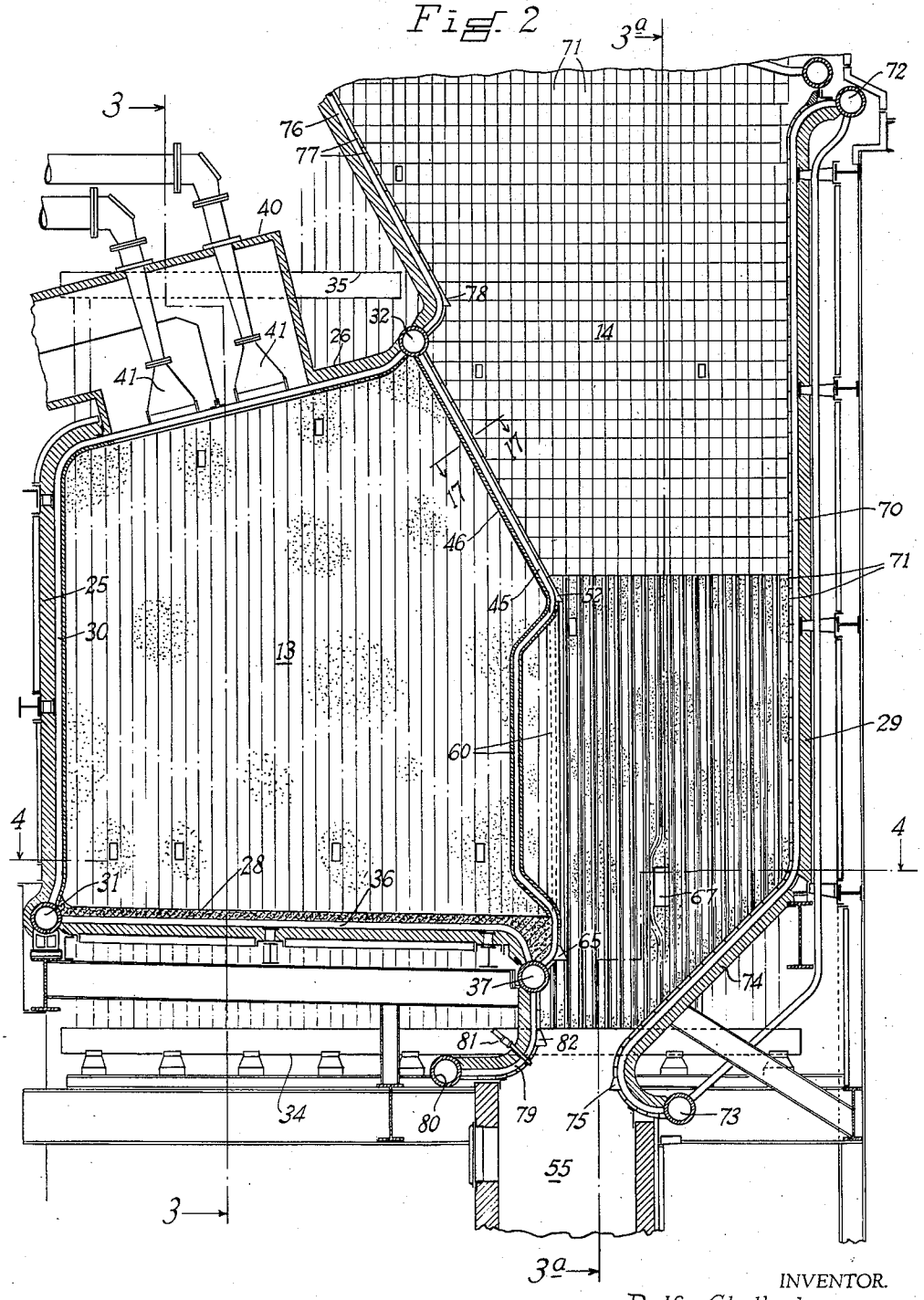
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Fig. 2



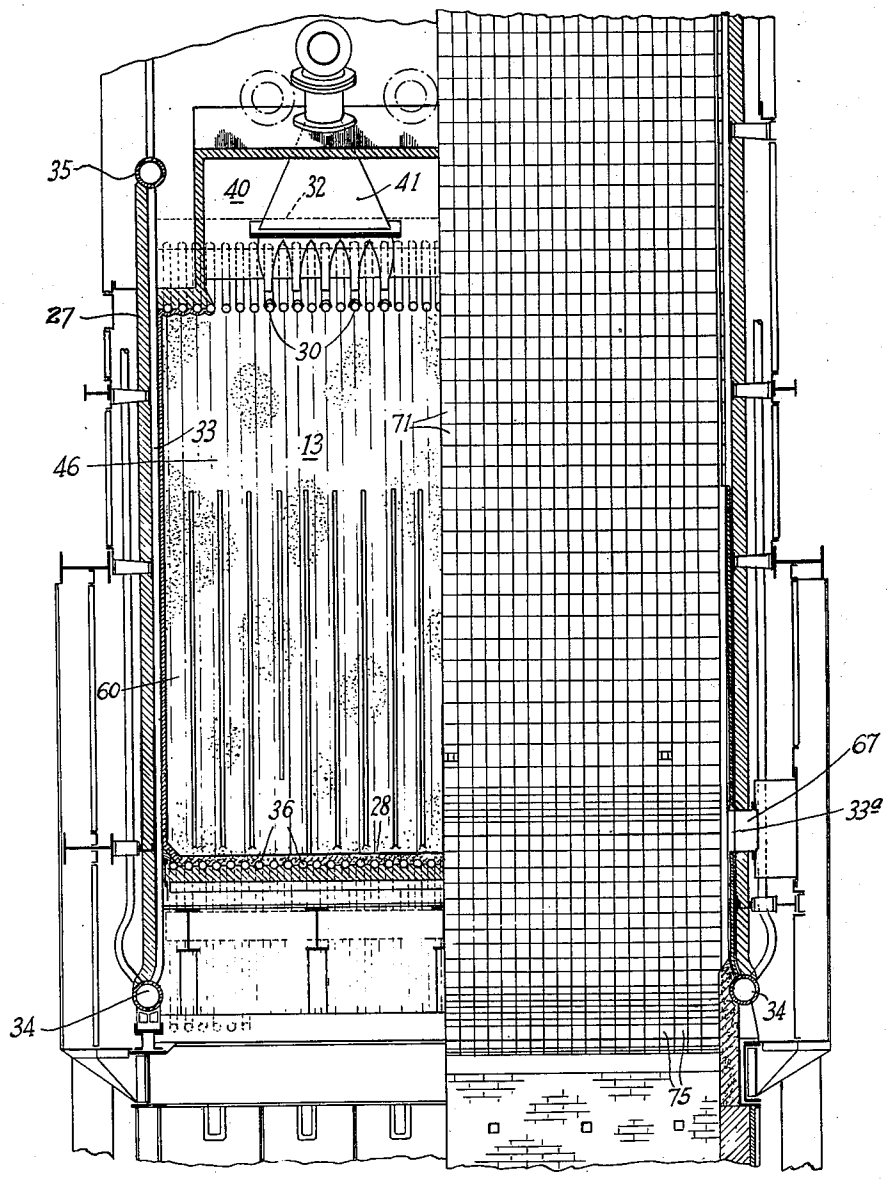
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Fig. 3



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Fig. 4

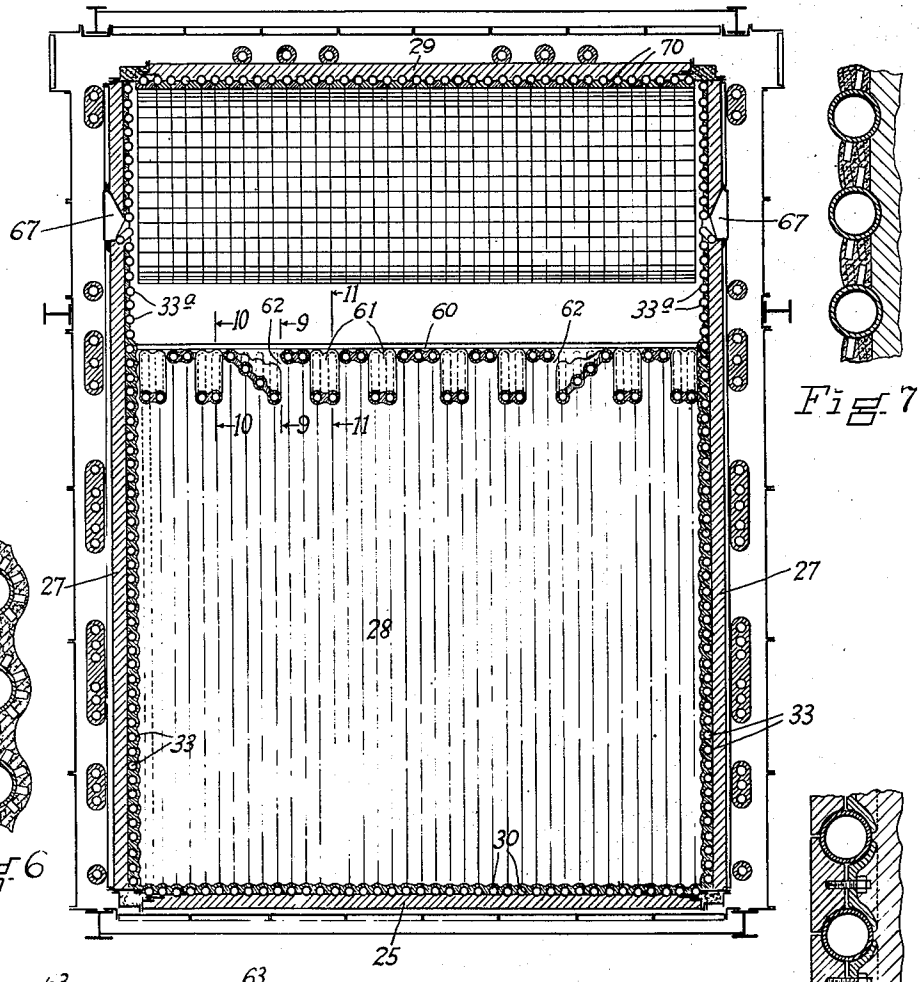


Fig. 7

Fig. 6

Fig. 8

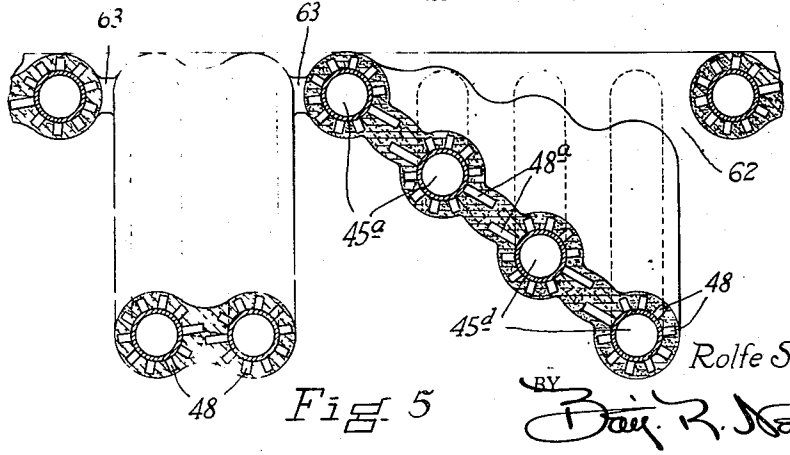


Fig. 5

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Fig. 18

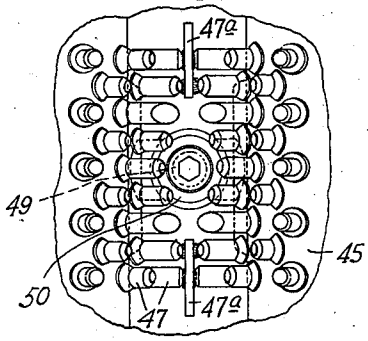


Fig. 9

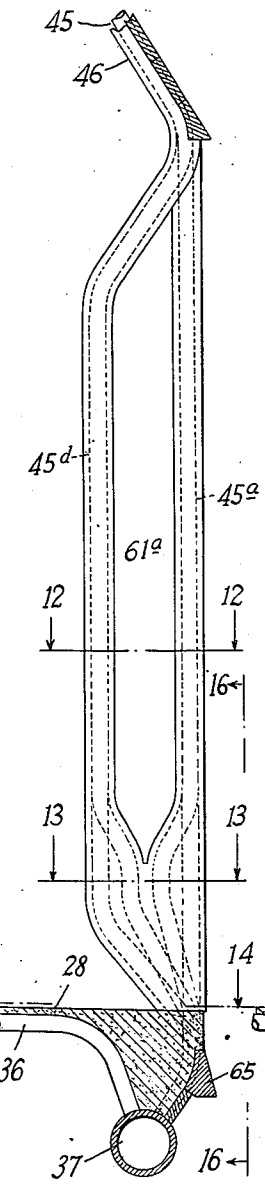


Fig. 10

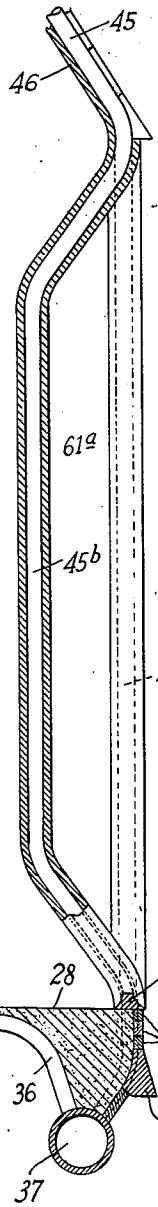


Fig. 17

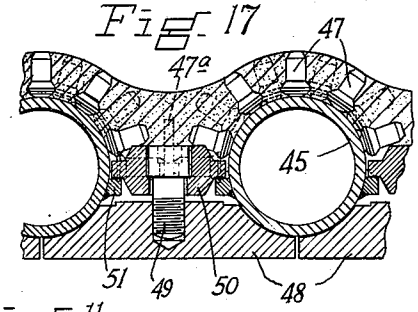


Fig. 11

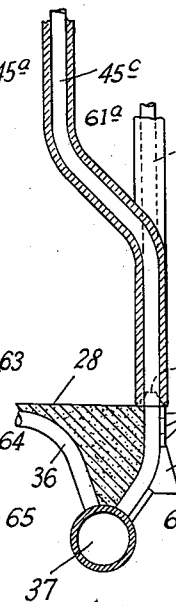
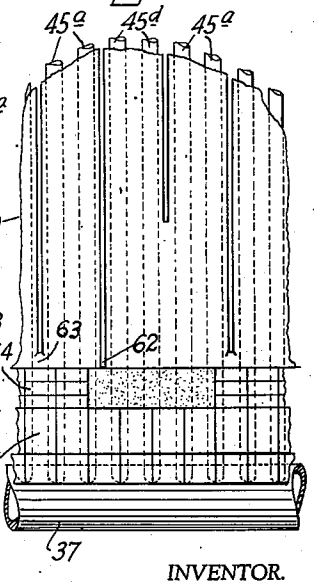


Fig. 16



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Fig. 12

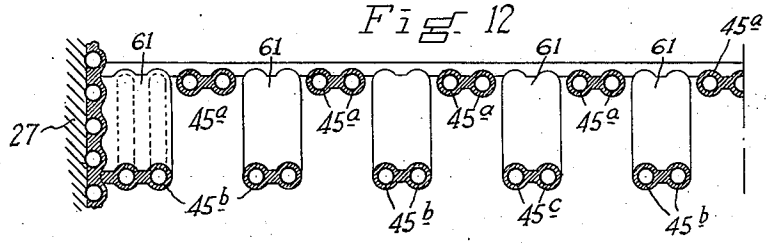


Fig. 13

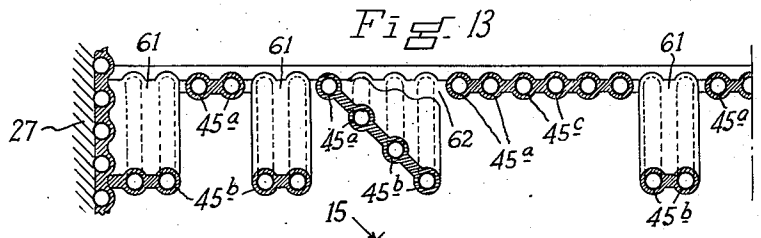


Fig. 14

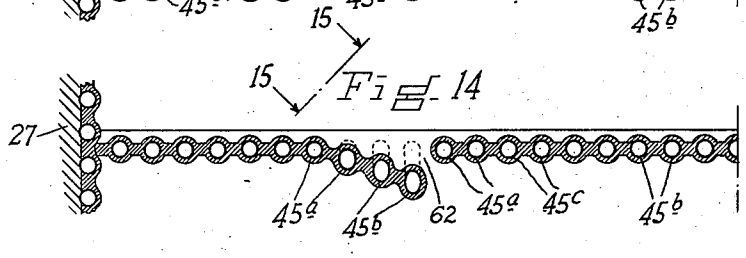


Fig. 15

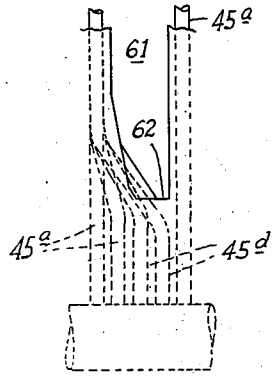
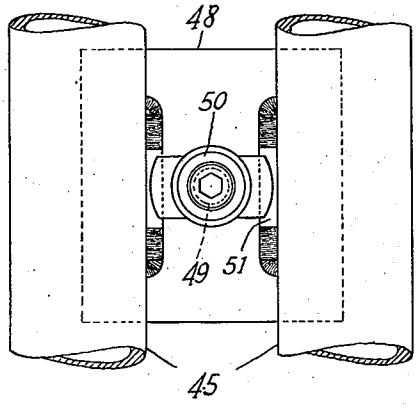


Fig. 19



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Patented May 20, 1941 2,242,762

UNITED STATES PATENT OFFICE

2,242,762

FURNACE

Rolfe Shellenberger, Westfield, N. J., assignor to The Babcock & Wilcox Company, Newark, N. J., a corporation of New Jersey

Application April 16, 1937, Serial No. 137,158
Renewed July 13, 1939

23 Claims. (Cl. 122—235)

The present invention relates in general to the construction and operation of furnaces for burning finely divided solid fuel in suspension, and more particularly to furnaces of this type which are especially adapted to form a part of a high capacity steam generating unit.

Pulverized fuel burning furnaces have heretofore been developed in which the furnace chamber is divided into two sections or stages by a furnace partition or screen formed by one or more rows of horizontal or vertical refractory covered water tubes. The furnace screen serves to partly shield the secondary or low temperature section of the furnace and the convection heated steam generating tubes from radiant heat from the primary or high temperature section which is the main combustion zone. The furnace screen further serves to promote mixing of the unburned gases leaving the high temperature section and also to collect ash particles in suspension from the furnace gases before reaching the convection heated surface.

In accordance with my invention a two-stage pulverized fuel burning furnace is provided having the furnace sections constructed and relatively arranged and the furnace slag screen constructed and arranged so that the primary or high temperature section will have a normal mean temperature therein permitting the efficient and stabilized combustion of a wide range of pulverized fuels, including bituminous coals of almost any volatile, ash or sulphur content, or ash fusion temperature, with low carbon loss, over a wide range of operation. The temperature conditions normally maintained facilitate the separation of a high percentage of the ash content of the fuel in the high temperature section and permit its continuous removal from this section as molten slag, a type of ash elimination which is not only most conducive to high combustion efficiencies but results in the least amount of ash being carried in suspension into the boiler gas passes and to the stack.

The furnace screen is constructed to almost entirely enclose that side of the high temperature section with refractory surface and correspondingly shield the secondary or low temperature section from radiant heat from the high temperature section, leaving only relatively narrow passages through the screen to the low temperature section, through which the gases pass after a substantial change in direction and at a sufficiently high velocity to keep the gas passages open and prevent substantial slag accumulations therein. The furnace screen is also constructed to provide shielded openings for the continuous discharge therethrough of molten slag from the high temperature section into an ash pit below the low temperature section.

The low temperature section is constructed and relatively arranged with respect to the furnace screen and convection tube bank that the temperatures of the furnace gases and suspended ash particles will be reduced by radiant heat transfer therein to the temperature required at the furnace exit for minimum fouling of the boiler tubes. The low temperature section has a substantially larger volume than the high temperature section and this large unobstructed volume causes a substantial reduction in furnace gas velocity. The resulting low velocity flow in and vertical arrangement of the low temperature section materially contributes to the separation of additional slag particles in suspension from the ascending furnace gases, augmenting the ash recovery from the high temperature section. The low temperature conditions in the secondary section cause the ash separating therein to be mainly in a solid or "dry" state. The ash so separated drops into an ash hopper receiving the molten slag flowing through the furnace screen openings and is similarly handled.

The general object of this invention is the provision of an improved construction of a two-stage pulverized fuel furnace and a method of operating the same which is characterized by its adaptability for burning a wide range of fuels at high efficiencies over a wide range of operation, the recovery of a high percentage of the fuel ash content in the furnace, and the continuous removal of the ash recovered mainly in a molten state. A further object is the provision of an improved furnace screen construction for a two-stage furnace which is characterized by its effectiveness in maintaining the desired difference in temperature conditions in the two stages, aiding the removal of separated ash in the two sections, and permitting the continuous removal therethrough of molten slag from the high temperature section.

The various features of novelty which characterize this 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 a preferred embodiment of the invention.

In the drawings:

Fig. 1 is a somewhat diagrammatic sectional elevation of a steam boiler unit constructed and operable in accordance with the invention;

Fig. 2 is an enlarged view of the furnace shown in Fig. 1;

Fig. 3 is a transverse section, the left half being taken on the line 3—3 and the right half on the line 3*a*—3*a*, of Fig. 2;

Fig. 4 is a horizontal section taken on the line 4—4 of Fig. 2;

Fig. 5 is an enlarged view of a portion of the furnace screen shown in Fig. 4;

Figs. 6, 7, and 8 are enlarged views of different portions of the furnace walls shown in Fig. 4;

Figs. 9, 10 and 11 are vertical sections through different portions of the furnace screen taken on the lines 9—9, 10—10, and 11—11 respectively, of Fig. 4;

Figs. 12, 13 and 14 are horizontal sections through one half of the furnace screen taken on the lines 12—12, 13—13, and 14—14 of Fig. 9;

Fig. 15 is a rear view of one of the slag drain openings taken on the line 15—15 of Fig. 14;

Fig. 16 is a rear view of a portion of the furnace screen taken on the line 16—16 of Fig. 9;

Fig. 17 is an enlarged transverse section through the baffle section of the furnace screen taken on the line 17—17 of Fig. 2;

Fig. 18 is a front view of the metallic parts of the baffle section of the furnace screen; and

Fig. 19 is a view similar to Fig. 18 with the tube studs omitted.

The steam boiler unit illustrated in Fig. 1 comprises a furnace 10 receiving a supply of pulverized fuel and primary air from one or more pulverizers 11, and preheated secondary air from a forced draft fan 12 and air heater 21. The pulverized fuel is burned in suspension in a two-stage furnace chamber having a primary or high temperature section 13, and a secondary or low temperature section 14 as hereinafter described. The furnace section 14 is positioned directly below a sectional header steam boiler having a high circulation head and comprising a bank of inclined steam generating tubes 15 extending across the upper end of the furnace section 14. The tube bank 15 is connected at opposite ends by vertically extending circulator tubes to a transverse steam and water drum 16. The lower rows of the tube bank are bent and arranged to form a boiler slag screen.

The boiler structure above the tube bank is arranged to provide a direct vertical gas flow from the furnace to the top of the setting. The space above the tube bank 15 is divided into two parallel gas passes 22, 23 by a baffle 17 carried on a row of supporting tubes 17a extending between the downtake end of the tube bank and the drum 16. A superheater 18 having two superposed sections is arranged in the gas pass 22, and an upflow economizer 19, also divided into two superposed sections, has its upper section extending through the baffle 17 into both gas passes, while its lower section is confined to the gas pass 23. Dampers 20 control the gas flow through the parallel gas passes, permitting variable by-passing of the heating gases around the superheater to protect the superheater at starting-up and provide an effective superheat control over a wide range. The air heater 21 extends across the portion of the setting above the dampers 20. Each of the superheater and economizer sections is formed by horizontally extending multiple-loop return bend tubes having their looped ends supported from the adjacent boiler circulator and baffle tubes.

The high temperature section of the furnace chamber is defined by a vertical front wall 25, rearwardly and upwardly inclined arch 26, vertical side walls 27 and rearwardly and downwardly inclined floor 28, all of which are fluid cooled. For this purpose a row of water tubes 30 extends upwardly along the inner side of the front wall from a transverse front header 31 and across the arch 26 to a transverse intermediate header 32. A row of water tubes 33 extends vertically along the inner side of each side wall 27 between a lower longitudinal header 34 and a shorter upper header 35. A row of tubes 36 slopes downwardly along the floor from the header 31 to a parallel transverse header 37 below the rear end of the floor. The tubes 30, 33, and 36 are of the fully studded type shown in Fig. 6, with the metallic studs and intertube spaces covered by initially plastic refractory to provide refractory faced boundary surfaces for the high temperature furnace section. The refractory covering on the floor tubes is applied so as to form a flat slightly sloping floor, as shown in Figs. 2 and 3.

The studs and refractory are omitted from a section of the tubes 30 in the arch to provide a rectangular opening therein registering with the discharge end of a sectional secondary air box 40 receiving preheated air from the air heater. A group of staggered pulverized fuel burners 41, each of the multiple stream turbulent discharge type and receiving a mixture of pulverized fuel and primary air from the pulverizer 11, extend downwardly through corresponding compartments in the air box 40 with their elongated discharge nozzles arranged slightly above and in alignment with protected portions of the tubes 30 to discharge streams of pulverized fuel and primary air against the tubes and thence downwardly through the intertube spaces into the furnace section 13. This location of the fuel burners provides a long 'J'-shaped path of gas travel through the contiguous sections of the furnace before reaching the boiler tubes 15.

The described construction of the high temperature section and the furnace screen construction hereinafter described 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 higher the rate of heat release in a given furnace chamber, the more rapidly will combustion progress, and consequently the more rapidly ash particles will be released and coalesce in the burning fuel stream. The ash particles are separated from the descending fuel stream by gravity and by the substantial change in direction in the lower part of the high temperature furnace section, and a layer of molten slag collects on substantially the entire area of the refractory floor 28. A large amount of ash will also deposit on and flow down the vertical front and side walls of the front section causing these walls to become wet and sticky in operation. The wall construction described insures adequate protection of the furnace wall tubes, and permits even high fusion temperature ash to be maintained in a molten condition at relatively low furnace ratings. The high furnace temperatures normally maintained in operation substantially contribute to the high com-

bustion efficiencies obtainable with the described furnace construction.

The rear side of the high temperature section of the furnace chamber is defined by a furnace screen, the high temperature side of which is entirely covered by refractory, providing a boundary surface for the rear side of the high temperature section of similar character to its front and side walls. The furnace screen is fluid cooled by a single row of vertically extending water tubes 45 having their lower ends connected to the header 37 and their upper ends to the header 32. The upper portions of all of the screen tubes 45 are arranged in lateral alignment with the intertube spaces entirely closed as hereinafter described to form in effect a fluid cooled baffle 46 extending from the rear end of the arch 26 downwardly and rearwardly for about half the height of this section. As shown in Figs. 17 to 19, the front or high temperature side of the tubes 45 have metallic studs 47 welded thereon with some of the studs extending into the intertube spaces and the studs covered and intertube spaces closed by refractory material. Adjacent tubes are secured together by welding some of the studs to vertically spaced tie plates 47a in the intertube spaces. The undulating refractory surface thus formed across the high temperature side of the baffle 46 substantially contributes to the maintenance of the desired high temperature conditions in the high temperature section.

The lower portions of the tubes 45 below the baffle 46 are arranged to form a slag screen 60 having a series of transversely spaced vertically elongated gas flow passages or ports through which the high temperature gases from the front section flow at a high velocity into the rear or low temperature section of the furnace chamber. The gas flow passages are formed by bending alternate pairs of the tubes 45 forwardly, as shown in Figs. 9–14, out of the plane of the tube row. As shown in Fig. 5, the slag screen portions of all of the tubes 45 are provided with studs 48 throughout their periphery, the studs 48a extending into the intertube space of each pair being longer than the others, and refractory entirely enclosing each pair of associated tubes.

The row of tubes 45 have slag screen portions of several shapes; pairs of straight tube portions 45a which extend vertically from the lower end of the baffle 46 to the rear edge of the floor 28; pairs of bent tube portions 45b which are symmetrically bent forwardly and then rearwardly in alignment with the tubes 45 at the rear edge of the floor, as shown in Fig. 10; bent tube portions 45c which are bent forwardly like the tube portions 45b and bent rearwardly into alignment with the tube portions 45a above the rearward bend in the tube portions 45b, as shown in Fig. 11; and pairs of tube portions 45d which follow the shape of the tube portions 45b except at their lower ends, each pair of the portions 45d having their lower ends bent rearwardly in a plane oblique to the plane of the tube portions 45a below the lower bend in the tube portions 45b and passing through the floor forwardly of its rear end, as shown in Figs. 9 and 14. One of the tube portions 45a adjacent each pair of tubes 45d is bent forwardly adjacent its lower end in oblique alignment with the lower bent sections of the tube portions 45d and the corresponding portion of this intertube space closed by refractory, as shown in Figs. 5, 9 and 16.

With this formation of the slag screen tubes, gas flow passages are defined at transversely spaced points in the slag screen row at the rear of the bends in the tube portions 45b, 45c, and 45d. Vertically elongated ports 61 of different lengths are thus provided at transversely spaced points in the plane of the tube portions 45a. The furnace gases reach the ports 61 by passing around both sides of the corresponding bent tube portions through vertically elongated ports 61a between the bent tube portions and the adjacent unbent tube portions to the corresponding port 61, the ports 61a being in planes approximately normal to the plane of the ports 61, as shown in Fig. 12. The furnace gases receive changes in direction flowing through the gas passages thus formed and the resultant mixing expedites the combustion of any unburned fuel particles or gases. The bent tube portions substantially prevent heat radiation from the high temperature section through the corresponding screen openings 61 in planes normal to the plane of the tube row. As shown in Figs. 3 and 16, only narrow slot-like portions of the screen gas passages appear when viewed from the high temperature section normal to the plane of the tube row.

The openings 61 behind the bent tube portions 45c terminate at their lower ends above those behind the tube portions 45b, except for the narrow slots between adjacent pairs of tubes. The openings at the rear of the tube portions 45b terminate near but slightly above the floor level, while the openings at the rear of the obliquely arranged tube portions 45d and 45a have their lower ends at the floor level. Refractory ledges 63 are formed on the floor in the spaces between the tube pairs 45a, 45b, and 45c, to provide a low dam at the rear edge of the floor except between the oblique tube portions 45d and the adjoining straight tube portions 45a which space is used as a slag drain opening 62. Only two such slag drain openings 62 are provided in the screen, with the openings symmetrically arranged at opposite sides of the center line of the furnace. The molten slag continuously flows through these drain openings in normal operation, and the fully studded refractory construction adequately protects the adjoining screen tubes from the flowing slag. The high gas velocities and highly molten condition of the slag keep the slag drain openings from clogging. Obliquely arranged openings 67 in the side walls at the rear of the screen permit the insertion of implements for cleaning the corresponding slag drain openings. If for any reason the slag level should abnormally increase, for instance, if the slag drain openings should become clogged, slag may flow over the narrow ledges 63 between the other tube groups of the screen.

The portions of the screen tubes below the floor level, except below the two slag drain openings, have tube blocks 64. At the slag drain openings plastic refractory is used, as shown in Fig. 16. A row of breaker blocks 65 on the screen tubes extends entirely across the rear side of the floor below the blocks 64 for deflecting the descending slag away from the header 37 into a hopper 55 through which it drops into the pit 56 where it is quenched in a water pool. The high velocity furnace gas flow through the screen gas flow passages in conjunction with the changes in direction to which they are subjected in entering and passing through the screen causes ash particles in suspension to be deposited on the high temperature side of the slag screen and any unburned fuel particles and gases to be further mixed with the combustion air and the com-

bustion thereof rapidly completed. On leaving the slag screen the gases flow upwardly through the rear low temperature section 14 of the furnace chamber.

The rear or low temperature section 14 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. As shown, the rear section side wall tubes 33a below the baffle 46 are only partly studded, with refractory filling the intertube spaces, as shown in Fig. 7, while the upper portions of the rear side wall tubes and tubes 70 along the rear wall 29 have metallic blocks 71 clamped thereon to form flat vertical wall surfaces, as shown in Fig. 8. The headers 35 and the upper ends of the side wall tubes rearwardly of these headers are connected to upper headers 57 adjacent the tube bank 15.

The tubes 70 extend downwardly from a header 72 along the rear wall, with their lower portions extending downwardly and forwardly along an inclined hopper wall 74 to a lower header 73. The inclined wall section 74 has a nose portion at its lower end along which are arranged a transverse row of breaker blocks 75. A row of tubes 76 extends upwardly and forwardly from the header 32 to define a steeply inclined front wall for the rear section. The tubes 76 are covered by blocks 77, constructed as shown in Fig. 8, with a transverse row of breaker blocks 78 at their lower ends. The front wall of the hopper 55 below the header 37 and opposite the hopper wall 74 is protected by block covered tubes 79 extending between the header 37 and a parallel lower header 80. A row of spray nozzles 81 extends between the tubes 79 and directs a water spray downwardly across the hopper 55. A row of breaker blocks 82 protect the nozzles 81. The headers 34, 35, 57, 72, 73, and 80 are suitably connected into the boiler circulation system by external supply connections, some of which are shown in Fig. 4, to provide an adequate supply of water to the various furnace wall tubes connected thereto.

The rear or low temperature side of the baffle 46 is advantageously provided with a flat metallic surface by means of tube blocks 48 extending across the spaces between the tubes 45 and held in thermal contact with the tubes. Each block receives a socket-headed cap screw 49 which extends through a central opening in an elongated clamp member 50 bearing against a pair of elongated supporting lugs 51 extending along and welded to the tubes 45. As shown in Fig. 19, the lugs 51 are welded along their ends only and the ends of the clamp member 50 rounded to permit the clamp member to be installed or removed through the low temperature side of the baffle. The clamp is inserted until at the front side of the lugs 51 and then turned 90° to bear against the supporting lugs. The cap screw is turned from the high temperature side of the baffle to engage the block and hold the parts assembled. The refractory at the front side can be easily removed to afford access to the cap screw, if the block requires renewal.

The rear furnace section has a substantially greater height and unobstructed volume than the front section, resulting in a substantial length of furnace gas travel in heat transfer relation to radiant heat absorbing surface. The vertical arrangement and upwardly flaring formation of this section and the drop in gas velocity facilitate the separation of ash particles in suspension. The steeply inclined upper portion of the arch 26 and of the baffle 46, and the use of smooth metallic blocks to define their rear surfaces causes these parts to remain clean in operation and exert a substantial cooling effect on the gases and particularly the ash particles ascending through the rear section. The low temperature furnace section 14 is thus mainly defined by bare metallic heat absorbing surface. Any radiation from the front section through the furnace screen openings will be to the lower portion of the rear section and mainly to the side walls thereof. The partial refractory construction of these walls will facilitate the completion of combustion of any unburned gases or fuel particles escaping from the high temperature section adjacent the furnace screen. There will be very little luminous flame in the low temperature section, and the ash particles in suspension will rapidly give up their heat by radiation to the surrounding heat absorbing surface. The ash separating in the rear section by gravity and the change in direction of the gases will be mostly in a dry granular state and can be easily handled. The descending ash either falls directly into the hopper 55 or slides down the surface of the inclined wall 74 thereto. The ash is quenched in the pit 56 and accumulates in the bottom thereof, from which it is removed as desired by means of the bucket hoist 83, as indicated in Fig. 1

Due to the arrangement and construction of the furnace baffle and slag screen, the boiler tube bank 15 and auxiliary heating surface will be completely shielded from direct radiant heat from the high temperature section. A high percentage of the ash content of the fuel is recovered in the high temperature section and much of the remaining ash in suspension caused to separate while passing through the low temperature section. Any ash particles which reach the boiler tubes will have lost their troublesome temperatures and can be easily blown off the tubes.

One installation of the steam boiler illustrated has a designed capacity of 500,000 lbs. of steam per hour at 1450 lbs. per sq. in. pressure and 935° F. total steam temperature. The designed heat release per front foot of furnace is 31,400,000 B. t. u., with a heat release per cubic foot of 38,000 B. t. u. for the total furnace and 100,000 B. t. u. for the high temperature section. Continuous slag removal is contemplated for coals having ash fusion temperatures up to 2800° F. Approximately 60% of the fuel ash content will be retained in the furnace. The furnace is thus virtually independent of the type of coal used.

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

I claim:

1. A steam generator unit comprising a furnace chamber having a high temperature section and a low temperature section laterally adjoining said high temperature section, a steam boiler receiving furnace gases from said low temperature section, heat absorbing means lining said high temperature section and proportioned

to maintain a normal mean temperature therein above the fuel ash fusion temperature, a closed floor for said high temperature section constructed to support a layer of molten slag, means for introducing a stream of finely divided solid fuel into said high temperature section and burning the same in suspension therein at temperatures above the fuel ash fusion temperature, a group of vertically disposed tubes extending upwardly from said floor and having portions so bent and arranged as to form a slag drain opening between adjacent tubes at the floor level of said high temperature section, means forming a slag dam between other pairs of adjacent tubes, and means forming an ash receiving space at the bottom of said low temperature section and constructed to receive molten slag from said slag drain opening.

2. A steam generator unit comprising a furnace chamber having a high temperature section and a low temperature section laterally adjoining said high temperature section, a steam boiler receiving furnace gases from said low temperature section, heat absorbing means lining the boundary surfaces of said high temperature section and proportioned to maintain a normal mean temperature therein above the fuel ash fusion temperature and including a closed fluid cooled floor constructed to support a layer of molten slag, means for downwardly introducing a stream of finely divided solid fuel into the upper end of said high temperature section and burning the same in suspension therein at temperatures above the fuel ash fusion temperature, a group of vertically disposed refractory covered tubes extending upwardly from one end of said floor and arranged to form a fluid cooled screen having transversely spaced gas flow passages therein terminating at their lower ends above the floor level of said high temperature section for furnace gas flow between said sections, some of said screen tubes having portions so bent and arranged as to form a slag drain opening therein at the floor level of said high temperature section, and means forming an ash receiving space at the bottom of said low temperature section and constructed to receive molten slag from said slag drain opening.

3. A steam generator unit comprising a furnace chamber having a high temperature section and a low temperature section laterally adjoining said high temperature section, a steam boiler receiving furnace gases from the upper end of said low temperature section, heat absorbing means lining the boundary surfaces of said high temperature section and proportioned to maintain a normal mean temperature therein above the fuel ash fusion temperature and including a closed fluid cooled floor constructed to support a layer of molten slag, means for introducing a stream of finely divided solid fuel into said high temperature section and burning the same in suspension therein at temperatures above the fuel ash fusion temperature, a row of vertically disposed refractory covered tubes extending upwardly from said floor and arranged to form a fluid cooled screen having transversely spaced gas flow passages therein for furnace gas flow between said sections, a group of adjacent screen tubes having aligned bent portions out of the plane of said row and cooperating with an adjacent screen tube to define a slag drain opening therebetween at the floor level of said high temperature section, heat absorbing means lining the boundary surfaces of said low temperature section and proportioned to maintain a normal mean temperature therein below said fuel ash fusion temperature, and means forming an ash receiving space at the bottom of said low temperature section and constructed to receive molten slag from said slag drain opening and ash separated in said low temperature section.

4. A steam generator unit comprising a furnace chamber having a high temperature section and a low temperature section laterally adjoining said high temperature section, said low temperature section extending above and having a substantially greater unobstructed volume than said high temperature section, a steam boiler receiving furnace gases from the upper end of said low temperature section, heat absorbing means lining the boundary surfaces of said high temperature section and proportioned to maintain a normal mean temperature therein above the fuel ash fusion temperature and including a closed fluid cooled floor constructed to support a layer of molten slag, means for downwardly introducing a stream of finely divided solid fuel into the upper end of said high temperature section and burning the same in suspension therein at temperatures above the fuel ash fusion temperature, a group of vertically disposed refractory covered tubes extending upwardly from one end of said floor and arranged to form a fluid cooled screen having transversely spaced gas flow passages therein for furnace gas flow between said sections, some of said screen tubes having obliquely aligned bent portions with a closed intertube space arranged to form a shielded slag drain opening at the floor level of said high temperature section, heat absorbing means lining the boundary surfaces of said low temperature section and proportioned to maintain a normal mean temperature therein below said fuel ash fusion temperature, and means forming an ash receiving space at the bottom of said low temperature section and constructed to receive molten slag from said slag drain opening and ash separated in said low temperature section.

5. A furnace for burning pulverized fuel comprising walls defining a furnace chamber, means for burning pulverized fuel in suspension in said furnace chamber, a closed fluid cooled floor constructed to support a layer of molten slag, and a row of vertically disposed tubes at one side of said furnace chamber extending to said floor, spaced groups of adjacent tubes having aligned bent portions bent out of the plane of said row adjacent said floor, metallic projections on said tube bent portions, and refractory material closing the intertube space of the bent portions of each group and held in contact therewith by said projections.

6. A furnace for burning pulverized fuel comprising walls defining a furnace chamber, means for burning pulverized fuel in suspension in said furnace chamber, a closed fluid cooled floor constructed to support a layer of molten slag, and a row of vertically disposed tubes at one side of said furnace chamber extending to said floor, groups of adjacent tubes having aligned portions bent out of the plane of said row with the bent portions arranged relative to adjacent tubes in said row to form shielded flow passages therebetween, metallic projections mounted on said tube bent portions, and refractory material closing the intertube space of the bent portions

in each group and held in contact therewith by said metallic projections.

7. A furnace for burning pulverized fuel comprising walls defining a furnace chamber, means for burning pulverized fuel in suspension in said furnace chamber, a closed fluid cooled floor constructed to support a layer of molten slag, and a row of vertically disposed tubes arranged to form a fluid cooled screen at one side of said furnace chamber extending to said floor, certain adjacent tubes having refractory covered portions bent out of the plane of said row with the bent portions in alignment to partly define a flow passage through said screen shielded by said tube bent portions.

8. A furnace for burning pulverized fuel comprising walls defining a furnace chamber, means for burning pulverized fuel in suspension in said furnace chamber, a closed floor constructed to support a layer of molten slag, and a row of vertically disposed tubes arranged to form a fluid cooled screen at one side of said furnace chamber, certain adjacent tubes having portions bent to progressively greater distances out of said tube row with the bent portions in alignment in a plane oblique to the plane of the tube row to partly define a slag drain passage through said screen at the floor level.

9. A furnace for burning pulverized fuel comprising walls defining a furnace chamber, means for burning pulverized fuel in suspension in said furnace chamber, a closed fluid cooled floor constructed to support a layer of molten slag, and a row of vertically disposed refractory covered studded tubes arranged to form a fluid cooled screen at one side of said furnace chamber, certain pairs of adjacent tubes having lower portions bent out of the plane of said row with the bent portions in alignment in a plane parallel to the plane of said row to form gas flow passages through said screen shielded from furnace radiant heat by said tube bent portions, the lower ends of some of said tubes having portions bent in alignment in a plane oblique to the plane of said tube row to define a slag drain opening in said screen at the level of said floor to permit molten slag to flow therethrough.

10. 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 baffle 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 adjacent the furnace bottom, 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 front section at temperatures above the fuel ash fusion temperature, a closed fluid cooled floor below said front section constructed to support a layer of molten slag, means forming a fluid cooled screen between the lower end of said baffle and the furnace bottom having a slag drain opening therein at the slag level in said front section, and an ash receiving space below said rear section constructed to receive molten ash flowing through said slag drain opening from said front section floor.

11. 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 baffle 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 downwardly into the upper end of and burning the same in suspension in said high temperature section at furnace temperatures above the fuel ash fusion temperature, 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 closed fluid cooled floor constructed to receive a layer of molten slag, heat absorbing means lining the boundary surfaces of said low temperature section and constructed to maintain a normal mean temperature therein below the fuel ash fusion temperature, a group of vertically disposed refractory covered tubes between the lower end of said baffle and the furnace bottom arranged to form a fluid cooled screen having a slag drain opening therein adjacent the floor level in said high temperature section, and a fluid cooled hopper below said low temperature section constructed to receive dry ash separated in said low temperature section and molten slag flowing through said slag drain opening from said high temperature section floor.

12. In a furnace having a furnace chamber divided into a high temperature zone and a laterally adjoining low temperature zone communicating therewith, the method of burning a finely divided solid fuel and eliminating a high percentage of the ash content of the fuel in the furnace chamber which comprises downwardly discharging a stream of the fuel and air for combustion into and burning the fuel in suspension in said high temperature zone at temperatures above the fuel ash fusion temperature, collecting molten slag separated in said high temperature zone in the lower portion of said zone, directing the furnace gases from the lower part of said high temperature zone into the lower part of said low temperature zone, cooling the furnace gases to a temperature below the fuel ash fusion temperature while passing upwardly through said low temperature zone, and draining the molten slag collecting in said high temperature zone into the lower portion of said low temperature zone.

13. In a furnace having a furnace chamber divided into a high temperature zone and a low temperature zone communicating at their lower ends, the method of burning a finely divided solid fuel and eliminating a high percentage of the ash content of the fuel in the furnace chamber which comprises introducing a stream of the fuel and air for combustion into the upper end of and burning the fuel in suspension while passing downwardly in said high temperature zone at temperatures above the fuel ash fusion temperature, collecting molten slag separated in said high temperature zone in the lower portion of said zone, directing the furnace gases from said high temperature zone into said low temperature zone through shielded high velocity flow passages, cooling the furnace gases and suspended ash to a temperature below the fuel ash fushion temperature while passing upwardly through said low temperature zone, and draining the molten slag from said high temperature zone through said flow passages into the lower portion of said low temperature zone.

14. In a furnace having a furnace chamber divided into a high temperature zone and a laterally adjoining low temperature zone communicating therewith, the method of burning a finely divided solid fuel and eliminating a high percentage of the ash content of the fuel in the furnace chamber which comprises downwardly discharging a stream of the fuel and air for combustion into and burning the fuel in suspension in said high temperature zone at temperatures above the fuel ash fusion temperature, collecting molten slag separated in said high temperature zone in the lower portion of said zone, directing the furnace gases from the lower part of said high temperature zone into the lower part of said low temperature zone through high velocity flow passages, cooling the furnace gases and suspended ash to a temperature below the fuel ash fusion temperature while passing upwardly at a lower velocity through said low temperature zone, and collecting the ash separated in said low temperature zone and draining the molten slag collecting in said high temperature zone into the lower portion of said low temperature zone.

15. In a fluid heater, a wall having its opposite sides adapted to be exposed in operation to different temperature conditions and comprising a row of spaced fluid heating tubes, a series of metallic projections mounted on the high temperature side of said tubes and projecting into the intertube spaces, refractory material held by said projections in contact with said tubes and arranged to close the intertube spaces at the high temperature side of said tubes, metallic blocks at the low temperature side of said tubes, and means for holding said blocks in thermal contact with said tubes.

16. In a fluid heater, a wall having its opposite sides adapted to be exposed in operation to different temperature conditions and comprising a row of spaced fluid heating tubes, a series of metallic projections mounted on the high temperature side of said tubes, refractory material between said projections arranged to cover the high temperature side of said tubes, metallic blocks arranged to cover the low temperature side of said tubes, and means for holding said blocks in thermal contact with said tubes.

17. In a fluid heater, a wall having its opposite sides adapted to be exposed in operation to different temperature conditions and comprising a row of spaced heating fluid tubes, a series of metallic projections mounted on said tubes and projecting into the intertube spaces, refractory material between said projections in contact with said tubes and arranged to close the intertube spaces at the high temperature side of said tubes, lugs mounted on said tubes and extending into the intertube spaces, metallic blocks at the low temperature side of said tubes, and means engaging said lugs and blocks to hold said blocks in thermal contact with said tubes.

18. In a furnace, a furnace baffle having its opposite sides adapted to be exposed in operation to different furnace temperature conditions and comprising a row of vertically disposed spaced fluid heating tubes, a series of metallic projections mounted on the high temperature side of said tubes and projecting into the intertube spaces, refractory material between said projections covering the high temperature side of said tubes and arranged to close the intertube spaces at the high temperature side of said tubes, lugs welded on said tubes and extending into the intertube spaces, metallic blocks arranged to cover the low temperature side of said tubes, and clamping means engaging said lugs and blocks to hold said blocks in thermal contact with said tubes.

19. A steam generator unit comprising a furnace chamber having a high temperature section and a low temperature section laterally adjoining said high temperature section, a steam boiler receiving furnace gases from said low temperature section, means for burning finely divided solid fuel in suspension in said high temperature section and maintaining a normal mean temperature therein above the fuel ash fusion temperature, a closed floor for said high temperature section constructed to support a layer of molten slag, a row of water tubes extending along and fluid cooling said floor, means forming an ash receiving space at the bottom of said low temperature section and constructed to receive molten slag from one end of said floor, means forming a fluid cooled screen extending upwardly from the slag discharge end of said floor and having spaced gas flow passages therein for furnace gas flow between said sections and lower tube portions bent to form spaced slag drain openings therebetween, and means forming a slag dam at the slag discharge end of said floor.

20. A steam generator unit comprising a furnace chamber having a high temperature section and a low temperature section laterally adjoining said high temperature section, a steam boiler receiving furnace gases from said low temperature section, means for burning finely divided solid fuel in suspension in said high temperature section and maintaining a normal mean temperature therein above the fuel ash fusion temperature, a flat sloping floor for said high temperature section constructed to support a layer of molten slag, a row of inclined water tubes extending along and fluid cooling said floor, means forming an ash receiving space at the bottom of said low temperature section and constructed to receive molten slag from the lower end of said floor, means forming a slag dam at the lower end of said floor and spaced slag drain openings below the top level of said dam, and means for fluid cooling said slag dam.

21. A steam generator unit comprising a furnace chamber having a high temperature section and a low temperature section laterally adjoining said high temperature section, a steam boiler receiving furnace gases from said low temperature section, a closed floor for said high temperature section constructed to support a layer of molten slag and discharge the same at one end thereof, heat absorbing means lining the boundary surfaces of said high temperature section and proportioned to maintain a normal mean temperature therein above the fuel ash fusion temperature, said heat absorbing means including a row of vertically disposed water tubes extending upwardly from the slag discharge end of said floor and having portions grouped to form transversely spaced gas flow passages therein for furnace gas flow between said sections and lower tube portions differently grouped to form a substantially lesser number of slag discharge openings therebetween for the slag on said floor, means for introducing finely divided solid fuel into said high temperature section and burning the same in suspension therein at temperatures above the fuel ash fusion temperature, and means forming an ash

receiving space at the bottom of said low temperature section and constructed to receive molten slag from said slag discharge opening or openings.

22. A steam generator unit comprising a furnace chamber having a high temperature section and a low temperature section laterally adjoining said high temperature section, a steam boiler receiving furnace gases from said low temperature section, a sloping floor for said high temperature section constructed to support a layer of molten slag, heat absorbing means lining the boundary surfaces of said high temperature section and proportioned to maintain a normal mean temperature therein above the fuel ash fusion temperature, said heat absorbing means including a row of water tubes extending along said high temperature section floor and a group of vertically disposed water tubes extending upwardly from the lower end of said floor and arranged to form a fluid cooled screen having transversely spaced gas flow passages therein for furnace gas flow between said sections, means for introducing finely divided solid fuel into said high temperature section and burning the same in suspension therein at temperatures above the fuel ash fusion temperature, a transversely extending header below the lower end of said floor and directly connected to the lower ends of said floor and screen tubes, said header and tube connections thereto being arranged to minimize relative movement of said floor and screen tubes adjacent the floor level, and means for connecting said header into the circulation system of said steam boiler.

23. A steam generator unit comprising a furnace chamber having a high temperature section and a low temperature section laterally adjoining said high temperature section, a steam boiler receiving furnace gases from said low temperature section, a closed floor for said high temperature section constructed to support a layer of molten slag, heat absorbing means lining the boundary surfaces of said high temperature section and proportioned to maintain a normal mean temperature therein above the fuel ash fusion temperature, said heat absorbing means including a row of water tubes extending along said high temperature section floor and a group of vertically disposed water tubes extending upwardly from the slag discharge end of said floor and arranged to form a fluid cooled screen having transversely spaced gas flow passages therein for furnace gas flow between said sections, means for downwardly introducing a stream of finely divided solid fuel into the upper end of said high temperature section and burning the same in suspension therein at temperatures above the fuel ash fusion temperature, a transversely extending header below the level of the slag discharge end of said floor and directly connected to the lower ends of said floor and screen tubes, said header and tube connections thereto being arranged to minimize relative movement of said floor and screen tubes adjacent the floor level, means for connecting said header into the circulation system of said steam boiler, and means forming an ash receiving space at the bottom of said low temperature section and constructed to receive molten slag from said floor.

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