

June 28, 1966

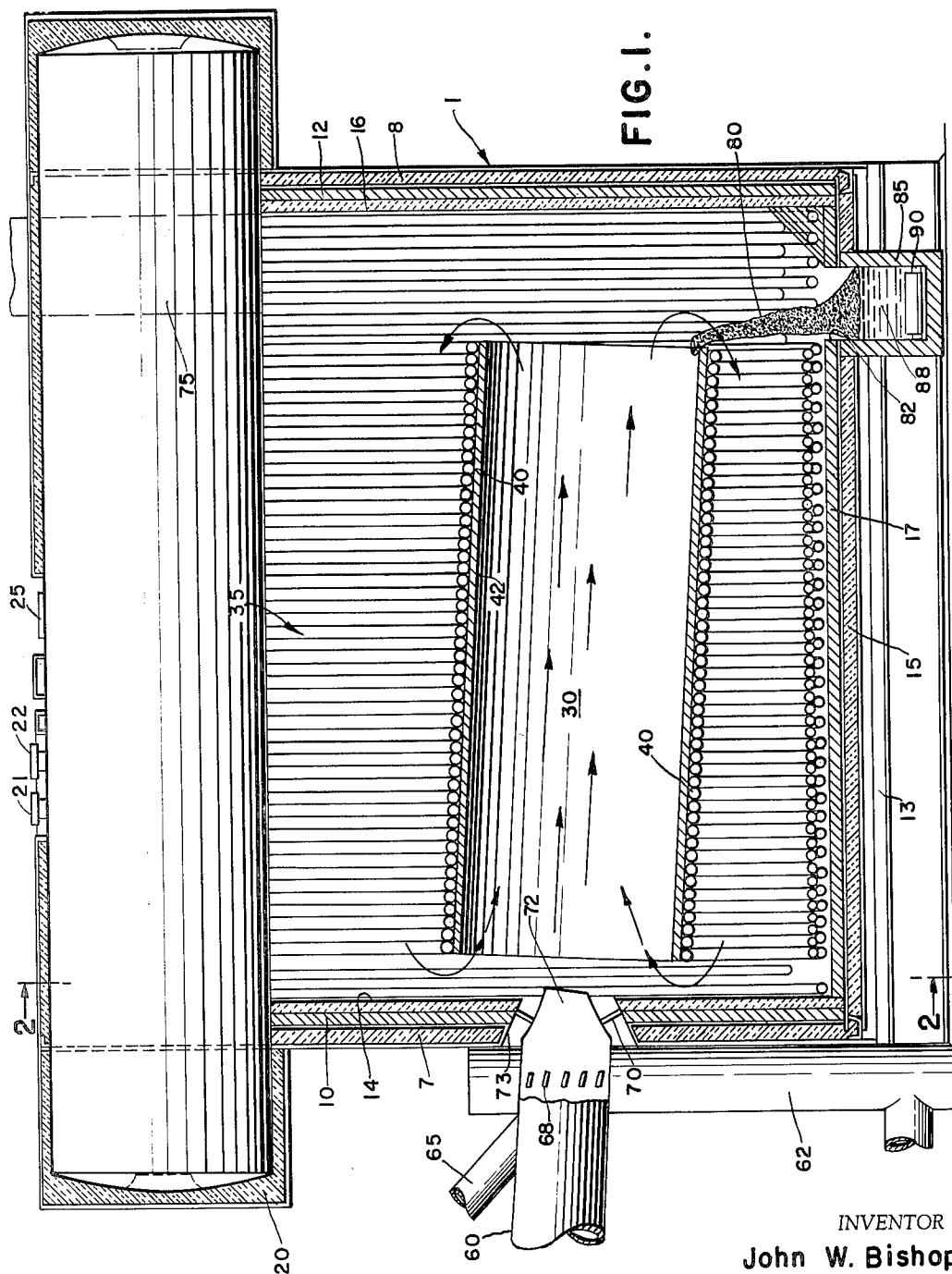
J. W. BISHOP

3,257,992

COAL BURNING WATER TUBE STEAM GENERATOR CONSTRUCTION EMBODYING
INTEGRAL PRIMARY COAL SLAGGING TYPE FURNACE AND
SECONDARY FURNACE

Filed May 28, 1964

4 Sheets-Sheet 1



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4 Sheets-Sheet 2

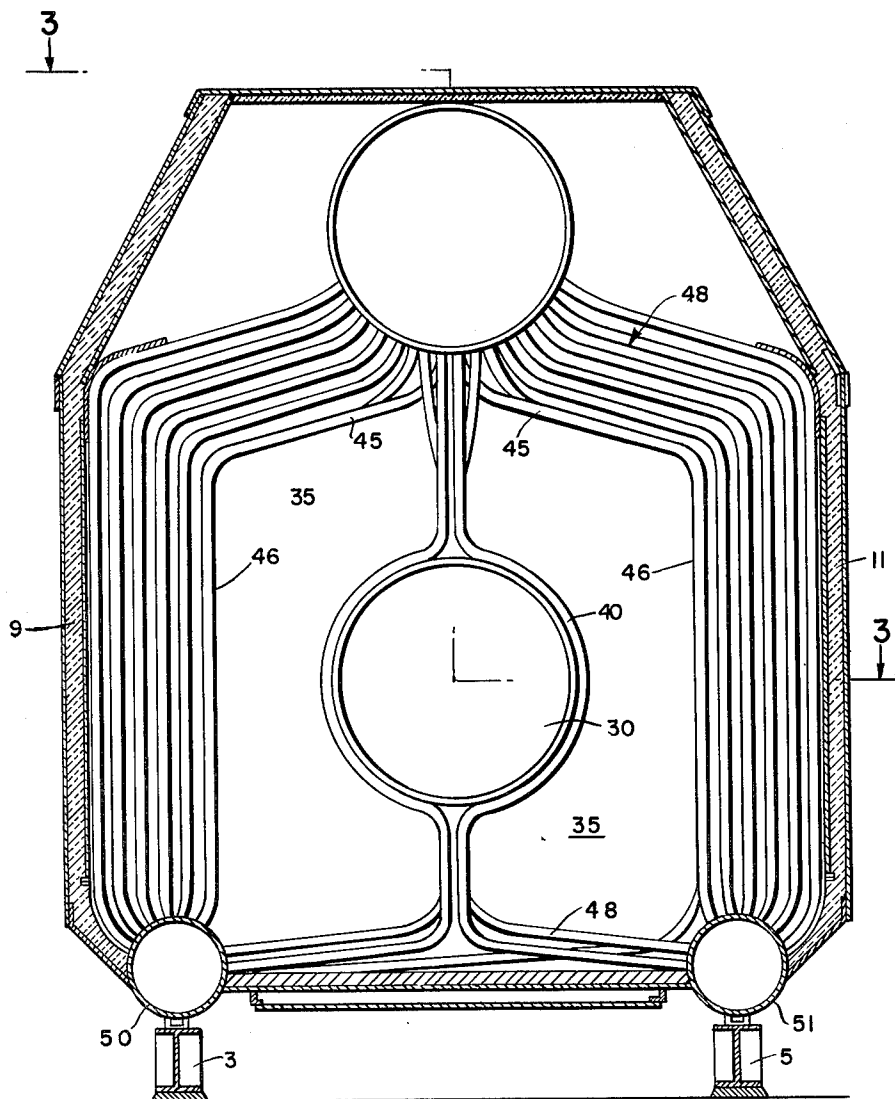


FIG. 2.

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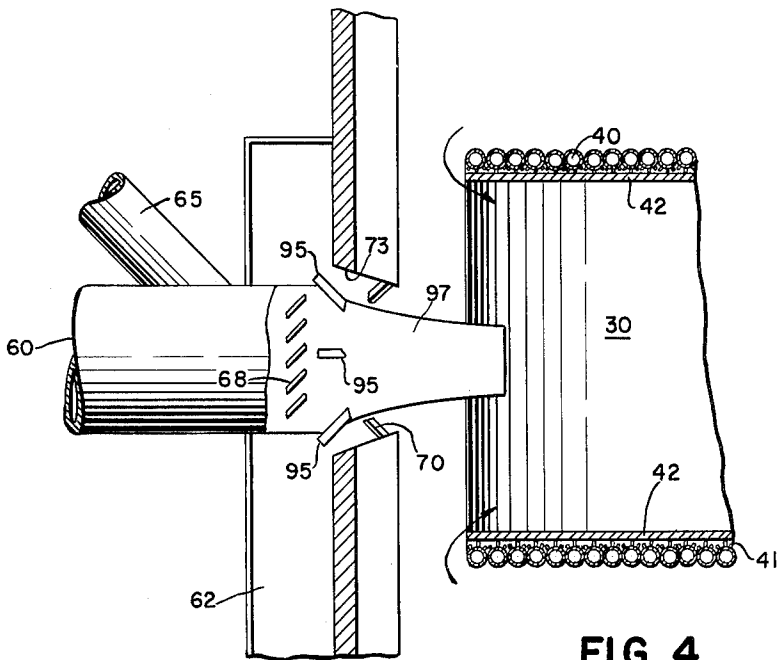


FIG. 4.

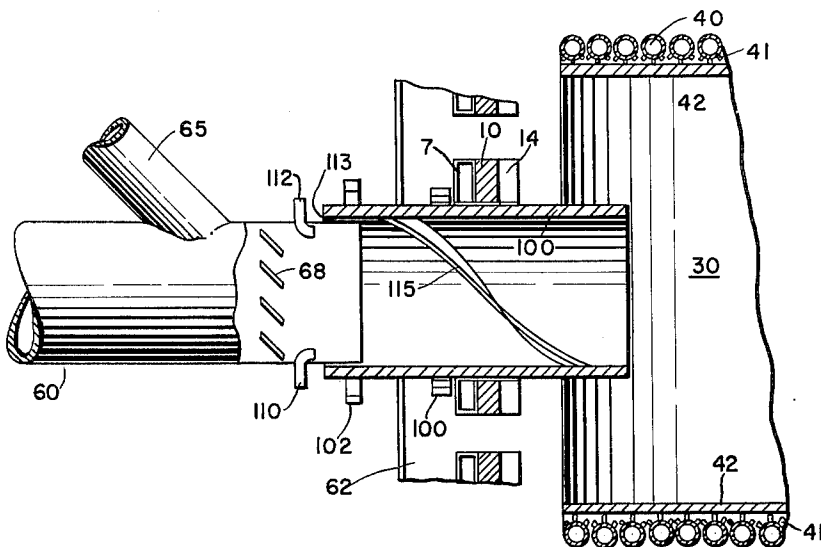


FIG. 5.

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COAL BURNING WATER TUBE STEAM GENERATOR CONSTRUCTION EMBODYING INTEGRAL PRIMARY COAL SLAGGING TYPE FURNACE AND SECONDARY FURNACE

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Filed May 28, 1964, Ser. No. 370,990

10 Claims. (Cl. 122—328)

This invention relates to a new and improved method of generating steam with coal fuel. More particularly, the invention is directed to a novel arrangement of elements that render this type of assembly most adaptable to high capacity rail, truck and barge transportable steam generating units in a single assembled package, thus eliminating the need for the on-site assembly and erection of the involved components.

As prefatory to a more particularized description of my invention, the same involves substantial departures over the known prior art. A basic advance underlying the involved concept lies in the use of a high-heat release, internally lined, erosion inhibiting, indirect combustion gas-to-tube heat transfer; also the basic improvement revolves about a slagging type, water cooled primary furnace which is disposed entirely within the confines of a water cooled secondary furnace. Coal and primary combustion air are introduced into the primary furnace in such manner as to induce a flow of secondary air, and also, to effectively recirculate the combustion products through both primary and secondary units.

Such a novel system permits radiant heat transfer, by means of indirect combustion gas contact, to take place over the entire internal primary furnace surface. The system thus provides for a longer path of primary gas and coal travel. It further renders possible a construction wherein such a primary coal burning slagging type furnace lies entirely within the confines of a completely unitized, packaged boiler. The latter, which can be prefatory assembled, also employs the entire external surface of said primary furnace for heat transfer from the secondary furnace.

It is further important to note that the ash formed as the result of the combustion process is rendered molten due to the relatively high temperature produced by the unit; this ash, in molten form, is removed from the combustion gas stream, quenched and conveyed by a suitable conveyor arrangement to a point exterior of the unit. The result is that combustion gases passed into the secondary furnace are consequently returned relatively ash free, thus reducing the ash deposits normally present in the common type of boiler designs utilizing conventional convection banks of tubing.

It is of course acknowledged that boiler arrangements of various types constructed with primary and secondary type furnaces are well known to the prior art. However, such known types of units are more generally than not burdened with structural features that render them too expensive to compete with furnace-boiler arrangements which burn fuels other than coal. This is particularly true with respect to those steaming capacity ranges where oil and gas fired boilers can now be compactly and inexpensively made, factory assembled, and shipped as a unit. Also, where coal fired boilers, under the present state of the art, must be constructed in much larger proportions, such cannot be shipped as "packaged units." These larger, and typical, installations must be field erected, and hence generally cost many times as much as oil and gas fired boilers, in similar size ranges, particularly in boilers generating steam in capacity ranges of from about 50,000 to 120,000 pounds per hour.

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It is also recognized that there exist known devices which are directed to the use of circular water-cooled combustion chambers that lie partially within the furnace and which partially form the outer envelope of the boiler. But these arrangements are particularly suited to the burning of only fluid fuels, such as oil or gas. Conversely, these assemblies are completely unsuitable for the burning of a solid, ash bearing fuel such as coal. One such system is described in the patent to McNeal, No. 3,107,656.

It is significant, also typical of such arrangements, that the construction of the combustion chamber of the cited patent is one, and as particularly defined in the claims thereof, wherein each tube is "in direct contact with combustion gases passing through said chamber." In contrast, in the coal fired slagging type furnace to which the instant invention appertains, the erosive effect of the solid fuel and the ash is such as to preclude the use of direct flame contact with the combustion gases and tubes.

My invention accordingly requires the use of an indirect heat transfer surface from the burning coal-air mixture to the tubes via a heat-conductive castable material which is replaceable. The result, inter alia, is to achieve a materially extended tube life for the tubes of both primary and secondary units.

Reference is also made in the cited patent to a horizontally arranged diverging-converging fuel ignition chamber. This, if employed in conjunction with a solid ash bearing fuel, such as coal, would entrap and solidify the ash. Under the basic concept of my invention, the ash is maintained in a molten state and conveniently discharged by the inclining of the cylindrical furnace to the rear.

Also, the high heat release requirement for coal firing in the slagging type of furnace comprising this invention dictates the use of a tangential tube construction, involving adjacent and contacting tube placement. Such further distinguishes the instant reference over prior art similar to that mentioned in the foregoing paragraph.

It is also of significance that my invention utilizes the entire exterior periphery of the tangentially disposed primary furnace tubes as a heat absorbing surface. In contradistinction, previous devices are directed to constructions wherein a substantial part of the outer periphery of the involved tubes are uncovered. Along with this difference it should be emphasized that the primary furnace of my invention is entirely within the confines of the secondary, encircling furnace, and as shown in the drawings referred to hereafter, the primary unit does not form any extremity of either the boiler, or the secondary furnace sides, as top or bottom, and is the case, for example, in the patent referred to in the foregoing. In fact, the extremely high (in the million B.t.u.'s per cubic foot range) heat release in the primary slag-furnace precludes its use to form a portion of the boiler exterior wall, roof or floor construction, without requiring either excessive quantities of refractory and insulating materials, or, and just as disadvantageous, resulting in overheating the boiler casing.

The present unavailability of inexpensive coal fired steam generating equipment has not only caused a marked reduction in the market for coal, but has also contributed to a serious economic condition in the coal producing areas due to resulting unemployment. While representing an improvement in the art of coal fired steam generation, it is also a resultant objective of this invention to increase the market for coal and help to alleviate the present economic depression in coal producing areas.

A primary objective of my invention is thus to provide a primary coal-fired slagging furnace which is completely within the confines of the boiler-casing proper. This eliminates the external primary furnace, which in current

slagging primary furnace designs, extends out from the envelope encasing the secondary furnace and boiler of present and past designs. It also eliminates the need for insulating such primary furnace and in addition, excludes the necessity of a casing therefor, as is necessary with respect to the exterior type of primary furnace known to the art.

An additional objective of the invention is the provision of a unit of the described type wherein the primary coal fired slagging furnace not only comprises an integral part of the boiler circulatory system, yet, as indicated, is positioned within the confines of the boiler envelope. Construction of the system of my invention therefore requires but a single, integrated operation, and does not demand a complex and time consuming assembly of many components, as is ordinarily necessary. The furnace of this invention thereby lends itself to complete pre-factory erection and assembly of such coal-fired steam generating units prior to shipment.

Another object of my invention is to provide, in a boiler embodying the use of an integral primary coal fired slagging furnace, such as generally defined in the foregoing, a unique system of recirculating the products of combustion in such manner as to provide a high temperature environment for combustion, hence to reduce or eliminate excess oxygen requirements.

Another objective of the invention is the provision of apparatus such as generally referred to in the foregoing which contemplates the fusing of the resultant ash, reducing same to a molten state. In addition, means are provided to efficiently remove this molten residue from the furnace proper.

As another purpose of the invention I have provided a unique assembly obtaining, in this same sense, efficient ash removal by reason of the fact that the so-called primary furnace is slanted and lacks the convergent-divergent area where the slag might otherwise be retained or built up to that extent to cause undesirable clogging.

A further object of the invention is to provide an assembly wherein the involved tubes of the primary furnace are so insulated as to prevent excessive corrosion or erosion at the extremely high temperatures which are involved. This is achieved by providing, for example, a chrome ore lining for the primary furnace and also by placing the tubes in tangential relationship with each other so as to form a continuous wall.

Additional and further objects of the invention include the provision of improved types of means for the feed in of the coal-air mixture. In one alternate this takes the form of a primary air and coal injection nozzle wherein the inner periphery of such primary air duct is provided with a plurality of inclined vanes, such that the primary air is caused to be rotated or circulated in rotary fashion; the secondary air outlet, surrounding the primary air injection nozzle, is also provided with a series of spaced vanes, also angled in that direction as to cause rotary travel of the secondary air in the same direction as that of the primary air-coal mixture. This results in a whirling form of agitation assuring complete admixture of the coal fines with the primary-secondary medium supporting combustion. Again, I have provided an alternate type of injection means wherein the same type of angled vanes (with respect to both the primary air duct as well as the secondary air duct) are utilized, but additionally, a series of water injection nozzles are employed; these are located intermediate the vanes in the primary duct and those externally of the nozzle which are adapted to provide rotary circulation, as stated, of the secondary air. By this media, the nozzle is kept reasonably cool despite extremely high temperature rates. And finally, a third variant includes means for rotation of the primary air injection nozzle. If desirable, such rotatable nozzle is also provided with an impeller formation, further thrusting the air coal mixture outwardly into the primary

furnace. In this modification, in addition, water nozzles are used to cool down, as in the former instance, the primary air, rotatable, injection nozzle.

Additional and further objectives and advantages of my invention will become apparent from consideration of the following more detailed description thereof, having particular reference to the several accompanying drawings, wherein:

FIGURE 1 is a vertical section view of one embodiment of my invention illustrating one manner of constructing the integrally contained primary coal-fired furnace completely within the secondary furnace of the boiler;

FIGURE 2 is a vertical section view taken on line 2—2 of FIGURE 1;

FIGURE 3 is a plan section view taken on the line 3—3 of FIGURE 2;

FIGURE 4 is an alternate type of water-cooled primary air-coal nozzle arrangement; and

FIGURE 5 represents a further embodiment of the primary air-coal nozzle arrangement, also water cooled, wherein suitable means are provided to rotate the latter, thus additionally forcing the coal and primary-secondary air to be discharged into the furnace in rotary, circulatory fashion.

Referring more particularly to FIGURE 1 of these various views, the general arrangement of the assembly is here depicted in cross section. The furnace itself is generally indicated at 1. As here shown, the entire unit is raised from the floor, being supported upon H-angle iron stanchions 3 and 5. The furnace is of course provided with the usual end walls 7 and 8, and side walls 9 and 11 (FIGURE 2). All walls are of course constructed of refractory material (i.e. the usual silica refractory compositions), and as shown in this version of the invention the end walls are comprised, in a sense, of several laminations of such material including on the one hand intermediate wall 10 and side wall 14 and, on the other hand, intermediate wall 12 and inner wall 16. As shown in FIGURE 3, the intermediate walls in each instance, 10 and 12, may be suitably reinforced, as indicated.

Such structure is of course typical, following the usual method of fabrication of refractory furnace walls adapted to withstand the high temperatures encountered in such cases.

The coal fired furnace is of course provided with the usual base members 13 (FIGURE 1), above which is disposed a similar refractory lining as indicated at 15 and 17.

This walled enclosure, as it has just been described, is surmounted by a steam drum 20. The latter is provided with the usual steam valve connections 21 and 22 and of course, among other basic elements of the design, the steam drum is necessarily fitted with the usual steam connection 25.

As indicated in the foregoing, an essential concept of my invention revolves about the use of a primary furnace which is completely enclosed within the confines of a surrounding, enclosing, secondary furnace. The primary furnace 30, is thus disposed within such secondary furnace, generally indicated at 35. The primary furnace is slanted and in FIGURE 1, representing the preferred form of the invention, the angularity of such slant, from inlet to outlet, is in the order of from about 3° to about 6°. It is necessary that the primary furnace be tilted in this fashion, as stated above, since the temperatures reached within the primary furnace are sufficiently high to reduce the resultant coal ash to molten form. Such inclination of the primary furnace 30 consequently causes discharge of the molten material through the outby end of the primary furnace, as indicated in FIGURE 1.

Referring to FIGURE 2, it will be appreciated that the primary furnace consists essentially of a circular, heat castable element 42, around which are positioned the ad-

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jacent and tangentially disposed primary furnace tubes 40. As shown in, e.g., FIGURE 5, this tubular element 42 forms a protective, heat conductive liner separating the tubes 40 from direct contact with the resultant, high temperature flames of the combustion process. Such element 42 is fabricated of a suitable chrome alloy material, or any other appropriate material which is highly resistant to the corrosive or erosive effect of direct, high temperature flame contact, yet which is highly efficient with respect to its heat transfer properties.

The encircling tubes 40 which form a part of the primary furnace are affixed to tubular element 42 by suitable studs 41 (see FIGURE 5) which are welded or otherwise attached directly to the external surface of the tubular liner 42. Hence it is seen that upon discharge of the combustion products into the area 30 represented by the area enclosed by element 42, such do not directly contact the tubes themselves, the latter being protected from direct and erosive flame contact. However, such tubes 42 of the primary furnace efficiently absorb the heat, by conduction, induced in the element 42.

It also should be understood that although the primary furnace 30 is shown in the appended drawings, and in this embodiment of the invention described as being circular in configuration, such structure is not necessarily confined to this shape. Thus, with respect to a cross section of the configuration, it may, if desired, be elliptical, somewhat rectangular or any other shape conducive to efficiency of the combustion and heat transfer function of these related components.

Referring again to FIGURE 2, it will thus be seen that the general arrangement of the integral-to-the-boiler primary furnace 30 essentially comprises this referred to series of primary furnace tubes 40 which are connected at their upper ends with the steam drum 20, extend downwardly, are disposed tangentially to one another from top to bottom and particularly around the furnace liner 42, and finally, further continue downwardly and outwardly to extend to the two lower headers 50 and 51. They are suitably connected to the latter as by such conventional methods as rolling in or welding of the tubes 40 thereto. As previously indicated, the entire internal surface of the primary furnace consists of the flame resistant, tubular element 42 which is fabricated of a castable material that is not only heat conductive within boundaries of substantial efficiency but also is, to all practical purposes, resistant to erosion or deterioration consequent upon high temperature flame contact.

There are two sources of air supply—primary and secondary. Primary air is admitted through line 60 and secondary air through conduit 62. Depending upon certain variables within the skill of the art, the primary and secondary air pressures are correlated to achieve maximum efficiency. Both primary and secondary air supplies may be obtained from suitable air pressure sources, not shown, and the fact that the primary air supply structure is positioned within the secondary air discharge point, or adjacent thereto, may result in a Venturi effect, the function of which will be to induce flow of air through conduit 60 without the involved secondary air being under substantial, or any, inby pressure.

At any rate, coal is admitted through the conduit 65. Such coal may take the form of coal fines or coal of such relatively fine mesh that it becomes readily air-borne or entrained in the flow of air through conduit 60, and, when subjected to the additional substantial turbulence created by the secondary air flow, becomes intimately intermixed with these respective air supplies. The result of such intimate admixture (the coal-air mixture) is to render such air-borne fines subject to immediate, effective and high temperature combustion.

This desideratum of complete admixture of the combustible material and the combustion supporting medium is achieved by a double series of vanes which cause the air-coal stream to achieve a swirling motion. Certain

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of these vanes, indicated at 68, are mounted in spaced and fixed relationship with respect to each other about the inner periphery of the conduit 60. They are angled to the same degree, also as shown, so that primary air forced through the conduit 60 is caused to rotate circularly within such conduit. Such primary air is then emitted, still swirling in rotary fashion, through the nozzle 72, appropriately mounted through a suitable aperture 73 formed in the end wall and comprising the series of laminations of refractory material represented by numerals 7, 10 and 14.

In addition, another series of vanes 70 (see FIGURE 4) are positioned, likewise in spaced relationship with respect to each other, between the nozzle 72, in which the conduit 60 terminates, and the inner wall of the aperture 73. These vanes 70 are also angled in that direction which will cause the secondary air to be rotated or swirled in the same direction as that of the swirling primary air.

It will of course be recognized that the aperture 73 opens directly into the secondary air conduit 62, and thus represents the discharge opening of the secondary air forced through, or induced through, the secondary air supply conduit 62. Such relationship of these components of the assembly is clearly shown in FIGURE 1.

In any event, the functional relationship of these described elements is such that the primary and secondary air streams, exiting respectively from nozzle 72 and outlet 73 are rapidly rotating in circulatory fashion, in the same direction; the coal fines admitted through conduit 65, becoming air-borne in this conduit and intimately intermixed with primary air by means of the vanes 68 in this conduit, are discharged with a relatively violent swirling motion through the nozzle 72, are met by the additional swirling air stream comprising secondary air, and additionally thoroughly intermixed with these two air mediums so as to promote immediate and effective combustion.

The nature of the combustion process achieved by the combination of elements just referred to may be more clearly understood by reference to FIGURES 1 and 3. Here it is seen, as indicated above, that the primary air and coal mixture, discharged through nozzle 72, induces the flow of the secondary air through conduit 62, due to the venturi effect described above. The combustion products emanating from nozzle 72 are discharged directly into the primary furnace 30, flowing therethrough in the direction indicated by the arrows within the chamber. Combustion takes place in the latter, delivering high temperature radiant heat upon the inside surface of the tubular liner 42. The latter, as stated, is comprised of a highly heat-conductive material in order to effect indirect contact heat transfer from the combustion products to the series of primary tubes 40 which entirely surround, and are affixed to, the chamber 42. The latter may thus be considered an erosion shield for this bank of tubes 40, protecting the latter from direct erosive and deteriorative flame contact.

This initial flow of combustion gases (from left to right as viewed in FIGURE 1) is reversed in direction upon emanating from the primary furnace 30 and passes toward the front wall 14 of the secondary furnace 35, further delivering radiant heat energy to the tubes 45 and 46 comprising the boundary of the secondary furnace 35 and to the outside of the tubes 40 comprising the outer periphery of the primary furnace 30. A portion of such super heated gases, after having passed through the secondary furnace, are then re-cycled through the primary furnace 30, also as indicated by the curved arrows at the inlet side of the primary furnace, and as appearing in FIGURE 1. By such re-cycling, a high temperature environment is pre-provided for the incoming coal and air mixture which helps to support ignition and reduce excess oxygen requirements.

The combustion gases entering the open tube construction 49 (see FIGURE 3) of the secondary furnace finally

progress to the rear of the boiler, delivering convective heat to the series of convection tubes 48 (see FIGURES 2 and 3). They then pass out of such convection bank at the rear of the furnace, being ultimately discharged to the atmosphere through an appropriate stack 75.

Mention has been made in the foregoing of "coal fines." As a matter of fact, any relatively fine material can be used as the combustible material. At any rate, for the purpose of this invention, coal fines are herein defined as one-quarter inch or smaller coal particles, as normally defined by the coal trade, or sizes which are larger than one-quarter inch where the motion of air and recirculated combustion products are capable of keeping the coal in sufficient suspension to complete combustion within the primary furnace.

Reference in the foregoing has also been made to the removal of the molten ash, such being indicated at 80 in FIGURE 1, which is discharged in its molten state from the primary furnace 30 by means of its natural flow due to the inclination of such primary furnace. The molten ash drops through an appropriate opening 82 in the bottom wall 17 of the furnace to be received within an appropriate chute 85 which has been partially filled with water to quench the ash. Upon quenching, the ash settles to the bottom of chute 85 where it is picked up by an endless conveyor mechanism represented by a series of drag conveyors 90 (FIGURES 1 and 3). The latter mechanism, of usual and known construction, conveys the quenched ash to a point exterior of the furnace proper for disposal by any suitable means.

I have also provided for two alternate embodiments or arrangements of the nozzle structure for feed in of the air-coal mixture into the primary furnace 30.

The first of these is illustrated in FIGURE 4. Such comprises a stationery convergent water cooled primary air and coal injection nozzle. As in the former case, primary air is admitted through conduit 60, secondary air through line 62, and the coal, in the form of coal fines, through inlet conduit 65. In this version of the structure the nozzle 97 is of the shape as shown, being of gradually reduced diameter toward its outlet end. As before, a series of angled vanes 68 are provided around the inner periphery of conduit 60 adjacent to the nozzle formation, and also, a series of spaced and similarly angled vanes 70 are located upon the inner surface of the aperture 73 in the furnace wall. Both sets of vanes 68 and 70, and as described above, are so inclined in the same relative direction as to promote a circulatory impulse to the primary and secondary air, respectively emitted through conduit 60 and exit aperture 73.

In this version of the nozzle set up, however, a series of water connections 95 are provided in between the vanes 68 and vanes 70, and so located as to inject into the interior of the nozzle separated streams of water, directed against the inner periphery of the nozzle at the points indicated by the elements 95. The purpose of this water injection means is to cool down the nozzle 97 during the combustion process, when the nozzle is of course subjected to extremely high temperatures. Such purpose is achieved in this fashion: because of the rotating mass of primary air and coal within the nozzle, water is caused to adhere to the sides of the nozzle through the influence of centrifugal force. Hence, the nozzle is cooled by this fluid medium where the same is subjected to high temperature radiant heat from both primary and secondary furnaces.

As an alternate method of induction of primary air, secondary air and coal, reference is made to FIGURE 5. Here is shown a nozzle 100 adapted to be rotated at relatively high speed, thereby causing the combustible material to be slung outwardly with additional force toward the periphery of the primary furnace 30.

To this end the nozzle 100 is journaled to suitable bearings 100. Mounted upon its outer end is an appropriate sprocket 102 adapted to be chain driven through

any suitable drive means. The conduit 60, somewhat of lesser diameter than the nozzle itself, is positioned within the opening into the latter, as shown in FIGURE 5, and also provided with a series of water injection nozzles as at 110 and 112, positioned to emit water in the direction of line of flow of the coal-air mixture. As here shown these water injection nozzles 110, 112 force ejected water into the space 113 between conduits 60 and fuel nozzle 100. If desired, an internal propeller 115, positioned as shown, may be affixed between opposed points on the inner periphery of the fuel injection nozzle 100, so that, upon rotation of the latter the vane or propeller device 115 throws the coal-air and water mixture with some force outwardly and into the primary furnace 30. This projection of the referred to mixture is, in other words, slung outwardly toward the inner periphery of the primary furnace as represented by the tubular liner 42 thereof.

From the foregoing it will be seen that I have provided a novel means and method for the efficient combustion, at high temperatures, of fine materials such as coal fines, the means employed contemplating the "furnace within a furnace" concept. In this latter respect resides the inherent advantage that the mechanical combination is one which can be pre-assembled at the factory. Such factor also renders the unit transportable to the site of ultimate use. In addition, and considering the relatively high B.t.u. output of such a unit, means have been provided for the protection of the tube system which represents the inner or primary furnace—an all important factor lending practicality and real commercial merit to this unique improvement.

Although it is obvious that this invention may be varied in many ways and other expedients and alternates employed to accomplish the purposes hereof, it is to be understood that the same is to be limited only by the scope of the following claims.

I claim:

1. A coal fired steam generator for the combustion of coal fines comprising a substantially horizontally disposed and water-cooled secondary furnace envelope having a radiant heat absorbing surface, said envelope being provided with a primary furnace receiving zone therein, a coal-fired, water-cooled primary furnace within said zone surrounded by said envelope, and disposed downwardly from the inby end thereof with respect to the horizontal, thereby permitting gravity flow of slag there-through, said primary furnace comprising an open-ended heat conducting erosion inhibiting chamber and a plurality of tangentially disposed tubes upon the exterior surface of said chamber in heat conductive relationship therewith, air supply means feeding into said zone, means to discharge said coal fines into said primary furnace, said chamber and said tubes being arranged to direct the combustion products from said primary furnace to and through said secondary furnace envelope.

2. The invention as defined in claim 1 wherein said air supply means and said discharge means include a primary air duct and a secondary air duct, coal fine discharge means in interconnection with said primary air duct, said primary air duct having a discharge nozzle opening into said primary furnace, said secondary air duct terminating in an outlet surrounding said nozzle, whereby coal fine flow and air flow in said secondary air duct is induced by air flow through said primary air duct.

3. The invention as defined in claim 2 wherein means are provided to remove molten ash, said means comprising an open water containing trough positioned adjacent the lower end of said slanted primary furnace, said trough containing a conveyor system extending from said adjacent position to a point exterior to said furnaces.

4. The invention as defined in claim 2 wherein additional means are provided to intermix said coal fines with air from said primary and said secondary air ducts, said means comprising angled vanes upon the inner pe-

riphery of said primary air duct adjacent said nozzle, whereby said air in said primary air duct is caused to swirl in rotary fashion.

5. The invention as defined in claim 4 wherein said intermixing means includes a second series of angled vanes, said second series of angled vanes being mounted in said secondary air duct outlet, whereby said secondary air is caused to swirl in rotary fashion in the same direction as said primary air.

6. The invention as defined in claim 5 wherein means are provided to rotate said nozzle in the same direction as the direction of movement of said primary and secondary air.

7. The invention as defined in claim 5 wherein means are provided to cool said nozzle, said means comprising water injection means directed toward the inner periphery of said nozzle.

8. The invention as defined in claim 5 wherein means are provided to remove molten slag resulting from the combustion products of said primary furnace zone, said means comprising a water filled trough disposed adjacent the lower end of said slanted primary furnace, said trough having disposed therein an endless conveyor system extending from said lower end of said primary furnace to a point exterior of said primary and secondary furnaces, whereby said molten ash is removed from the areas defined by said primary and secondary furnaces.

9. In a coal fired steam generator, a downwardly slanted primary coal burning water cooled furnace, said furnace comprising a series of tangentially disposed tubes defining an elongated, tubular combustion zone, said combustion zone being lined internally with a heat conducting erosion inhibiting plate in contact with said tubes, a secondary water cooled furnace disposed as an envelope surrounding said primary furnace, means for mixing primary combustion air and coal, means for injecting said mixture into said primary furnace, said last named means including means to induce a flow of secondary air into said primary combustion air, means to introduce fine coal into said primary-secondary air mixture, whereby said coal fines are combusted in said primary furnace

and reduced to molten ash, said plate being positioned to direct the products of combustion to said secondary furnace, and means to remove said molten ash to a point exterior to said primary and secondary furnaces.

10. In a factory assembled, railroad transportable, single-package-unit constructed coal fired steam generator, a downwardly slanted primary coal-burning water cooled furnace, said furnace including a series of tangentially disposed water tubes positioned to define an interior combustion zone, a heat conducting and erosion resistant lining disposed upon the inner side of said tubes defining said zone and attached thereto, a horizontally disposed secondary furnace, said secondary furnace comprising a series of additional tubes, said additional tubes being disposed around said primary furnace as to completely contain said primary furnace therewithin, said lining being positioned to recycle the products of combustion to said secondary furnace, and means to inject a mixture of air and coal fines into said primary furnace for the combustion thereof, whereby said coal fines are initially combusted in said primary furnace, the product thereof being then directed to said secondary furnace, and means to discharge said combustion products to the atmosphere.

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CHARLES J. MYHRE, *Primary Examiner*.