June 3, 1941. M. K. DREWRY 2,244,144

APPARATUS FOR AND METHOD OF BURNING FUEL TO GENERATE STEAM

Filed Aug. 2, 1937 7 Sheets-Sheet 1

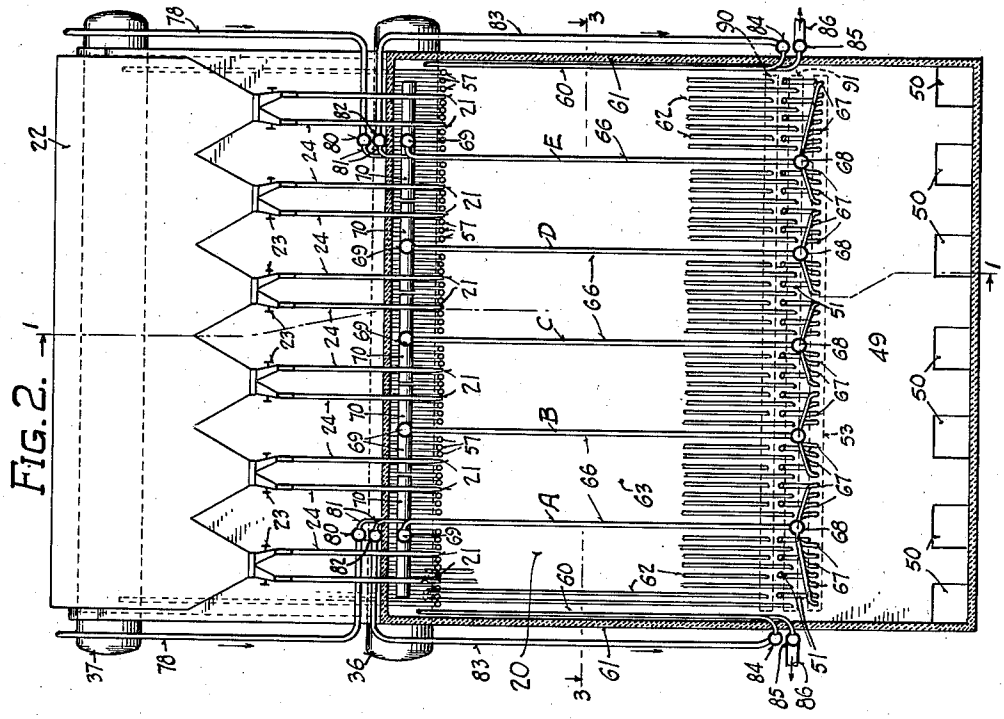


FIG. 2.

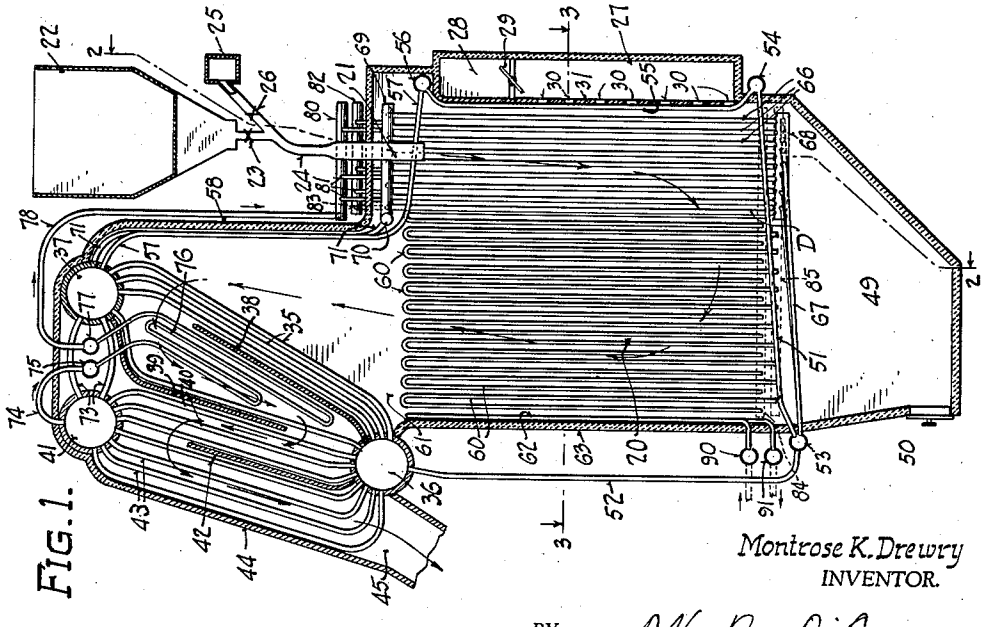


FIG. 1.

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Filed Aug. 2, 1937. 7 Sheets-Sheet 2

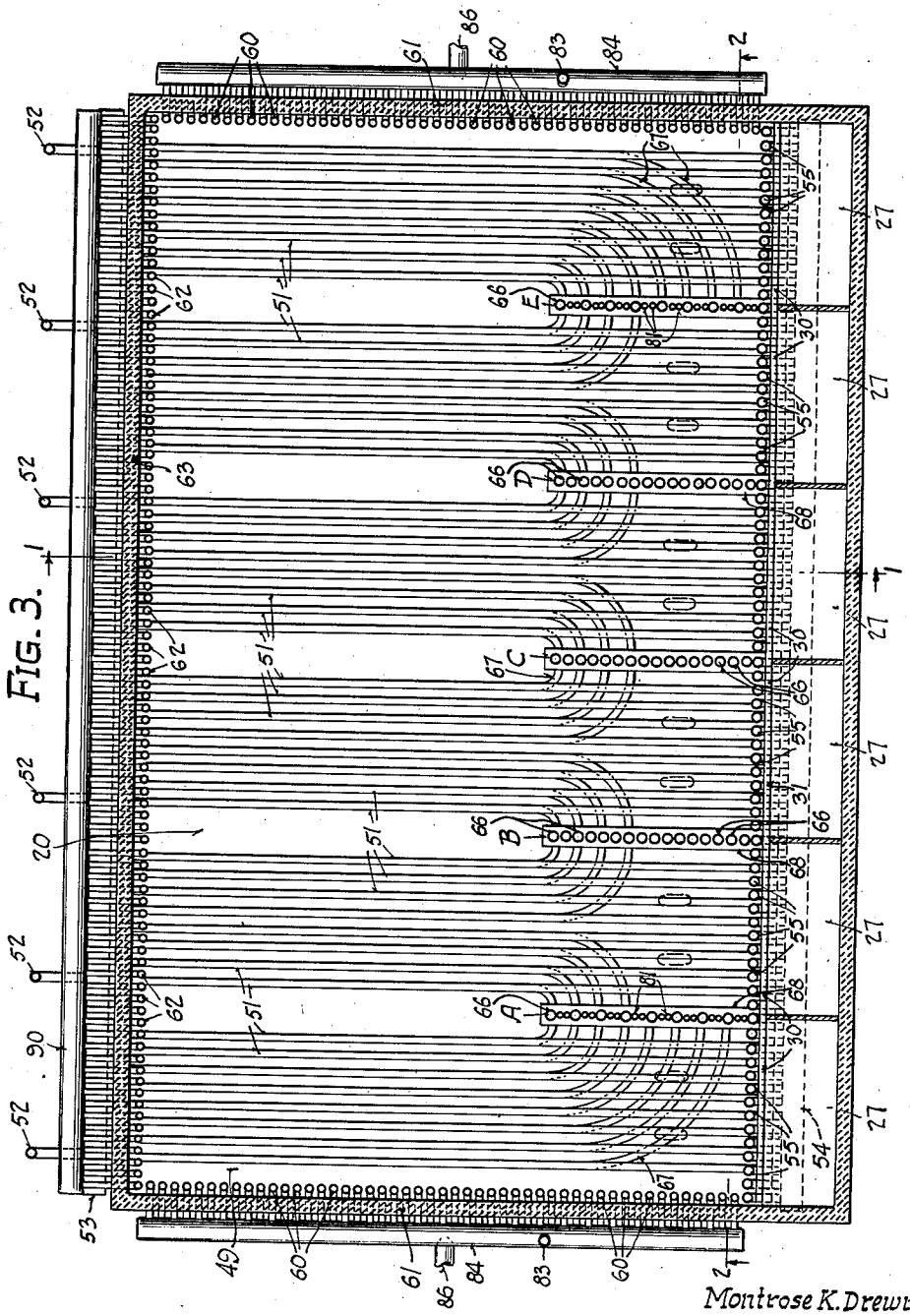


FIG. 3.

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APPARATUS FOR AND METHOD OF BURNING FUEL TO GENERATE STEAM

Filed Aug. 2, 1937 7 Sheets-Sheet 3

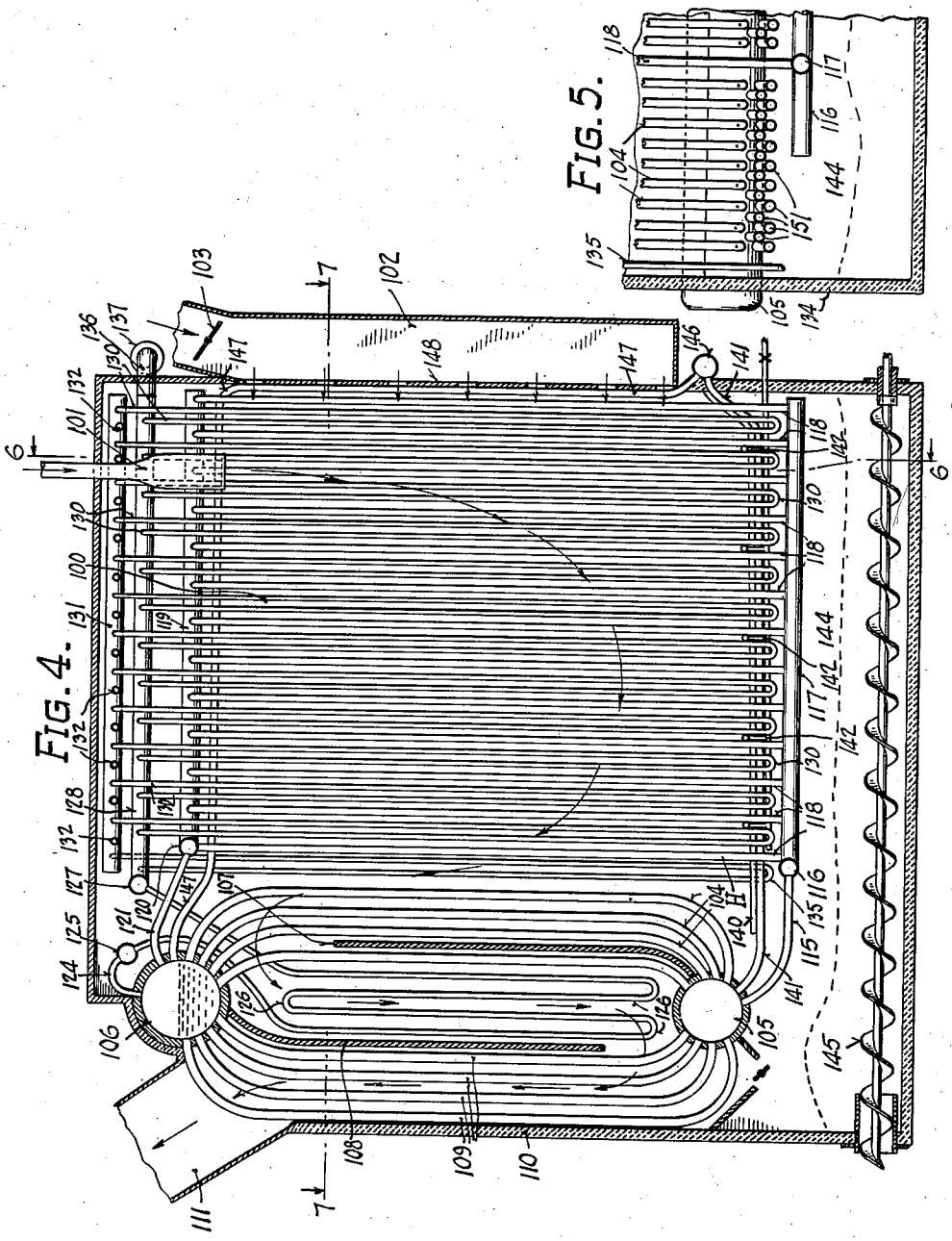


FIG. 4.

FIG. 5.

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APPARATUS FOR AND METHOD OF BURNING FUEL TO GENERATE STEAM

Filed Aug. 2, 1937 7 Sheets-Sheet 4

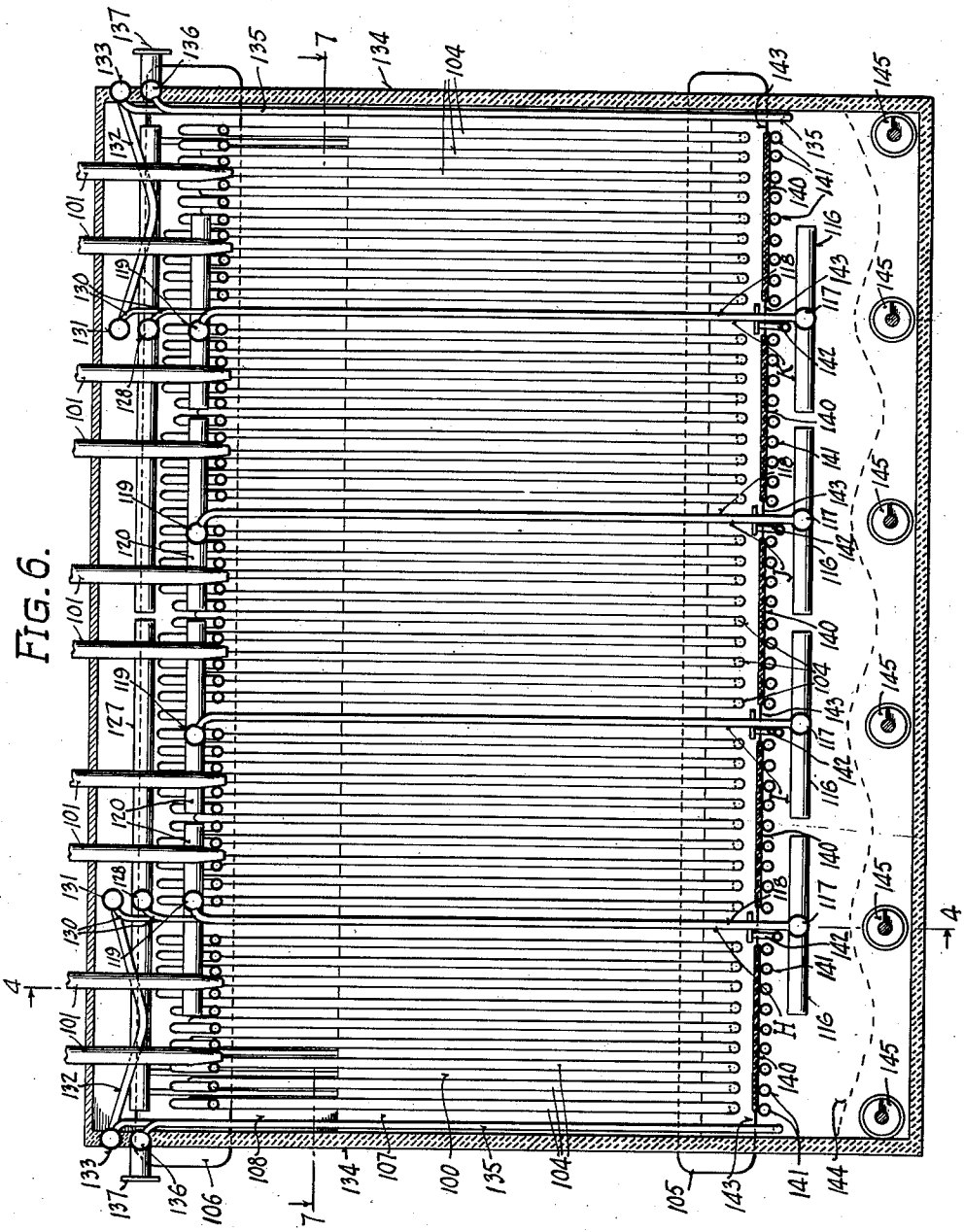


FIG. 6.

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APPARATUS FOR AND METHOD OF BURNING FUEL TO GENERATE STEAM

Filed Aug. 2, 1937 7 Sheets-Sheet 5

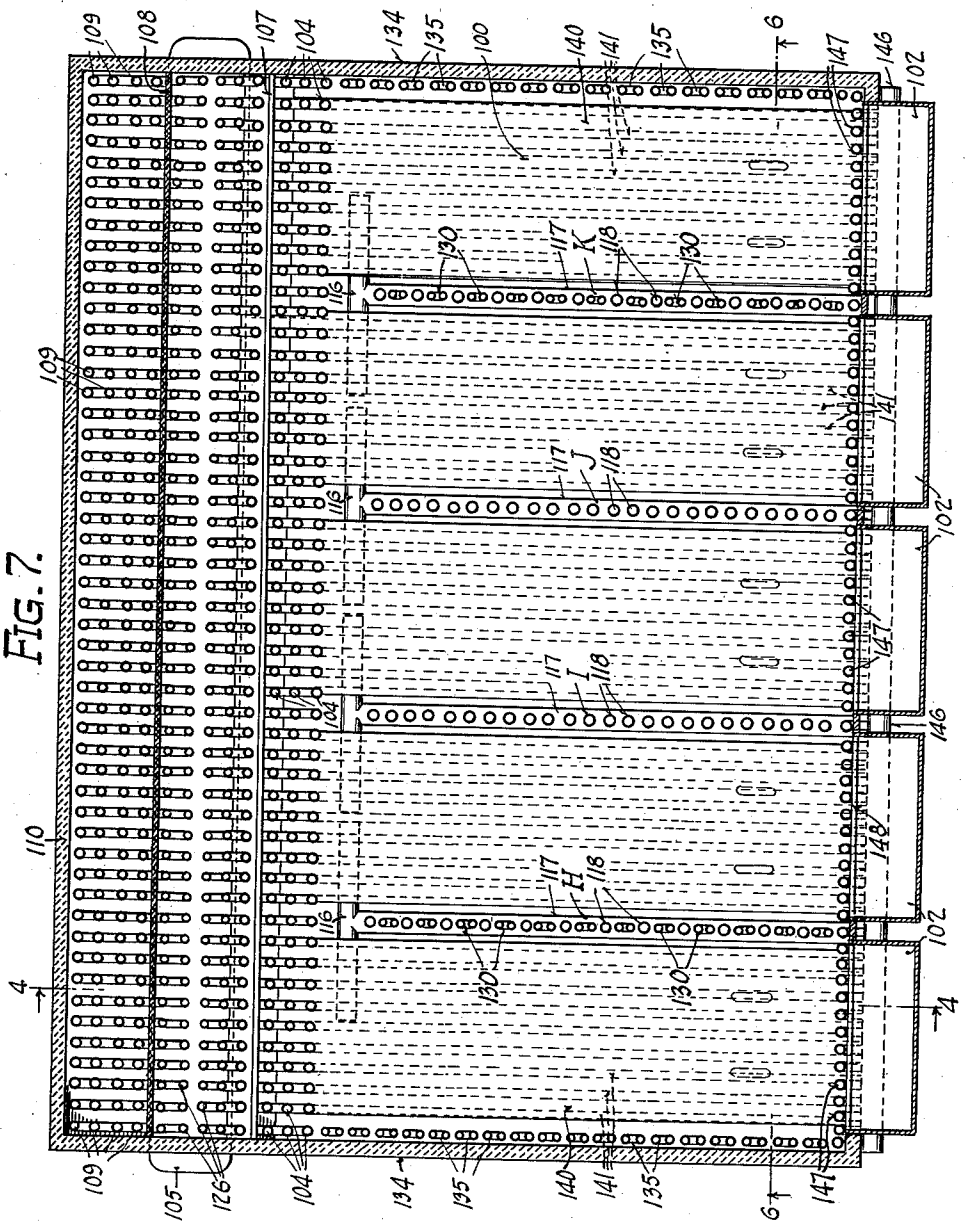


FIG. 7.

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APPARATUS FOR AND METHOD OF BURNING FUEL TO GENERATE STEAM

Filed Aug. 2, 1937 7 Sheets-Sheet 6

FIG. 9.

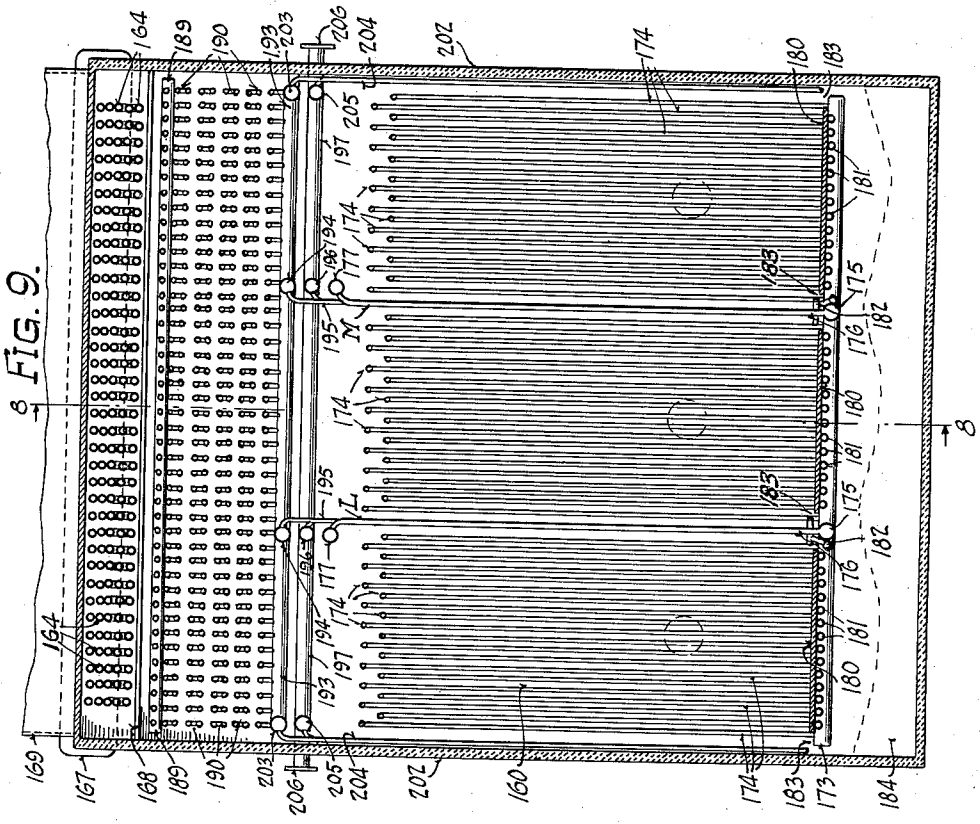
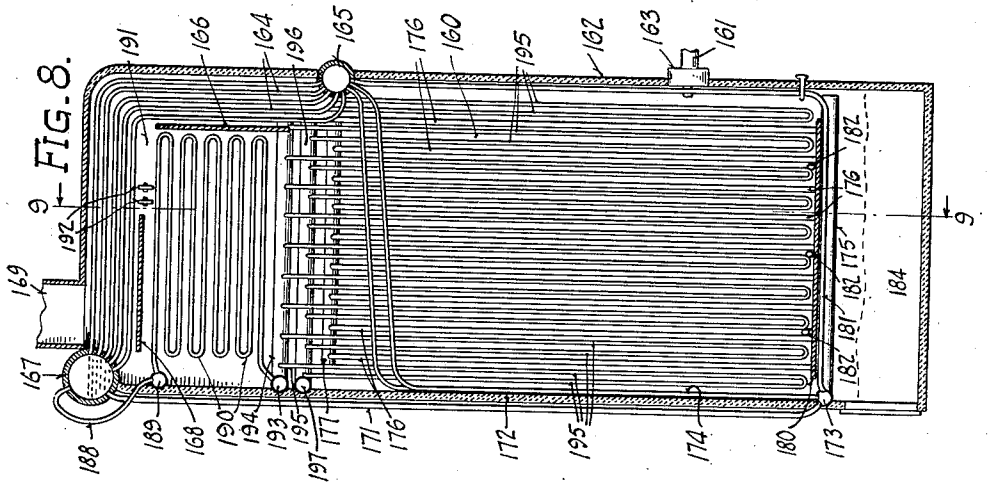


FIG. 8.



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APPARATUS FOR AND METHOD OF BURNING FUEL TO GENERATE STEAM

Filed Aug. 2, 1937 7 Sheets-Sheet 7

FIG. 10.

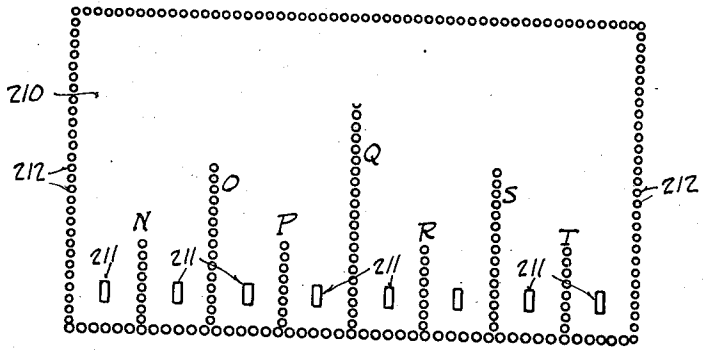


FIG. 11.

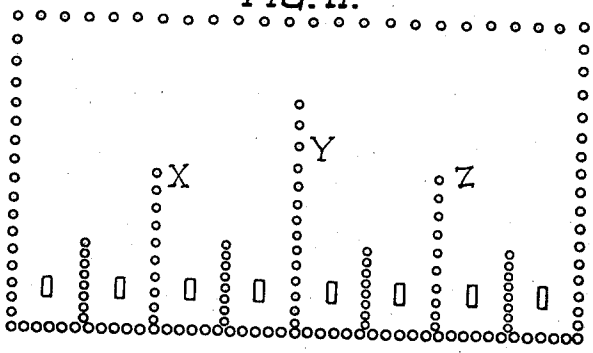


FIG. 12.

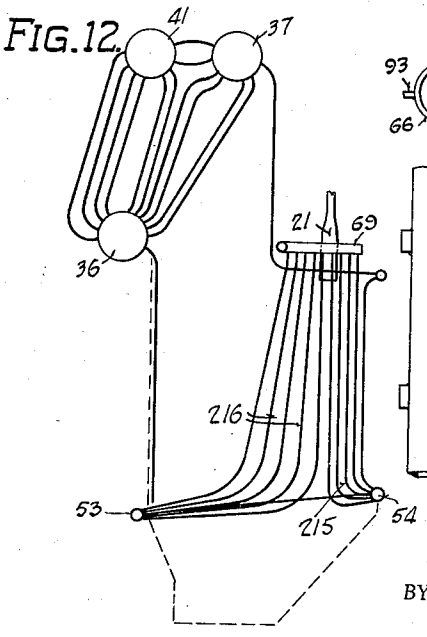
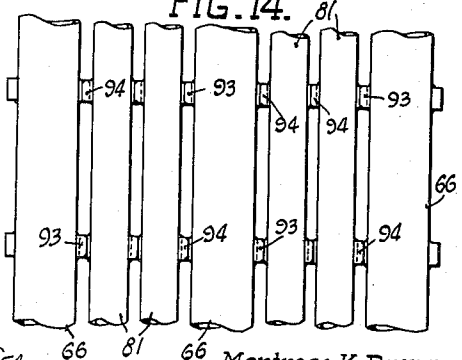


FIG. 13.



FIG. 14.



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Patented June 3, 1941 2,244,144

UNITED STATES PATENT OFFICE

2,244,144

APPARATUS FOR AND METHOD OF BURNING FUEL TO GENERATE STEAM

Montrose K. Drewry, Milwaukee, Wis.,

Application August 2, 1937, Serial No. 156,866

28 Claims. (Cl. 122—235)

My invention relates generally to the art of burning fuel to generate steam, and more particularly to improved apparatus for and methods of generating superheated steam in large quantities at high temperatures.

In steam generating and utilizing systems, the efficiency of operation may generally be improved by increasing the size and capacity of the various units of apparatus and by increasing the pressure and temperature of the steam flowing in the system to the highest values that the apparatus is capable of withstanding safely. However, the improved results attained by these measures are gained only at the expense of increased difficulties in successfully operating and maintaining the apparatus.

In operating a steam generating unit at the higher steam temperatures, the amount of heat used in superheating the steam becomes a large proportion of the total heat required to generate the steam. Under these conditions, self-regulation of the steam temperature becomes inadequate, particularly since the amount of heat required to superheat the steam varies with changes in output of the boiler and with other changes in conditions, with the result that undesirable and uncontrollable steam temperature variations occur.

In steam generating units of large capacity, the furnace combustion space volume is very large in proportion to the surface area of the enclosing walls when compared with the relations existing in small furnaces. Consequently, proportionately less heat is absorbed by heat absorbing elements mounted on the walls of a large furnace and therefore the temperature within a large combustion space is ordinarily much higher than the temperature in a furnace of small capacity operating under otherwise similar conditions. High temperatures in the furnace cause melting or fusing of the ashes within the combustion space, with the result that the ashes coming in contact with heat absorbing surfaces adhere to and collect upon them to the detriment of efficiency and of uniform conditions of operation. Since the ashes in cooling change from molten clinging state to dry state at different points within the furnace under different operating conditions, deposits of tenacious ashes are formed upon the various heat absorbing surfaces in uncontrollable and unpredictable patterns.

In a steam generating unit producing highly superheated steam these deposits of molten ashes constitute a major problem, since they may result in materially changing the heat absorbing characteristics, both of the associated boiler and of the superheating elements, in such manner as to alter the normal self-regulating character of the unit with the result that the temperature of the steam may vary considerably under different conditions.

Further, the structural elements of steam generating units operating at high temperatures are necessarily subjected to high stresses, and any appreciable variation in the steam temperature may cause differential expansions that result in imposing additional stresses of dangerous magnitude on the structure, these stresses being of particularly great importance since steel and other structural materials are considerably weakened by high temperatures.

A general object of my invention is to provide an improved steam generating unit of large capacity that is capable of continuous, highly efficient operation.

Another object of the invention is to provide an improved furnace of large capacity that is of small size in proportion to the amount of heat generated and absorbed in it.

Another object is to provide a fuel burning furnace arranged to operate without excessive deposits of ash occurring on associated heat absorbing surfaces and without clinkering of ash in the furnace bottom.

Another object is to provide a steam generating unit having improved means for regulating the temperature of the steam being generated.

Another object is to provide a steam generating unit capable of being regulated to control the temperature of the generated steam, and that normally operates at a furnace temperature below that at which ash fuses and sticks to heat absorbing surfaces, the arrangement being such that the furnace occupies a minimum amount of space.

Another object is to provide a steam generating unit having steam superheating tubes so disposed in the furnace that their entire peripheries are exposed to heat radiated directly from burning fuel.

Another object is to provide a furnace having heat absorbing division walls in which both water heating and steam superheating elements are incorporated.

Another object is to provide a method of operating a steam generating unit wherein the temperature of the generated steam may be regulated by adjusting the rate of combustion of fuel adja-

cent to division walls containing superheating tubes.

Another object is to provide an improved method of adjusting a furnace to change the character of the steam generated by it, that involves altering the ratio of water tubes to steam tubes in a dividing wall of the furnace.

A still further object is to provide a convenient and economical arrangement for cooling ashes and removing them from a furnace.

According to my invention, difficulties previously experienced in operating large steam generating units, arising from molten ash adhering to heat absorbing surfaces, are obviated by operating the furnace combustion chamber at a temperature below that at which the ash fuses and forms slag. This is accomplished by directly absorbing a sufficiently large amount of heat as it is radiated from the burning fuel particles, by means of radiant heat absorbing elements disposed in the zone of greatest heat liberation, to effect the desired temperature reduction. For this purpose, vertically disposed tubes are arranged to constitute partial division walls positioned between spaced regions of intense combustion in the furnace.

Since the entire peripheries of these tubes are exposed to radiant heat, they function to absorb heat in the most efficient and direct manner, enabling the combustion space to operate at high capacity, yet at moderately low temperature. In a powdered fuel burning furnace the dividing walls are disposed between spaced fuel burners in manner to divide the otherwise hottest part of the combustion chamber into sections. The tubes in the dividing walls may constitute part of the water circulating system or part of the steam superheating system, some of the walls being formed by tubes of both kinds arranged alternately with the water tubes serving to support the superheating tubes. To provide for regulating the steam temperature, some of the walls may be formed entirely of water tubes, and different proportions of water tubes and steam tubes may be utilized in the other walls. By adjusting the fuel burners to effect different rates of firing adjacent to these various walls, any degree of superheat may be established, the rate being maintained under varying load conditions by continued adjustments of the burners as circumstances may require. Various modified arrangements of the tubes and of the dividing walls may be employed to meet various conditions of operation, and adjustments of permanent nature may be effected readily by altering the ratios of the two types of tubes in one or more of the walls. Fuels requiring different combustion conditions may be burned separately in the different sections of the furnace, and the furnace may be operated efficiently under low load conditions by burning fuel in only one or two of the sections. Because of the low operating temperature in the furnace, the ashes within the combustion chamber fall in dry state and are collected upon a flat heat absorbing bottom in each section from which they are transferred periodically into a shielded ash pit provided with conveyors for removing the ashes from the furnace.

The foregoing and other objects of the invention, which will become more fully apparent from the following detailed description, may be achieved by the apparatus herein set forth as exemplary of several preferred embodiments of the invention and that is described in connection with illustrative structures depicted in the accompanying drawings, in which:

Figure 1 is a view in vertical cross section of a large steam generating unit embodying the principles of the present invention, taken substantially on the plane represented by the lines 1—1 in Figs. 2 and 3;

Fig. 2 is a view in vertical longitudinal section of the steam generating unit taken substantially on the plane represented by the lines 2—2 in Figs. 1 and 3 looking into the combustion chamber from the front;

Fig. 3 is a view in horizontal section of the steam generating unit taken substantially on the plane represented by the lines 3—3 in Figs. 1 and 2, looking down into the combustion chamber;

Fig. 4 is a view in vertical cross section generally similar to Fig. 1, of a steam generating unit embodying a modification of the invention, taken substantially on the plane represented by the lines 4—4 in Figs. 6 and 7;

Fig. 5 is a fragmentary detail view in vertical cross section of a modified ash screen tube arrangement corresponding generally to the ash screen shown in section in Fig. 2.

Fig. 6 is a view in vertical longitudinal section of the modified steam generating unit taken substantially on the plane represented by the lines 6—6 in Figs. 4 and 7;

Fig. 7 is a view in horizontal section of the modified steam generating unit taken substantially on the plane represented by the lines 7—7 in Figs. 4 and 6;

Fig. 8 is a view in vertical cross section, generally similar to Figs. 1 and 4, of another steam generating unit constituting a further embodiment of the invention, taken substantially on the plane represented by the line 8—8 in Fig. 9.

Fig. 9 is a view in vertical longitudinal section of the further modification, taken substantially on the plane represented by the line 9—9 in Fig. 8;

Fig. 10 is a somewhat diagrammatic view in horizontal section, generally similar to Figs. 3 and 7, showing another arrangement of dividing walls constituting a further modification of my invention;

Fig. 11 is a view similar to Fig. 10 but showing a different arrangement of tubes in the dividing walls;

Fig. 12 is a somewhat diagrammatic view in vertical section, generally similar to Figs. 1 and 4 showing an arrangement of dividing wall tubes constituting a still further modification of my invention.

Fig. 13 is a somewhat diagrammatic plan view of part of a division wall showing the manner in which the superheating tubes are supported in water tubes; and

Fig. 14 is a fragmentary view in elevation of the interlocked division wall tubes shown in Fig. 13.

Referring more particularly to the drawings, and especially to Figs. 1, 2 and 3 thereof, the steam generating unit there illustrated as constituting structure exemplifying a preferred embodiment of my invention, includes a vertically fired pulverized fuel burning furnace associated with and furnishing heat to a boiler of the three-drum bent-tube type.

The furnace element of the unit comprises an enclosed unitary combustion chamber 20 into which mixtures of pulverized fuel and air are projected at spaced positions for burning in a plurality of distinct zones of intense combustion,

In this particular furnace, the fuel is projected downward from each of a plurality of spaced vertically disposed burners 21 distributed along the forward upper part of the chamber 20, as shown in Fig. 2. Each of the burners 21 is supplied with powdered coal from a storage bin 22 above and at the front of the furnace from which the coal descends through a feeder or control valve 23 and is delivered in measured quantities into a pipe 24 leading to the associated burner. Primary air for projecting the coal from the burner into the combustion chamber and for providing part of the oxygen to support combustion, enters each of the pipes 24 from a primary air duct 25, a control valve or damper 26 being provided for regulating the flow of air to each burner individually.

By adjusting the fuel feeder 23 and the primary air valve 26 associated with each burner, the rate of fuel consumption and the amount of heat liberated in the combustion zones supplied by the various burners may be individually regulated.

As may be seen in Fig. 2, the burners 21 are preferably arranged in groups of two. Auxiliary or secondary air for providing the additional oxygen necessary to complete the combustion of the fuel is admitted to each pair of burners from a separate air box 27, the air boxes being disposed vertically in side by side relation at the front of the furnace, as shown in Figs. 1 and 3. A duct 28 extends lengthwise of the furnace above the air boxes 27 and supplies air to each of them through an individual control valve or damper 29 that is adjustable to regulate the supply of secondary air to each pair of burners. From the air boxes 27, the secondary air flows horizontally through vertically spaced openings 30 in a forward wall 31 of the combustion chamber in manner to mix with the fuel and the primary air descending from the burners 21. The flames from each of the burners 21 extend downward into the combustion chamber 20 and constitute spaced zones of maximum combustion in the regions directly below the burners where the fuel mixes with the inflowing secondary air and the greater part of the combustion and heat liberating reaction occurs.

The secondary air flowing horizontally through the openings 30 causes the flames to curve back into the rear part of the combustion chamber and to turn upward therein as indicated by the arrows in Fig. 1. The flames from the several burners intermingle and equalize in temperature as they curve upward in the back part of the combustion chamber, the process of combustion being slowly completed in this region.

The hot gases resulting from the combustion process flow upward from the combustion chamber 20 under the influence of the furnace draft into the boiler, passing along and through a bank of boiler tubes 35 through which water circulates upward from a mud drum 36 at the bottom of the boiler to a steam drum 37 at the top thereof, a baffle 38 being provided for causing the hot gases to flow in the direction generally longitudinally of the tubes 35 until they reach the portions thereof immediately below the steam drum 37. In the region of the steam drum 37 the hot gases flow through the tube bank 35 and downward between the baffle 38 and a baffle 39 which projects downwardly from the steam drum 37. The gases then enter another bank of boiler tubes 40 which extend upward from the mud drum 36 to a second steam drum 41 disposed adjacent to and parallel with the first steam drum 37.

The hot gases enter the tube bank 40 in the region immediately above the mud drum 36, and flow upward parallel with the tubes 40 between the baffle 39 and a baffle 42 extending upward from the mud drum. Immediately below the steam drum 41 the gases enter another bank of tubes 43 disposed parallel with the tubes 40, and flow downward parallel with these tubes between the baffle 42 and a baffle 44, the baffle 44 constituting the rear wall of the boiler setting and part of a duct 45 through which the gases pass from the boiler to be discharged up the stack.

Ashes remaining after the combustion of the coal in the combustion chamber 20, descend into an ash pit 49 beneath the furnace, from which they may be removed periodically by way of doors 50 provided in the back wall of the ash pit for that purpose. In order to cool the ashes as they descend into the ash pit, to thereby prevent the formation of clinkers, and to utilize heat in the ashes which would otherwise be wasted, a plurality of heat absorbing tubes 51 are disposed, substantially horizontally across the bottom of the combustion chamber in spaced relation to constitute a water screen. As the ashes fall onto and between the spaced tubes 51 of the water screen they give up sufficient heat to the tubes to prevent the ash particles from sticking to the tubes or coalescing in the bottom of the ash pit. Further functions of the tubes 51 are to shield the ash pit from the heat radiated from the flames in the combustion chamber 20 and to asorb heat passing upward from the ashes in the ash pit.

The tubes 51 of the water screen are connected in the water circulating system of the boiler, water for flowing through them being brought down from the mud drum 36 through downcoming pipes 52, which pass outside of the furnace, to an inlet header 53 disposed longitudinally of the furnace at the rear thereof and below the bottom of the combustion space, as shown in Fig. 1. Each of the screen tubes 51 is connected at one end to the header 53, the tubes extending forwardly from the header with a slightly upward inclination across the bottom of the combustion chamber to a header 54 disposed longitudinally of the furnace at the front thereof immediately below the air boxes 27.

From the header 54, a bank of tubes 55 extends upwardly along the inner surface of the front wall 31 in manner to substantially cover and protect this wall from the intense heat of the flames in the regions of maximum combustion below the burners 21. At their upper ends, the front wall tubes 55 enter a header 56 disposed parallel with the header 54 and immediately above the air boxes 27.

From the header 56 other tubes 57 extend substantially horizontally back into the combustion chamber 20 in manner to form a screen at the top of the chamber in the region of the downwardly projecting burners 21. These tubes then turn upwardly along the inside of the upper front wall 58 to the top of the furnace where they connect with and discharge into the forward steam drum 37.

The water wall formed by the tubes 55 at the front of the combustion chamber is exposed to heat radiated directly from burning fuel particles in the zones of maximum combustion below the burners 21. Radiant heat emitted from the burning fuel is likewise absorbed by the water

screen tubes 51 at the bottom of the combustion chamber and by the tubes 57 at the top thereof. Furthermore, banks of radiant superheater tubes 60 are disposed at each end of the combustion chamber to absorb additional radiant heat, these banks also serving to protect the end walls 61 of the furnace structure. Likewise a bank of radiant resuperheating tubes 62 is mounted on and protects the back wall 63 of the furnace.

The most efficient method of absorbing heat liberated by burning fuel is to absorb the heat as it is transmitted by direct radiation from incandescent fuel particles to heat absorbing elements. By this method much less heat absorbing surface is required to absorb a given amount of heat than would be necessary to absorb the same amount of heat after it had been transferred from the fuel particles to the combustion gases, since the rate of radiation of heat from gases is much less than from fuel particles. In order to take advantage of this more efficient process of heat absorption, the entire inner surface of the combustion chamber 20 is covered with heat absorbing tubes arranged in various banks as previously explained. To operate a furnace constructed in this manner successfully, it is necessary to maintain the furnace temperature sufficiently low to avoid overheating the heat absorbing tubes.

Because of the fact that the volume of a furnace combustion space changes with the cube of its linear dimensions while the wall area changes with the square of its linear dimensions, as furnace sizes become larger the proportion of wall surface area to combustion space volume becomes materially less. Consequently, in very large furnaces, the radiant heat absorbing elements on the combustion chamber walls cannot absorb sufficient heat, unless the furnace is operated at very low rating, to maintain the temperature in the combustion space below that at which the ash coalesces. Under conditions of excessive temperature in the combustion chamber the fusing ashes adhere tenaciously to and insulate the heat absorbing surfaces, thereby further reducing the amount of heat absorbed by them with the result that the furnace becomes still hotter. For these reasons, furnace volumes have in the past been determined in accordance with the permissible furnace temperatures, rather than by other factors such as considerations relating to combustion reactions or the like.

In accordance with my invention, the difficulties heretofore encountered in furnaces of large size resulting from excessive temperature in the combustion chamber, are overcome by providing additional radiant heat absorbing surfaces at positions in the combustion chamber favorable to absorbing most effectively the heat radiated from the burning fuel. To this end, the additional radiant heat absorbing elements are positioned between the spaced zones of maximum heat liberation occurring beneath the various burners, in manner to present both sides thereof toward the flames from the burners to directly absorb the heat radiated from the burning fuel particles. By this arrangement, sufficient additional heat is absorbed to maintain the temperature in the furnace below that at which the ashes fuse and adhere to heat absorbing elements.

As illustrated in the drawings, the additional heat absorbing elements are arranged to form vertically disposed division walls between the groups or pairs of burners 21, the walls being exposed at both sides to heat radiated from the flames. As may best be seen in Figs. 2 and 3, the particular furnace illustrated is provided with five division walls designated respectively, A, B, C, D and E, which divide the forward part of the combustion chamber into six open-sided compartments or sections, each section being served by a pair of burners 21 and by one of the secondary air boxes 27. As shown in Figs. 1 and 3, the division walls are disposed primarily in the region of maximum combustion at the front of the combustion chamber in order that they may function at maximum efficiency in absorbing radiant heat, the back part of the combustion chamber in which heat transfer rates are low being left open to permit intermingling of the combustion gases from the various sections in order to equalize the flow of gases into the boiler.

By this arrangement of the additional heat absorbing tubes, highly efficient absorption of heat radiated directly from the burning fuel particles is accomplished, and furthermore the tubes function at higher rates of heat absorption than do tubes exposed at only one side to radiant heat. Because of the highly efficient performance of the heat absorbing elements in the division walls, a greater amount of heat is absorbed in proportion to the total heat absorbing surface of the furnace and boiler than was formerly possible. This increased effectiveness coupled with the fact that the total radiant heat absorbing surface area in the furnace is materially increased by the addition of the division walls, results in much higher heat absorbing capacity in a furnace of a given size, or permits a furnace of given capacity to be made much smaller than has heretofore been practicable.

Although the size of the furnace may be materially reduced as a result of the additional radiant heat absorbing surface provided by the division walls, the temperature in the combustion chamber 20 is, nevertheless, actually reduced because of the increased rate of heat absorption to a point below that at which the ashes resulting from the combustion of the coal fuse and coalesce upon the heat absorbing surfaces in the furnace or upon the tubes in the boiler proper. By reason of the low temperature thus maintained in the combustion space, the ashes remain in dry state and fall as separate particles into the ash pit 49 without adhering to any part of the furnace. Since the furnace heat absorbing surfaces are kept free from clinging ashes in this manner, uniformly high heat absorbing efficiency is attained and uniform response to adjustments for effecting regulation of the steam temperature is assured.

As a further result, the efficiency of the combustion process is actually increased by the reduction in the furnace temperature, for the reason that the gases in the combustion chamber 20 are not as rarified and do not occupy as much space as do the gases in a highly heated furnace and more time is thus afforded for the combustion reaction.

By disposing the division walls in the front part only of the combustion chamber between the zones of most intense combustion, where they will absorb the most heat, both the efficiency of heat absorption and the efficiency of the combustion process are increased. With the walls in this position, all of the tubes are exposed to intense heat and function at substantially the same high rate of heat absorption, whereas if some of the tubes were positioned in the rear or secondary combustion zone where

very little radiant heat from burning coal particles is available, the average heat absorption rate would be materially reduced. Furthermore, the beneficial effects upon combustion efficiency occur in the zone of greatest combustion and highest temperature where it is desirable to reduce the temperature. On the other hand it is desirable to permit the temperature in the back of the furnace to increase in order to improve combustion in the secondary combustion zone. By this arrangement of the tubes, both of these conditions are met, and the temperature throughout the furnace is thus maintained more nearly uniform and at the point most conducive to complete and highly efficient combustion.

The heat absorbing elements forming the division walls may be water tubes or they may be superheater tubes, the water tubes constituting part of the water circulating system of the boiler. As shown in Fig. 1, water for circulating upward through water tubes 66 in each division wall, flows from the header 53 at the back of the furnace through a plurality of bent tubes 67 disposed below the screen tubes 51, into a short header 68 beneath each division wall, the headers 68 being connected to the lower ends of the vertical water tubes 66. At their upper ends the tubes 66 are connected to headers 69 disposed parallel with the headers 68 and above the horizontal portions of the tubes 57. Each of the headers 69 is joined at its inner end to a transverse header 70, the headers 70 being disposed in alignment lengthwise of the furnace. From the transverse headers 70 a plurality of tubes 71 extend upward inside the upper front wall 58 and parallel with the tubes 57, to the upper part of the boiler where they connect with the front steam drum 37.

Steam generated in the boiler tubes or in the furnace tubes passes upward into either the steam drum 37 or the steam drum 41, the two drums being connected by tubes 73 to permit flow of steam from the drum 37 to the drum 41. From the steam drum 41, a plurality of tubes 74 lead to a superheater inlet header 75 from which the steam flows into the tubes of a convection superheater 76 that is disposed between the baffles 38 and 39 and in the path of the hot furnace gases. The tubes of the superheater 76 connect with and discharge into a header 77 from each end of which the steam is withdrawn in superheated condition through pipes 78.

An important feature of my invention is to provide means for regulating the temperature of the steam in such manner that steam of uniform temperature may be supplied to steam consuming apparatus regardless of changing loads or other varying conditions. To this end, additional superheating elements of the radiant heat absorbing type are placed in and constitute part of some of the division walls, the arrangement being such that the amount of superheating effected by them may be regulated by adjusting the amount of fuel consumed in the burners adjacent to them.

As shown in the drawings, these additional superheating elements are provided in the end division walls A and E in this instance, although they may be placed in any or all of the division walls. Referring to Fig. 2, steam for the division wall superheating elements is provided through the steam pipes 78 leading from the convection superheater 76 and which are brought down at the ends of the furnace and turn inward near the burners to connect with inlet headers 80 disposed above the division walls A and E, respectively. From the headers 80 superheating tubes 81 pass downward within the division walls A and E between spaced water tubes 66, as best shown in Fig. 3, and then return upward to connect with discharge headers 82 disposed parallel with and just below the inlet headers 80. From the headers 82 the superheated steam flows through pipes 83 out to the ends of the furnace and downward to headers 84 to which one end of each tube 60 of the radiant superheater bank in each end of the furnace is connected. The other ends of the tubes 60 are connected to discharge headers 85 disposed just below and parallel with the headers 84.

After passing through the end wall superheating elements to the headers 85, the steam at the regulated temperature is conducted away through pipes 86 to steam consuming apparatus such as a steam turbine. From the turbine some of the steam may be returned for resuperheating, the return piping being connected to an inlet header 90 extending along the back wall 63 of the furnace to which one end of each of the tubes 62 of the rear wall resuperheating tube bank is connected. The other end of each tube 62 is connected to a header 91 disposed parallel with and below the header 90 and from which the resuperheated steam is returned to the turbine.

As the superheating tubes 81 in the division walls A and E are exposed to radiant heat at both sides and operate at relatively high temperatures, it is desirable that each superheating tube be disposed adjacent to a water tube 66 which serves to support it in manner to prevent it from warping. As shown in detail in Figs. 13 and 14, the water tubes 66 in the division walls A and E are provided on each side thereof, and in the plane of the wall, with vertically spaced projecting lugs 93 that engage similar lugs 94 on the sides of the adjacent superheater tubes 81, the lugs being disposed alternately and interlaced as indicated in Fig. 14, to prevent movement of the superheating tubes 81 in either direction out of the plane of the division wall.

When changes in operating conditions make it desirable to regulate the temperature of the steam supplied to the steam consuming apparatus, the burners 21 adjacent to the end division walls A and E may be adjusted to regulate the amount of heat supplied to the radiant superheating elements in these walls. For example, if the steam temperature becomes too low, the amount of fuel being consumed by the burners disposed between each of the end division walls A and E and the tube banks 60 on the respective end walls 61, may be increased to increase the amount of heat absorbed by the superheating tube banks 60 and the superheating tubes 81 in the end division walls, thereby increasing the superheating effect and raising the steam temperature. In case a further increase in the steam temperature is required, the burners disposed between the division walls A and B and those between the division walls D and E may also be adjusted to increase the amount of heat supplied to the tubes 81.

If it is desired to maintain the total fuel consumption of the furnace substantially constant under these conditions, the increased amount of fuel being consumed in the end sections may be compensated for by correspondingly reducing the amount of fuel being consumed by the burners in the two central sections between the di-

vision walls B and D. Conversely, if the steam temperature becomes too high, the amount of fuel being consumed in the end sections may be reduced to effect a reduction in the steam temperature. Likewise, the amount of fuel being consumed in the central sections may then be increased to balance the total fuel consumption.

In modern steam generating plants utilizing high temperature steam, changes in load on the steam consuming apparatus may result in greatly changing the amount of heat required to generate the steam and the amount of heat required to superheat it to the desired temperature. These conditions can be compensated for, in a steam generating unit constructed in accordance with my invention, by adjusting the burners to regulate the steam temperature as previously explained.

Further adjustments of steam temperatures may be effected by changing the positions of the flames projected from the burners, this being accomplished by regulating the flow of primary and secondary combustion air into the furnace. Thus if it is desired to decrease the amount of heat being absorbed by the division walls and to increase the amount of heat being absorbed by the resuperheater tubes **62** on the back wall **63** of the furnace to thereby increase the temperature of the resuperheated steam, the amount of secondary air being admitted horizontally through the openings **30** in the front wall **31** may be increased to cause the flames emanating from the sections to be displaced toward the rear of the combustion chamber to increase their heating effect upon the tubes **62**. To balance the total amount of air supplied for supporting combustion and to delay the combustion of the fuel, the amount of primary air being supplied through the burners may be correspondingly reduced. This method of adjusting the temperature of the resuperheated steam may be used in conjunction with the previously explained method of adjusting the initial steam temperature in order to attain complete control of the various steam temperatures. If the bank of tubes **62** on the rear wall of the furnace were connected to constitute part of the superheating surface, displacement of the flames toward the rear wall would result in reducing the amount of heat absorbed by the water tubes **55** on the front wall and the water tubes **66** in the division walls, and in increasing the amount of heat absorbed by the superheating tubes **62**, thereby increasing the temperature of the steam.

Because of the fact that ashes do not adhere to the heat absorbing surfaces in a furnace operated in accordance with this invention, the heat absorbing characteristics of the various water heating and steam superheating elements remain substantially uniform, and consequently the effect of adjusting the burners to regulate the steam temperature is substantially the same at all times.

If it is found desirable to effect an adjustment of permanent nature in the normal temperature of the steam being generated, the desired results may be accomplished readily by altering the ratio or proportion of water tubes and steam superheating tubes in one or both of the end division walls A and E. If the steam temperature is to be lowered, it is merely necessary to remove one or more of the superheater tubes **81** from the division wall and to substitute water tubes **66** for them. Conversely, to increase the steam temperature, water tubes may be removed and superheater tubes substituted. This adjustment may be made conveniently, with the furnace shut down, since the tubes in the division walls are interchangeable and are readily accessible, the various headers being so positioned as to permit substitution of superheater tubes for water tubes or vice versa without difficulty.

In a steam generating unit constructed in accordance with my invention, the danger of overheating the radiant superheater tubes before sufficient steam is generated to pass through them is obviated by first starting the fuel burners **21** positioned between the division walls B and C and between the division walls C and D. Since these division walls contain only water circulating tubes they are capable of immediately absorbing the heat from the burners without injury. After sufficient steam has been generated by operating the burners in the central sections of the furnace to provide a flow of steam through the superheater tubes, the burners in the end sections may be started and the final steam temperature regulated by adjusting the various burners as previously described. After one or more of the burners have been lighted it is not necessary to light the subsequently started burners independently since the flames from one burner will pass between the tubes of the division walls and ignite the coal introduced through the adjacent burners.

An additional advantage of the sectionalized furnace resides in the fact that different grades of fuel requiring different combustion conditions may be burned in separate sections of the furnace simultaneously by suitably adjusting the fuel feeders **23**, the primary air valves **26** and the secondary air dampers **29** individually in each section to effect the conditions most favorable to the combustion of the particular fuel being fed to that section.

Another important advantage of the sectional arrangement in the furnace is that when operating at low loads some of the burners may be turned off entirely and the load carried by the burners in only one or two of the sections. Since each section is in effect a small independent furnace, any one or more of the sections may be operated efficiently as a generating unit of reduced capacity. As the effective heat absorbing area is correspondingly reduced because the radiant heat reaches only the adjacent division walls, the necessary furnace temperature is maintained, the hot gases of combustion spreading in the back of the combustion chamber and flowing uniformly into the boiler tube banks. By operating individual sections of the furnace in this manner, it is possible to avoid the necessity of shutting down a large furnace and starting a smaller one in order to maintain efficient operation at low loads.

The particular arrangement of apparatus set forth in the foregoing description is but one of many possible combinations which may be utilized in practicing my invention under various conditions of steam requirements and of load variations. Obviously, the invention may be embodied in steam generating units of various other types with equally advantageous results. For example, the steam generating unit shown in Figs. 4 to 7 inclusive, as another embodiment of my invention, differs somewhat in arrangement from the apparatus shown in Figs. 1 to 3 but incorporates the features constituting the principal aspects of the invention. In this ar-

rangement, the boiler is of the two-drum type and is disposed at the back of the furnace.

As shown, the furnace comprises an enclosed combustion chamber 100 into which fuel is projected by a plurality of spaced, vertically disposed burners 101, the burners being individually controlled in a manner similar to that described in connection with the burners 21 shown in Figs. 1 and 2. Secondary air is admitted from air boxes 102 at the front of the furnace under the control of individual dampers 103, the air moving horizontally through openings in the front wall of the furnace into the chamber 100 and carrying the flames from the burners 101 to the rear of the combustion chamber, as indicated by the arrows in Fig. 4, the combustion air flow to each section being under individual control.

At the rear of the combustion chamber, the hot gases resulting from combustion enter a bank of vertically disposed boiler tubes 104, through which water flows from a mud drum 105 near the bottom of the combustion chamber to a steam drum 106 near the top thereof, the gases having been guided upward by a baffle 107. Near the steam drum 106 the gases flow over the top of the baffle 107 and downward between it and a baffle 108 to a point near the mud drum 105 where they enter another bank of boiler tubes 109 also extending upward from the mud drum 105 to the steam drum 106. The gases are guided upward parallel with the tubes 109 between the baffle 108 and an outer baffle 110 constituting the rear wall of the furnace, and they are then discharged at the top of the boiler into a duct 111 leading to the stack.

As best shown in Figs. 6 and 7, the combustion chamber 100 is divided into five compartments or sections by vertically disposed division walls of heat absorbing tubes designated respectively H, I, J and K, the walls extending back toward the boiler tubes 104, sufficient space being provided beyond the ends of the walls to permit equalization of the gases flowing from the different furnace sections into the boiler.

Water for circulating upward through the water tubes of the division walls flows from the mud drum 105 through a plurality of tubes 115 into transverse headers 116, Figs. 4 and 7, each of which is joined at right angles to a header 117 disposed beneath each of the division walls. From each of the headers 117, water tubes 118 constituting part of the division wall heat absorbing elements extend upward to a header 119 disposed at the top of the wall and parallel with the corresponding lower header 117. Each of the upper headers 119 is connected to a transverse header 120 from which the water flows through a plurality of tubes 121 into the steam drum 106.

Steam generated in the water tubes of the boiler or of the division walls passes upward into the steam drum 106 from which it passes through tubes 124 into a header 125 and thence into the tubes of a convection type superheater 126 that is disposed between the baffle 107 and the baffle 108 in the path of the hot furnace gases flowing through the boiler. From the superheater 126 the steam flows into transverse headers 127 each of which is connected to a header 128 extending at right angles thereto and overlying the end division walls H and K respectively. From the headers 128 radiant superheating tubes 130 extend downward in the division walls H and K between the water tubes 118 thereof, and return upward therein to connect with headers 131 disposed above and parallel with the headers 128, the superheating tubes 130 constituting additional radiant heat absorbing elements in the division walls. From the headers 131 the steam flows through a plurality of tubes 132 to headers 133 disposed respectively at the ends of the furnace parallel with and adjacent to end walls 134 thereof. The headers 133 are each connected to a plurality of radiant superheating tubes 135 which extend downward along the inner side of each end wall 134 and return upward to connect to headers 136 disposed below and parallel with the headers 133. The radiant superheating tubes 135 constitute banks of heat absorbing elements that function to protect the end walls 134 from the intense heat of the combustion chamber. From the headers 136 steam may be conducted to a steam turbine or other steam consuming apparatus by pipes connected to flanges 137 at the ends of the headers 136.

By regulating the various fuel burners 101 in a manner to increase or to decrease the amount of fuel being consumed adjacent to the radiant superheater tube banks 135 on the end walls 134, and adjacent to the radiant superheater tubes 130 in the divisional walls H and K, the temperature of the steam being delivered from the discharge header 136 may be raised or lowered, as desired.

Since radiant superheating tubes will fail if overheated, it is necessary in order to successfully utilize them, that they be operated at relatively low heat transfer rates, hence high temperatures in the combustion chamber must be avoided. In a furnace constructed in accordance with my invention, the large total area of heat absorbing surface presented in the combustion chamber, together with the fact that the heat absorbing division walls are disposed in the zone of greatest heat liberation, result in sufficient heat being absorbed directly from the burning fuel particles to reduce the temperature in the combustion space below that at which the radiant superheater tubes might become overheated. Because of the high rate of heat absorption and the relatively low temperature in the combustion space, it becomes practical to utilize radiant superheating tubes in the heat absorbing division walls and in the banks of tubes at the ends of the combustion chamber, and to employ this arrangement of tubes in a furnace of very large capacity in which it would otherwise be impractical to use radiant superheating elements.

Another advantage resulting from the large heat absorbing capacity of the elements in the combustion space of a furnace constructed in accordance with my invention and the relatively low temperature therein, is that it becomes possible to utilize an improved water cooled ash receiving bottom in the combustion chamber and to employ an improved method of disposing of the ashes.

In the embodiment of the invention shown in Figs. 4, 6 and 7, the ashes remaining after combustion of the coal, descend in the combustion chamber onto a plurality of water cooled flat plates 140 constituting respectively the bottoms of the several furnace sections and forming a nearly continuous ash receiving surface for the bottom of the combustion chamber. As best shown in Figs. 4 and 6, the several plates 140 are supported upon and cooled by water circulating

tubes 141 extending from the back to the front of the furnace. The ashes falling upon the water cooled plates 140 give up their heat to the plates and are quickly cooled by them sufficiently to prevent fusing or clinkering of the ash. Particles of coal falling with the ashes are consumed before they become covered with ash, thereby insuring complete combustion of the fuel.

Before the ashes accumulate sufficiently to form a layer of such thickness as to insulate the plates 140 enough to interfere materially with the absorption of heat from additional ashes as they fall from the combustion chamber, the layer of ashes is removed from the plates by means of tools or preferably by soot-blowers 142 or the like. The soot-blowers may be operated to direct jets of steam or of air against the ashes periodically before they become hot enough to fuse, to blow them from the plates into intervening openings 143 through which they fall into the ash pit 144. The soot-blowers can be arranged to operate automatically to remove the ashes at predetermined intervals, if desired.

As shown in Fig. 6, the openings 143 are formed by spaces between the edges of adjacent plates 140 and they occur at the vertical division walls thereby providing passageways permitting ashes which accumulate on the walls to fall directly into the ash pit 144. The ash receiving plates 140 serve to shield the ash pit 144 from the heat of the combustion space, and the plates and supporting water circulating tubes 141 serve to absorb heat radiated upward from the ashes in the ash pit. This results in cooling the ashes to such extent that little heat is lost with them when they are removed and mechanical conveyors may be utilized to remove them from the ash pit without danger of the conveyors becoming over heated. For this purpose screw conveyors 145 may be installed as shown in Figs. 4 and 6, preferably beneath the openings 143 between adjacent bottom plates 140, where the greatest accumulation of ashes occurs. An ash receiving furnace bottom of this type is practicable only in a furnace in which the temperature is maintained relatively low. If the temperature were held still lower by directly absorbing a much larger amount of heat, it would be possible to dispense with the ash cooling elements altogether and to permit the ashes to fall directly into the ash pit. In that case a conventional furnace bottom might be used.

As shown in Fig. 4, the bottom plate supporting tubes 141 are connected at the rear of the furnace to the mud drum 105. From the drum 105, boiler water flows forward through the tubes 141 to a header 146, to which each of the tubes is connected, the header being disposed longitudinally of the furnace just below the secondary air boxes 102 at the front of the furnace. From the header 146 a bank of tubes 147 extends upwardly along the inner surface of the front wall 148 of the furnace, serving to shield the wall from the intense heat in the region of maximum combustion where the secondary air enters the combustion chamber and mixes with the fuel descending from the burners 101. At the top of the combustion chamber, the tubes 147 are curved inwardly and extend horizontally along the top of the chamber to the rear thereof where they connect with the steam drum 106.

According to a modification of the furnace bottom, shown in Fig. 5, the bottom plates 140 may be replaced by two banks of spaced screen tubes 151 disposed in staggered relationship. The screen tubes 151 serve to completely shield the ash pit 144 from radiant heat and yet they provide spaces through which the ashes may descend freely into the ash pit. To maintain high heat absorbing efficiency in the screen tubes 151, soot-blowers may be provided to dislodge ashes which may accumulate on or between them.

In another embodiment of my invention, shown in Figs. 8 and 9, the boiler portion of the steam generating unit is disposed above the furnace and the fuel is introduced into the furnace horizontally. As shown in Fig. 8, the furnace comprises an enclosed combustion chamber 160 into which the fuel in projected by means of a plurality of horizontally disposed burners 161 arranged in horizontally spaced relationship in the lower part of a front wall 162 of the furnace. The burners 161 may be generally similar to the previously described burners 21 and 101 and they are arranged to be individually adjustable in like manner, the secondary air being admitted through an air box 163 encircling each burner.

The flames from the burners 161 extend horizontally into the combustion chamber 160 and turn upwardly therein toward the boiler. The hot gases resulting from the combustion of the fuel enter a bank of boiler tubes 164 which extend generally upward from a mud drum 165 at the front of the furnace, the gases being guided parallel with the tubes by a vertically disposed baffle 166. At the top of the furnace, the boiler tubes 164 bend back inwardly and extend horizontally to a steam drum 167 at the rear of the furnace, the gases passing horizontally over a baffle 168 disposed beneath and extending parallel with the tubes, and then escaping upward through a duct 169 adjacent to the steam drum.

From the steam drum 167 the boiler water circulates downward through pipes 171 back of a rear wall 172 of the furnace, to a header 173 disposed horizontally at the rear of the bottom of the combustion chamber. From the header 173 a bank of tubes 174 extends upwardly along the inner surface of the rear wall 172, constituting a protecting screen shielding the rear wall from the flames projected from the burners 161. At the top of the combustion chamber 160, the tubes 174 are bent forwardly from the wall 172 and extend across the top of the chamber in two staggered rows, inclined slightly upwardly, to the mud drum 165.

As shown in Fig. 9, the combustion chamber 160 is divided into three compartments or sections by means of two vertically disposed division walls designated L and M. The division walls in this instance extend entirely across the combustion chamber from front to back and each is composed of both water tubes and superheater tubes disposed vertically and alternately arranged in the manner previously described.

Water for circulating upward through the water tubes of the division walls, flows from the lower header 173 forwardly through two transverse headers 175, joined at right angles thereto and disposed respectively beneath the division walls. Water tubes 176 in the division walls extend upwardly from the headers 175 to parallel headers 177 at the top of the combustion chamber which are connected directly to the mud drum 165.

The bottom of each section of the furnace is provided with an ash receiving plate 180, the plates being supported upon and cooled by horizontally disposed water tubes 181 which extend forward from the header 173 and turn upwardly

along the inner surface of the front furnace wall 162 to the mud drum 165. Ashes which accumulate on the plates 180 are blown from them by soot-blowers 182 through openings 183 between the edges of adjacent plates, into an ash pit 184.

Steam generated in the various water tubes of the furnace and the boiler, passes upward through the boiler tubes 164 into the steam drum 167 from which it passes through tubes 188 into a header 189 below the steam drum. From the header 189 the steam flows into tubes 190 of a convection type superheater disposed directly above the combustion chamber 160, beneath the horizontal baffle 168 and back of the vertical baffle 166. Hot gases from the combustion chamber flow upward between the superheater tubes 190 and pass through an opening 191 provided for them between the ends of the vertical baffle and the horizontal baffle, a plurality of dampers 192 being provided for regulating the gas flow through the superheater for effecting a controlling action upon the steam temperature. From the superheater tubes 190, the steam flows into a header 193 below the header 189, from which transverse headers 194 extend at right angles forwardly over the division walls. From the headers 194 the steam flows downward through radiant superheater tubes 195 in the division walls L and M, the tubes returning to headers 196 disposed beneath the headers 194 and connected to a discharge header 197 at the rear of the furnace.

Adjacent to each end wall 202, a header 203 extends forwardly from the header 193 to deliver steam from the convection superheater tubes 190 to radiant superheater tubes 204 extending downwardly along the inner surface of the end walls 202 and returning to headers 205 disposed beneath the headers 203 and likewise connected to the discharge header 197. From the discharge header 197 the steam may be conducted, through pipes connected to flanges 206 at the ends thereof, to the steam consuming apparatus.

The temperature of the steam supplied to the discharge header 197 may be regulated, in accordance with my invention, by adjusting the ratio of the fuel supplied by the middle burner between the division walls L and M, to that supplied by the end section burners between the division walls and the respective end walls. Since the banks of tubes at the end walls are made up entirely of superheater tubes, an increase in the amount of fuel burned adjacent to them tends to increase the steam temperature, and conversely a reduction in the amount of fuel consumed in the end sections tends to reduce the steam temperature. Many other variations in the arrangement and disposition of the parts of steam generating units constructed according to my invention may be made by persons skilled in this art. For example, the various divisional or sectionalizing walls in the combustion chamber may be adjusted individually to contain any desired ratio of superheating tubes and water tubes. Further, the divisional walls may be so positioned in the combustion chamber as to form furnace compartments or sections having different volumes to better adapt the furnace for meeting particular conditions of operation. Under other conditions, it may be desirable to connect the superheating elements in manner to provide several different stages of superheat. By this arrangement steam may be returned from the turbine several times for successive reheatings, the various superheating elements being individually controlled, in accordance with my invention, to provide the desired degree of steam temperature in each stage. By suitably rearranging the connecting piping, a boiler constructed in accordance with my invention may be utilized to heat two different fluids. For instance, the boiler and part of the superheaters may be used to evaporate mercury and to superheat it, respectively, while others of the superheating elements are used to superheat and to resuperheat steam supplied from other sources.

Other variations in the structure may be made to improve the efficiency of heat absorption under various particular conditions of operation. As the amount of heat radiating from the gases and burning fuel particles in a furnace depends largely upon the degree of concentration of the burning fuel particles, maximum heat absorption efficiency may be attained by absorbing heat from gas strata of different thicknesses in various parts of the combustion chamber. To this end, the division walls may be more closely spaced in the parts of the combustion chamber having the highest concentration of burning fuel particles, as indicated diagrammatically in Fig. 10. As there shown, a furnace having an enclosed combustion chamber 210 into which a plurality of burners 211 project fuel at spaced positions, is provided with heat absorbing division walls disposed respectively between each burner and the next adjacent burner, the walls being designated N, O, P, Q, R, S and T, respectively. By separating each burner from the adjacent burners in this manner by heat absorbing division walls, large amounts of heat are absorbed in the regions closely adjacent to the burners, since the burning fuel particles are highly concentrated in that part of the combustion chamber. However, as the flames move back into the combustion chamber, the amount of heat radiated from them decreases as the concentration of burning fuel particles decreases, and it is not necessary to provide as much heat absorbing surface as is required closer to the burners. For this reason, alternate division walls N, P, R and T are extended into the combustion chamber for only about one quarter of its width, the remaining walls O, Q and S being sufficient to absorb the heat from the burning fuel particles remaining in the flames that project beyond the ends of the short walls. Likewise, the walls O and S extend about one-half way across the combustion chamber, the middle wall Q, which extends about three-quarters of the width of the combustion chamber, and end wall tube banks 212 serving effectively to absorb the heat radiated from the fuel particles in the flames in the rear part of the combustion space.

As a further variation, the spacings of the tubes in the several division walls may be varied, as indicated by the division walls X, Y and Z shown in Fig. 11, from close spacings in the regions of high heat absorption adjacent to the burners, to wide spacings toward the rear of the furnace.

The numbers and width of the various walls and the spacings of the tubes in each wall may be so selected in any particular steam generating unit as to result in best heat absorbing efficiency, when taking into account the cost of the

tubes in the division walls, the kind of fuel to be burned, and other factors.

As another variation, the division walls may be formed of curved tubes as indicated in Fig. 12, the tubes being more widely spaced near the bottom of the combustion chamber than near the top thereof. The apparatus represented diagrammatically in Fig. 12 is generally similar to that shown in Fig. 1, with the exception of the division walls. In this variation, a series of tubes **215** forming the forward part of each division wall, are connected to the forward water header **54** from which they extend inwardly and thence substantially vertically to the header **69**. A second set of tubes **216** extend forwardly from the rear water header **53** and curve upwardly to the header **69**, conforming approximately with the paths of the flames from the burners **21**. By this arrangement of the tubes **215** and **216**, the division walls are made to conform in width approximately to the width of the flames as they descend from the burners. Consequently, the tubes are disposed in a manner to absorb the maximum amount of heat radiated from the burning fuel particles in the flames.

From the foregoing descriptions of the several embodiments of this invention and the explanation of the mode of operation thereof, it is evident that there has been provided a new and improved steam generating apparatus, utilizing a new method of generating steam, that is, capable of furnishing steam in large quantities and of predetermined quality, the arrangement being such that space is conserved yet highly efficient operation is effected at moderate furnace temperatures with entire freedom from fusion of ash and complete control of steam temperature.

Although specific embodiments of my invention have been shown and described in detail to illustrate operative apparatus functioning in accordance with the invention, it is to be understood that various other modified structures may be devised by those skilled in this art, in order to utilize the principles herein set forth, without departing from the spirit and scope of the invention as it is defined in the subjoined claims.

I claim as my invention:

1. A powdered fuel steam generating unit, comprising an enclosure constituting a combustion chamber, a boiler including water tubes disposed to be heated by hot gases flowing from said combustion chamber, a plurality of fuel burners disposed to project powdered fuel into said combustion chamber at spaced positions, water tubes and superheater tubes connected to said boiler and disposed within said combustion chamber between the regions of greatest heat liberation occurring from the combustion of fuel projected from said burners, said tubes being capable of absorbing sufficient heat to maintain the temperature within said combustion chamber below that at which the ash resulting from combustion of said fuel fuses, an ash cooling bottom for said combustion chamber including a member presenting a flat substantially horizontal surface disposed to receive ashes falling within said combustion chamber, means for cooling said member to cool the ashes accumulating thereon, and means for removing the ashes from said ash receiving surface at intervals to prevent them from accumulating to sufficient thickness to interfere with the cooling action of said cooling member.

2. A steam generating apparatus, comprising a furnace constituting a combustion space, a boiler having convection water heating surfaces exposed to hot gases from said combustion space, division walls having radiant water heating surfaces and division walls having radiant steam superheating surfaces disposed within said combustion space, fuel burners in said combustion space providing heat for said convection water heating surfaces and including a burner disposed to provide radiant heat to one of said division walls having radiant water heating surfaces and a burner disposed to provide radiant heat to one of said division walls having radiant steam superheating surfaces, and means for regulating each of said burners to adjust the proportion of radiant heat absorbed by said water heating surface and by said steam superheating surface to thereby control the temperature of the steam delivered by said generating apparatus.

3. A steam generating unit having a combustion chamber dividing wall including both water heating tubes and steam superheating tubes exposed at both sides to radiant heat, said tubes being interchangeable in such manner that substituting tubes of one type for tubes of the other type in said wall to change the ratio of the water tubes to the superheating tubes will effect regulation of the temperature of the generated steam.

4. A furnace for burning powdered fuel to generate steam, comprising a housing constituting a combustion chamber, a plurality of fuel burners projecting into said combustion chamber, and a dividing wall composed of alternately arranged water tubes and superheater tubes disposed between two of said fuel burners within said combustion chamber.

5. In a steam generating unit, the combination with a combustion chamber, of heat absorbing walls disposed to divide said combustion chamber into compartments, said walls being formed by superheating tubes and water heating tubes, said superheating tubes being supported by said water heating tubes.

6. A steam generating unit comprising a boiler, a combustion chamber disposed to heat said boiler, water heating tubes connected to said boiler, and steam superheating tubes connected to receive steam from said boiler, said tubes being positioned vertically within said combustion chamber in manner to constitute a division wall therein with both sides thereof exposed to heat radiated from fuel burning in said chamber.

7. A steam generating unit comprising a boiler, a combustion chamber disposed to burn fuel for supplying heat to said boiler, steam superheating tubes positioned vertically within said combustion chamber in manner to present both sides thereof to heat radiated from fuel burning in said chamber, said tubes being connected to receive steam from said boiler for superheating, and water heating tubes for said boiler disposed in said combustion chamber adjacent to said superheating tubes and operatively secured thereto for supporting said superheating tubes in manner to prevent injurious distortion or warping thereof.

8. In a steam generating unit, the combination with a combustion chamber for the burning of fuel and a plurality of steam superheating tubes positioned vertically within said combustion chamber in manner to present both sides thereof to heat radiated from fuel burning in said chamber, of a plurality of water heating tubes suspended parallel with and adjacent to said super-

heating tubes, and means carried by said water tubes to engage and support said superheating tubes in manner to prevent distortion of said superheating tubes by the heat of the furnace.

9. A furnace for generating steam in large quantities by the combustion of fuel in suspension, comprising a large unitary combustion chamber, a plurality of fuel burners disposed to project fuel downward into the forward portion of said combustion chamber for burning in suspension in spaced regions of maximum heat liberation from which flames extend rearwardly to intermingle and turn upward in the rear portion of said chamber, convection heat absorbing elements disposed above the rear portion of said chamber in position to be heated by hot gases flowing therefrom, and radiant heat absorbing elements positioned vertically within the forward portion only of said chamber between said spaced regions of maximum heat liberation to form walls defining rearwardly opening compartments, said radiant heat absorbing elements serving to absorb sufficient heat from said regions of maximum heat liberation to reduce the temperature of the products of combustion below that at which ashes therein will fuse and adhere to said convection heat absorbing elements, the flames from said burning fuel turning rearwardly out of said open compartments at vertical positions depending upon the rate of combustion of said fuel, whereby the temperature reduction may be accomplished without interfering with the completion of the combustion process in the rear portion of said chamber.

10. A boiler furnace having a horizontally disposed top covering a part thereof, a boiler structure disposed over the remainder of said furnace, a plurality of pulverized coal burners in said furnace top adapted to project burning fuel downward into said furnace, and rows of vertically disposed heat absorbing tubes arranged in that portion of the furnace beneath said top and positioned to constitute dividing walls between adjacent burners defining open-sided compartments communicating rearwardly with the undivided part of said furnace, the arrangement being such that flames from said burners pass downward between said dividing walls of tubes and then outward through the rearwardly opening sides of said compartments into the undivided part of said furnace the products of combustion then flowing upward into said boiler.

11. A steam generating unit, comprising an enclosure constituting a combustion chamber, a boiler including water tubes disposed to be heated by hot gases flowing from said combustion chamber, a plurality of burners disposed to project fuel into said combustion chamber at spaced positions, heat absorbing tubes disposed within said combustion chamber in manner to constitute dividing walls between the regions of greatest heat liberation resulting from the combustion of fuel projected from said burners, said tubes functioning to absorb sufficient heat to maintain the temperature within said combustion chamber below that at which the ashes resulting from combustion of said fuel would fuse sufficiently to adhere to said boiler water tubes, an ash cooling bottom for said combustion chamber including a member presenting a flat substantially horizontal surface disposed to extend between two of said dividing walls with its edges in spaced relation therewith and serving to receive ashes falling from said combustion chamber, means for cooling said ash receiving member to cool the ashes accumulating thereon, and means for removing accumulated ashes from said ash receiving surface into the spaces at the edges of said member adjacent said dividing walls at intervals to prevent the accumulation of a sufficient thickness of ashes to interfere with the cooling action of said cooling member.

12. A boiler furnace having its front and rear walls protected by heat absorbing tubes, steam superheating tubes disposed on and protecting the end walls of said furnace, a plurality of division walls formed by interspersed water tubes and superheating tubes said walls being disposed transversely of said furnace and extending from the front wall thereof rearwardly parallel with and adjacent to said end walls, other division walls formed by water tubes disposed between and parallel with said superheating walls, a plurality of burners adapted to project burning fuel into said furnace between said various parallel walls, a boiler disposed to be heated by the products of combustion from said furnace and arranged to supply steam to said superheater tubes, and means to adjust said burners individually, whereby the degree of superheat of the steam may be regulated by changing the proportion of the fuel burned adjacent to said superheater tubes to that burned adjacent to said water tubes.

13. A boiler furnace having its end walls protected by steam superheating tubes, a plurality of division walls formed partly by superheating tubes extending rearwardly from the front of said furnace and parallel with said end walls, and a plurality of burners disposed to project burning fuel into said furnace between said parallel walls.

14. In a furnace for generating steam, an enclosure constituting a combustion chamber, heat absorbing walls disposed within said chamber in manner to divide it into compartments, and steam superheating tubes carried by and constituting part of said heat absorbing dividing walls.

15. In a furnace for generating steam, an enclosure constituting a combustion chamber, a plurality of fuel burners projecting into said combustion chamber, and heat absorbing walls disposed between said burners to divide said combustion chamber into compartments, said walls comprising both water heating tubes and steam superheating tubes arranged to be interchangeable, whereby adjustment of the quality of the steam generated may be effected by substituting tubes of one type for those of the other type.

16. A boiler furnace for generating steam, comprising a combustion chamber partly subdivided into open-sided sections by radiant heat absorbing elements having different effects respectively upon the steam being generated, means for introducing and burning fuel in said sections in such manner that flames emanating from the open sides of said sections intermingle and equalize in the undivided part of said combustion chamber, means for introducing auxiliary air into each of said sections, means for regulating the admission of said auxiliary air into each section to change the position of the flames therein relative to said radiant heat absorbing elements, and means for absorbing convection heat from hot gases flowing from said combustion chamber after the completion of the combustion process, whereby the quality of the steam being generated may be regulated and the temperature of the gases flowing from said combustion chamber may be reduced below that at which ashes carried thereby would fuse and adhere to said convection heat absorbing means, said temperature redu-

tion being effected by the rapid absorption of radiant heat in said sections and said quality regulation being effected by changing the positions of the flames relative to said radiant heat absorbing elements, both without detriment to the combustion process which is completed in the undivided part of said combustion chamber.

17. A boiler furnace comprising a plurality of open-sided combustion chamber sections lined with radiant heat absorbing elements, means for admitting burning fuel and air to each of said sections, a main combustion chamber communicating with said sections for receiving burning fuel emanating therefrom, said chamber being arranged to facilitate completion of the combustion process, means for regulating the admission of air into each of said sections to control the positions at which the flames pass from the open sides thereof into said main combustion chamber, and a boiler disposed to be heated by the products of combustion flowing from said main combustion chamber.

18. The method of operating a furnace for generating steam in large quantities by the combustion of powdered fuel, that comprises introducing said fuel into a single relatively large combustion space at a plurality of spaced positions for burning in suspension, absorbing radiant heat from said burning fuel at positions between the regions of greatest heat liberation adjacent to said fuel introducing positions by heat absorbing elements having predetermined effects upon the steam being generated, regulating the introduction of auxiliary air to change the positions at which said fuel burns relative to said heat absorbing elements for regulating the quality of the steam being generated, intermingling the flames emanating from said fuel introducing positions after they pass beyond said radiant heat absorbing positions to equalize them for completing the combustion of said fuel, and then absorbing convection heat from the resulting hot gases after the combustion process has been completed.

19. A boiler furnace for generating steam, comprising a combustion chamber partly subdivided into open-sided sections by radiant heat absorbing elements having predetermined effects upon the steam being generated, other heat absorbing elements associated with the undivided part of said combustion chamber and having other effects upon the steam being generated, means for introducing fuel into said sections for burning therein in manner to cause flames to emanate from the open sides thereof and intermingle in the undivided part of said combustion chamber, means for introducing auxiliary air into said sections, and means for regulating the flow of said auxiliary air into each section to adjust the position at which the flames therein emanate from the open side thereof for controlling the effect of said flames upon said subdividing heat absorbing elements, whereby the quality of the steam being generated may be regulated.

20. A boiler furnace for generating steam, comprising a combustion chamber partly subdivided by radiant heat absorbing elements into open-sided sections each communicating with an undivided part of said chamber, means for introducing fuel into the tops of said sections for burning therein in manner to cause flames to emanate from the open sides thereof and intermingle and equalize in the undivided part of said combustion chamber, means for introducing auxiliary air into said sections, and means for adjusting the flow of auxiliary air into each section in manner to control the position of the flames therein relative to said radiant heat absorbing elements, whereby the quality of the steam being generated may be regulated.

21. In a steam generating unit, a boiler, a combustion chamber associated with said boiler, a plurality of heat absorbing division walls disposed vertically within said combustion chamber in position to divide part of said chamber into compartments, said compartments opening at their sides into an undivided part of said chamber, other heat absorbing elements associated with said combustion chamber, said heat absorbing elements having different effects respectively upon the steam being generated, a fuel burner disposed to project fuel into the top of each of said compartments for burning therein the flames from said burners extending from the open sides of said compartments into said undivided part of said chamber, auxiliary air inlets disposed to project auxiliary air into said compartments in direction transverse to said burner flames, and means to control the flow of said auxiliary air into each compartment to regulate the position of said flames therein for altering the heating effect thereof upon said various heat absorbing elements.

22. In a steam generating unit, a combustion chamber, a plurality of vertically disposed heat absorbing walls arranged to divide said chamber into compartments, a flat plate extending horizontally across the bottom of each of said compartments between and spaced from said dividing walls for collecting ashes falling within said compartment, means to cool said plates, and means to remove ashes from each of said plates into the space between each edge thereof and the adjacent dividing wall.

23. In a steam generating unit, a combustion chamber, a plurality of parallelly disposed dividing walls in said chamber formed by vertically disposed heat absorbing tubes, means to introduce and burn powdered fuel between said dividing walls, a flat member presenting a horizontal surface disposed to receive ash particles falling between each pair of said dividing walls, said flat members being disposed with the edges thereof spaced from the tubes of the adjacent walls, means for cooling said flat members to cool the ash particles falling thereon, and means for moving the accumulating ashes from said flat members toward said walls to discharge them through the spaces adjacent to said tubes.

24. A dividing wall for a steam generating furnace, comprising a plurality of vertically disposed water circulating tubes arranged in spaced relationship, a steam superheating tube disposed at each side of each of said water circulating tubes, and means securing said superheating tubes to said water tubes, whereby each of said water tubes serves to support two of said superheating tubes against warping.

25. In a steam generating unit, the combination with a combustion chamber, of a heat absorbing wall disposed to divide said combustion chamber into compartments, said wall being formed by vertically disposed water heating tubes spaced apart and supported at their upper and lower ends, and looped steam superheating tubes disposed between said spaced water heating tubes and associated therewith in manner to receive support therefrom against warping.

26. In a steam generating unit, the combination with a combustion chamber for burning fuel,

of a plurality of looped superheating tubes disposed in vertical position within said combustion chamber in manner to present both sides thereof to heat radiated from fuel burning in said chamber, a plurality of water heating tubes disposed vertically within said chamber between and parallel with said looped superheating tubes, and means mechanically connecting said water heating tubes to said superheating tube loops in manner to support said superheating tubes to prevent distortion thereof by the heat of the furnace.

27. A steam generating unit comprising a boiler, a combustion chamber associated with said boiler, spaced pairs of steam superheating tubes disposed vertically within said combustion chamber in position to present both sides thereof to heat radiated from fuel burning in said chamber, and water heating tubes disposed vertically within said combustion chamber between said spaced pairs of superheating tubes, each water heating tube being operatively connected at each side to a superheating tube for supporting said tubes in manner to prevent distortion thereof by the heat in said combustion chamber.

28. In a steam generating unit having a combustion chamber for burning fuel, a dividing wall disposed to divide said chamber into compartments, said wall being formed by vertically disposed water circulating tubes and steam superheating tubes arranged alternately, said water heating tubes being supported only at their ends and serving to support said steam superheating tubes at intervals throughout their lengths.

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