Aug. 15, 1961 E. G. GRAF ET AL 2,996,292

GRAVITY-FED COMBUSTION EQUIPMENT APPLYING CROSSFEED IGNITION PRINCIPLE

Filed June 12, 1958 2 Sheets-Sheet 1

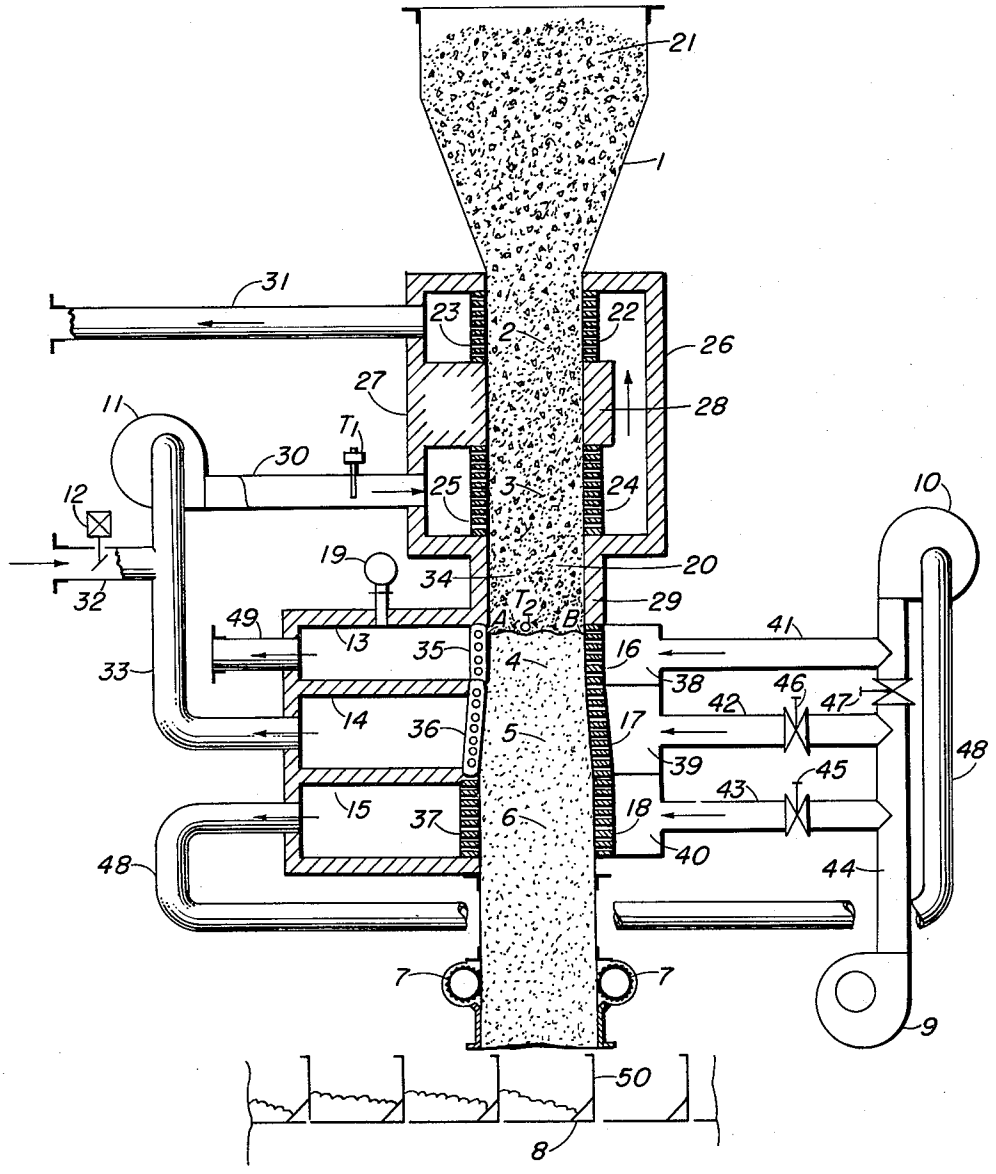


Fig. 1.

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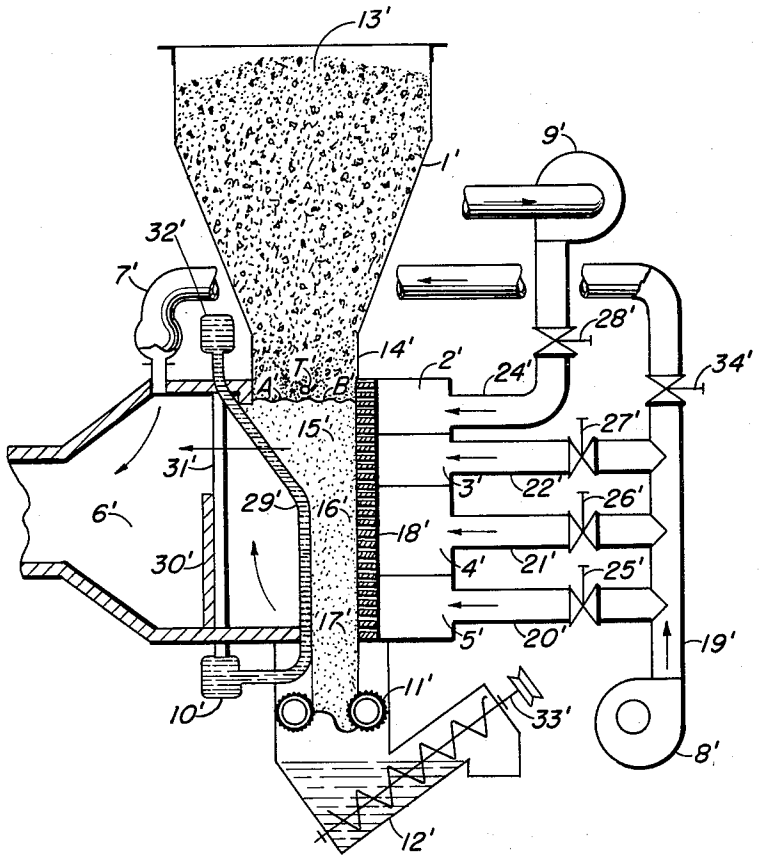


Fig. 2

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2,996,292

GRAVITY-FED COMBUSTION EQUIPMENT APPLYING CROSSFEED IGNITION PRINCIPLE

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(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention herein described and claimed may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of royalties thereon or therefor.

The invention relates to vertical shaft furnaces having crossfeed ignition.

Crossfeed ignition may be defined as that combustion process wherein the ignition plane travels in a direction perpendicular to the flow of combustion air in the fuel bed. On a traveling grate, however, it is difficult to maintain uniform crossfeed ignition because the necessary high air rates tended to lift the fuel from the grate and cause discontinuities in the fuel bed.

In the combustion of low-grade fuels, such as bituminous coal refuse, carbonaceous shale, oil shale, and artificial mixtures of higher-grade coals and clay or shale, difficulties are encountered in conventional burning equipment in obtaining high rates of initial ignition, of ignition travel, and of burning in the bed. Difficulties are caused also by the agglutinating properties of some of these fuels when passing through the carbonization stage and by the volatile matter released.

At the present time two types of combustion equipment are in use to burn low-grade fuels or mixtures of higher-grade fuel and clay or shale in such a manner that the burned-out residue can be further processed, for example as concrete aggregate. These types are: (1) The traveling-grate sintering machine with downward travel of air, and (2) the conventional traveling grate with upward travel of air. In the former type the ignition plane travels in the same direction as the flow of combustion air, while in the latter type, the ignition plane travels countercurrent to the flow of air.

The following difficulties are encountered in the downdraft sintering machine:

(*a*) The volatile matter in the fuel is distilled off by the hot combustion gases and does not burn in the bed, thus reducing the effective heat content of the fuel and requiring extensive treatment of the exhaust gases to eliminate buildup of condensed tars on ducts and fan blades and to prevent air pollution.

(*b*) Fuels that exhibit swelling and agglutinating characteristics tend to swell and cake, thus creating higher flow resistance and uneven distribution of the air. So far as is known, there has been no successful attempt to burn fuels of agglutinating properties on a downwdraft sintering machine to produce a sintered aggregate.

The difficulties encountered in burning low-grade fuels on conventional updraft traveling grates are:

(*a*) The relatively low rates of initial ignition and ignition travel through the bed and subsequent low unit capacities.

(*b*) The necessity of maintaining costly ignition arches of high-temperature refractories.

(*c*) The cost of operating and maintaining the moving grates.

We have found that ignition and burning rates, based upon the pure crossfeed principle, can be higher than those using the updraft burning principle, which involves the underfeed mode of ignition.

It is an object of this invention to provide a combustion unit and method that utilizes crossfeed ignition and burning.

It is a further object of this invention to provide a gravity-fed combustion unit and method employing the crossfeed ignition and combustion principle, whereby low-grade fuels such as bituminous coal refuse, oil shale, etc., may be successfully burned.

It is a further object of this invention to provide a gravity-fed combustion unit employing the crossfeed principle, whereby wet combustible material may be successively dried, heated, ignited and burned during a downward path of travel within the combustion unit.

It is a further object of this invention to provide a gravity-fed furnace boiler employing the crossfeed principle wherein hot combustion gas passing crosswise from the combustion bed pass over generally vertically disposed water tubes.

These and other objects of the invention not specifically set forth but inherent therein will be readily apparent from the following specification and claims.

This invention consists of a vertical shaft having a fuel hopper at its upper end and containing a downwardly moving fuel bed. Mounted vertically on the shaft are grate elements, through which air at proper temperatures is forced, to ignite the fuel, maintain combustion and cool the ashes. Also, if the fuel is wet, grates to admit drying air and preheating air are provided. A pair of corrugated rolls at the bottom of the shaft draw down and crush the ashes and chambers, thus making room for additional fuel at the top of the shaft. Sensible heat is recovered from the hot combustion gases by suitable heat exchangers, water tube boilers, etc. Some of the hot gases may be recycled to provide heat for the ignition, drying, preheating and combustion air streams.

The advantages of this crossfeed combustion apparatus and method may be summarized as follows:

(*a*) The fuel bed is restricted between two opposing grates and thus permits primary air rates several times greater than are possible in conventional updraft stokers.

(*b*) The higher air rates result in higher rates of combustion. Pressures higher than atmospheric are possible within the fuel bed. This is a decided advantage over the negative pressure that occurs in downdraft sintering machines. Positive pressure in combustion equipment and fuel beds permits better distribution of the air over a given cross section.

(*c*) Crossfeed combustion is superior in all respects to the downdraft sintering bed when burning fuels or mixtures of fuels with clay or shale containing appreciable amounts of volatile matter. The volatile matter renders utilization of these fuels difficult or impossible in downdraft sintering beds, due to deposition of tars on flues and blowers.

(*d*) A new principle of ignition is applied, in which the ignition plane is essentially horizontal and moves perpendicular to the flow of air, which also is essentially horizontal. Rates of ignition in the new combustion equipment can be higher than those encountered in updraft traveling grate beds, since very much higher air rates can be utilized.

(*e*) Ignition in the new combustion method is propagated continuously from inside the bed and does not depend upon ignition arches and other means as with traveling grates, or upon continuously operated ignition hoods, using auxiliary fuel, as with the sintering machines.

(*f*) The fuel bed is essentially upright and moves downward under gravity only. Thus, it contains no moving grates or other parts exposed to elevated temperatures.

(*g*) Owing to the high rates of combustion obtainable with the new combustion method, the equipment is very

compact. The vertical arrangement of the equipment results in smaller floor space than that required for conventional burning equipment with the same capacity.

(*h*) Recovery of sensible heat for the uses of drying and preheating of the feed is facilitated, since the essentially vertical arrangement of the fuel bed takes advantage of the natural-draft tendency in the preheating zone. Moreover, the cross section in every level is filled completely and affords even distribution of the air over the width and height of the air passages. In this respect the new combustion method is superior to both the updraft traveling grate and the downdraft sintering machine.

(*j*) The rapid rise of temperature of green fuel to combustion temperatures in the new combustion method prevents the full development of the plastic properties of bituminous fuels. By contrast, green fuel beds on traveling grates and sintering machines, are heated up more slowly, and caking creates difficulties. Whereas with these conventional fuel beds the carbonization zone covers the major portion or all of the grate area, in the new combustion equipment the carbonization zone extends over only a small fraction of the total grate area.

(*k*) Higher air preheat temperatures are possible with the stationary grates employed in the crossfeed method than with conventional grate types, because the metal can withstand higher temperatures when not subjected simultaneously to mechanical stress.

(*l*) The grates are more readily accessible for inspection and repair than are conventional grates.

Furnaces according to this invention may be employed with advantage where, for example, it is desired to:

(*a*) Employ low-grade fuel, or artificial mixtures of solid fuels and other minerals, for the purpose of fusing or chemically changing the residual material. This includes the production of lightweight aggregate for concrete, cement clinkers, burned lime, fused taconite pellets, or other mineral sinters, now produced in a shaft furnace or on a traveling sintering machine;

(*c*) Employ high-grade fuels for heat and power production.

In the accompanying drawings are shown two specific embodiments of furnaces according to the invention, embodying the crossfeed ignition and combustion principle.

FIGURE 1 is a diagrammatic elevation view, partly in section, of a furnace for employing a wet fuel.

FIGURE 2 is a diagrammatic elevation view, partly in section, of a boiler furnace for burning higher-grade fuels.

In FIGURE 1, **20** is vertical shaft furnace having at the upper end a feed hopper **1** containing fuel **21**. Hopper **1** carries a sufficient charge of fuel to act as a partial air seal.

Immediately below hopper **1** is a drying section **2** which is contained between opposing cast iron grates **22** and **23**, comprising a first grate means formed of cast iron wedges set in frames. Below drying section **2** is preheating zone **3**, which is contained between cast iron grates **24** and **25**, similar to grates **22** and **23**. Elements **24** and **25** comprise a second grate means. The drying section **2**, and the preheating zone **3**, including their respective first and second grate means, constitute a first fuel processing portion. Plenum chamber **26** having baffle member **27** and lined with insulation brick surrounds grates **22**, **23**, **24** and **25**. Sections **28** and **29** of the shaft **20** are likewise covered with insulating brick to protect and insulate the furnace walls. Hot flue gases from burning section **5**, as will appear hereinafter, are forced into plenum chamber **26** by fan **11** through ducts **30**, and passes through the fuel bed at grates **22**, **23**, **24** and **25**. Cool spent gas leaves the plenum chamber **26** through duct **31**. Tempering air may be admitted to the flue gases through inlet duct **32** on flue duct **33**, and is controlled by thermocouple T_1 which operates automatic damper **12**. The temperature of the preheating gases is selected so that maximum preheat with a minimum release of volatile matter is obtained, and the plastic range of the fuel is not reached.

The pressure in the fuel bed in the preheat section is regulated so that it closely approximates the pressure in ignition section **4** located below preheating section **3**, thereby eliminating vertical travel of gas in the fuel bed. This insures a direction of air and gas flow that is essentially normal to the path of fuel travel.

Buffer zone **34** separates the preheating zone **3** from ignition section **4**. Grate **16**, similar to the grates at the drying and ignition sections, is located at the ignition section **4** of the shaft. Located opposite it is a water tube section forming a grate **35**, the same size as **16** but containing water tubes connected to headers (not shown). Water circulates through the tubes and header to keep the grate cool. This arrangement can be incorporated into a boiler when the furnace is used for steam generation. Elements **16** and **35** comprise a third grate means.

A second fuel processing portion comprising the ignition section **4**, and combustion and cooling sections **5** and **6**, each section having a corresponding grate means, receives the preheated fuel from the first fuel processing portion above it. The fuel ignites at a plane represented by A and B which is close to the top of ignition section **4**, and is essentially horizontal over the cross-section of the bed. Thermocouple T_2 in the fuel above the ignition plane, serves to indicate the location of the plane. The ignition plane may be varied in location by controlling the rates of fuel and gas feeds. Maintaining the location of the ignition plane may be performed automatically by controls operated from thermocouple T_2.

The combustion and gasification section **5** extends from the ignition plane downwardly to a level where the combustible material has been burned out. Grate **17** located at section **5** of the shaft is similar to grate **16**, and opposing lower water tube section grate **36** is similar to grate **35**. Elements **17** and **36** comprise a fourth grate means. These grates flare outwardly, as is apparent from the drawing, to provide a larger cross-sectional area in the furnace, since during the combustion reaction the fuel mass expands, and also to facilitate the downward movement of the fuel bed. Below section **5** is cooling section **6**, having grates **18** and **37** similar to grate **17**. Elements **18** and **37** comprise a fifth grate means.

The intake air side of sections **4**, **5** and **6** divide into several horizontal sections with individual damper control, as shown in FIGURE 1. Plenum chambers **38**, **39** and **40** constituting a first group of separate conduits; feed air admitted through ducts **41**, **42** and **43** into grates **16**, **17** and **18**. Air is forced into these ducts by primary blower **9**, which is connected to them by manifold **44**, and is controlled by dampers **45**, **46** and **47**.

A second group of separate conduits including flues **13**, **14**, and **15**, receive the gases leaving sections **4**, **5**, and **6**. Combustion gases leave zones **4** and **5** and pass through grates **35** and **36** into exhaust flues **13** and **14**, which are of refractory construction. Heated air leaves zone **6**, and passes through grate **37** into flue **15**, faced inwardly with insulation brick. The heated air passes through duct **48** into fan **10**, and is then distributed into ducts **41**, **42** and **43** as required.

Hot combustion gas leaves flue **14** via duct **33** for use in the preheating and drying sections, as set forth supra. The gases from flue **13** may be exhausted through **49** to other process uses, or may be contacted with heat-transfer surfaces. Secondary air may be introduced into flue chamber **13** through inlet **19** if necessary, to obtain complete combustion of the gases.

Below clinker-cooling section **6**, are mounted a set of rolls **7** which act to support the column of clinkers. Rolls **7** have corrugated surfaces and are pressed against the clinker by springs (not shown) with sufficient force to support the weight of the column. The rolls are synchronized in rotation and are driven by a variable speed drive of conventional design. Since the rate of revolu-

tion of these rolls determines the feed rate, varying this factor and the air rate maintains the ignition plane in its proper location.

Below the feed rolls, is a traveling apron conveyor indicated generally by **8** which has upright member **50** that breaks the clinker off below rolls **7**. The conveyor removes the clinker from the furnace and carries it to disposal, or further processing.

A minimum of refractory is used in the furnace. Its use is confined mainly to exhaust flue **13**, corresponding to the ignition and carbonization section **4**. The remaining lining is made of insulating brick, except for the walls between preheating section **3** and section **4**, where abrasion-resistant refractory is applied. The hopper and the casing are mild steel.

The embodiment of FIGURE 2 shows an application of the invention intended primarily for the burning of higher grade fuels to utilize the heat of combustion.

Fuel **13'** in hopper **1'** travels by gravity through shaft **14'** which has therein an ignition section **15'**, a burning section **16'** and a cooling section **17'**. At one side of the shaft is a vertical grate **18'**, similar to the grates described in connection with FIGURE 1. Plenum air chambers **2'**, **3'**, **4'** and **5'** subdivide the grate into sections corresponding to the ignition, burning or combustion, and cooling sections. Blower **8'** forces air through manifold **19'** into ducts **20'**, **21'** and **22'** which are connected with plenums **3'**, **4'** and **5'**. Preheated air from a conventional preheater is passed through blower **9'**, and duct **24'**. Dampers **25'**, **26'**, **27'** and **28'** control the rate of air flow into the plenums.

The fuel bed is restricted between the air inlet grate **18'** and one or more rows of water tubes **29'**. The latter are bent as shown in FIGURE 2 so as to form a deeper fuel bed in the upper section and a thinner bed in the lower section. Tube spacing varies with fuel size; the larger the fuel, the wider the spacing. The ignition plane is shown by A'—B', and T' indicates a thermocouple for controlling the location thereof in a manner similar to that described in connection with FIGURE 1.

Hot gases leaving section **15'**, **16'** and **17'** pass through water tubes **29'** into secondary combustion chamber **6'**. Hot air from the cooling section **17'** is directed upward by means of baffle **30'** and vertical water tubes **31'**.

Water tubes **29'** and **31'** have common lower and upper headers **10'** and **32'**, and may be part of a steam generating apparatus. The hot air burns the combustibles in the gases evolved from the top section of the bed. If needed, additional secondary air may be admitted through line **7'** from manifold **19'** and controlled by damper **34'** into secondary combustion chamber **6'**. Flue gas from chamber **6'** is removed through a stack (not shown).

The clinkers and ashes formed are crushed by means of rolls **11** which are similar to those described in connection with FIGURE 1. The ashes fall into a conventional water filled pit **12'** and are removed by worm conveyor **33'**.

Various changes and modifications within the skill of the art may be made in the above described invention without departing from the spirit and essence thereof.

We claim:

1. A method for burning solid particulate fuel in a furnace which comprises, maintaining columnar bed of descending fuel, charging fuel at the top of the bed and subjecting the fuel bed at the bottom to tractive and ash crushing action, discharging ashes from the bottom of said bed, establishing a series of zones having an upper portion in the fuel bed including in descending order an ignition zone, a combustion zone and a cooling zone, forcing oxygen-containing gas at fuel ignition temperature into the fuel bed at the ignition zone perpendicularly to the path of fuel travel at the ignition zone maintaining the direction of gas flow through the fuel bed essentially normal to the path of the descending fuel, whereby the fuel is ignited at an ignition plane near the upper portion of the ignition zone, said ignition plane being substantially parallel to the path of gas flow, maintaining combustion by forcing oxygen-containing gas into the burning fuel perpendicularly to the path of fuel travel at the combustion zone, cooling the hot cinders or ashes by forcing cool oxygen-containing gas into the fuel bed below the combustion zone in a direction perpendicular to the path of fuel travel, maintaining the location of the ignition plane by varying the feed rate and the oxygen containing gas flow removing the heated gas from the cooling zone perpendicularly to the path of fuel travel, recirculating at least a portion of the heated gases to the ignition zone, and removing the hot combustion gases from the ignition and combustion zones perpendicularly to the path of fuel travel.

2. A method for burning solid particulate fuel in a furnace which comprises maintaining a columnar bed of descending fuel, charging fuel at the top of the bed and subjecting the fuel bed at the bottom to tractive and ash crushing action, discharging ashes from the bottom of said bed, establishing a series of zones in said fuel bed, including in descending order a drying zone, a preheating zone, an ignition zone having an upper portion, a combustion zone and a cooling zone, forcing gases through the fuel bed at these zones in a direction perpendicular to the direction of fuel travel, as hereinafter set forth, passing hot gas through the drying zone to dry the fuel, passing hot gas through the preheating zone to preheat the fuel, passing oxygen-containing gas at fuel igniting temperature through the ignition zones to ignite the fuel at an ignition plane near the upper part of the ignition zone, said ignition plane being substantially parallel to the path of gas flow, passing oxygen-containing gas through the combustion zone to maintain combustion, maintaining the direction of gas flow through the fuel bed essentially normal to the path of fuel travel, maintaining the location of the ignition plane by varying the fuel feed rate and the oxygen-containing gas flow, cooling the hot cinders or ashes by passing cool oxygen-containing gas through the cooling zone, removing the hot oxygen-containing gas from the cooling zone, recirculating said hot oxygen-containing gas to the ignition zone, removing the combustion gases from said ignition and combustion zones, and recirculating a portion of said combustion gases to the preheating section.

3. A method for burning solid particulate fuel in a furnace which comprises maintaining a columnar bed of descending fuel, charging fuel at the top of the bed and subjecting the fuel bed at the bottom to tractive and ash crushing action, discharging ashes from the bottom of said bed, establishing a series of zones in said fuel bed including in descending order an ignition zone having an upper portion, a combustion zone and a cooling zone, forcing gases through the fuel bed at these zones in a direction perpendicular to the direction of fuel travel, as hereinafter set forth, maintaining the direction of gas flow through the fuel bed essentially normal to the path of fuel travel passing hot oxygen-containing gas at fuel ignition temperature through the fuel ignition zone, whereby the fuel is ignited at an ignition plane near the upper portion of the ignition zone, maintaining the location of the ignition plane by varying the fuel feed rate and the oxygen-containing gas flow passing oxygen-containing gas through the combustion zone, passing cool oxygen-containing gas through the cooling zone, removing the combustion gases from the fuel bed into a secondary combustion zone adjacent the ignition combustion and cooling zones, admitting secondary oxygen-containing gas into said secondary combustion zone to complete the combustion reaction, recovering at least a portion of the heat of the hot combustion gases, and removing the resulting flue gas from the secondary combustion zone.

4. A method for burning solid particulate fuel in a furnace which comprises, maintaining a substantially vertical bed of descending fuel, charging fuel at the top

of the bed and subjecting the fuel bed at the bottom to tractive and ash crushing action, discharging ashes from the bottom of said bed, establishing a series of zones in the fuel bed including in descending order an ignition zone, a combustion zone, and a cooling zone, forcing air at fuel ignition temperature into the fuel bed at the ignition zone in a substantially horizontal path, maintaining the direction of gas flow through the fuel bed essentially horizontal, whereby the fuel is ignited at an ignition plane near the upper part of the ignition zone, said ignition plane being substantially horizontal, maintaining combustion by forcing air into the burning fuel in a substantially horizontal path, cooling the hot cinders or ashes by forcing relatively cool air into the fuel bed below the combustion zone in a substantially horizontal path, maintaining the location of the ignition plane by varying the fuel feed rate and the rate of air flow, removing the heated gas from the cooling zone, recirculating at least a portion of the heated gases to the ignition zone, and removing separate stream of hot combustion gases horizontally from the ignition and combustion zones, respectively.

5. A method as in claim 4, wherein the fuel consists of a mixture of coal with other mineral material and wherein the ash discharged at the bottom of the furnace is a product comprising said mineral altered by the high temperature furnace conditions.

6. A method for burning solid particulate fuel in a furnace which comprises maintaining a substantially vertical columnar bed of descending fuel, charging fuel at the top of the bed and subjecting the fuel bed at the bottom to tractive and ash crushing action, discharging ashes from the bottom of said bed, establishing a series of zones in said fuel bed including in descending order an ignition zone, a combustion zone, and an ash cooling zone, forcing gases through the fuel bed at these zones in a horizontal direction, maintaining the direction of gas flow through the fuel bed essentially horizontal, passing hot air at fuel ignition temperature through the fuel ignition zone, whereby the fuel is ignited at an ignition plane near the upper part of the ignition zone, said ignition plane being substantially hroizontal, maintaining the location of the ignition plane by varying the fuel feed rate and the air flow, passing air through the combustion zone, passing relatively cool air through the ash cooling zone, removing the combustion gases from the fuel bed into a secondary combustion zone adjacent the ignition, combustion and cooling zones, admitting secondary air into said second combustion zone to complete the combustion reaction, recovering at least a portion of the heat of the hot combustion gases, and removing the resultant flue gas from the secondary combustion zone.

7. A method for burning solid particulate fuel in a furnace, which comprises maintaining a substantially vertical columnar bed of descending fuel, charging fuel at the top of the bed and subjecting the fuel bed at the bottom to tractive and ash crushing action, discharging ashes from the bottom of said bed, establishing a series of zones in said fuel bed, including in descending order a drying zone, a preheating zone, an ignition zone, a combustion zone, and an ash cooling zone, forcing gases through the fuel bed at these zones in a generally horizontal direction, as hereinafter set forth, passing hot gas through the drying zone to dry the fuel, passing hot gas through the preheat-zone to preheat the fuel, passing air at fuel igniting temperature through the ignition zone to ignite the fuel at a substantially horizontal ignition plane near the top of the ignition zone, passing air through the combustion zone to maintain combustion, maintaining the flow of gas through the fuel bed in a substantial horizontal direction, maintaining the location of the ignition plane by varying the fuel feed rate and the air flow, cooling the hot cinders or ashes by passing relatively cool air through the cooling zone, removing hot air from the cooling zone, recirculating the hot air to the ignition zone, removing separate stream of combustion gases from the ignition and combustion zones, respectively, and recirculating a portion of the combustion gas to the preheating section.

8. A furnace for crossfeed ignition and combustion of fuel, comprising a feed hopper, a vertical shaft section adapted to hold fuel below said hopper, said shaft being defined by two fuel processing portions, each comprising an arrangement of sections having generally opposing grates, the first portion being more particularly defined by a plurality of sections, including in descending order a fuel drying section, a preheating section, the second portion being more particularly defined by a plurality of sections including an ignition section, a combustion section, a cooling section, the opposing grates of each section being spaced vertically on said shaft below said hopper, whereby one pair is spaced at the said drying section, one pair is spaced at said preheating section, one grate each is located at the ignition and combustion sections having opposite thereto a plurality of water tube sections, including one upper and one lower water tube section, each section defining a grate, and one pair of opposing grates is located at the cooling section, means for forcing air through a first group of separate conduits and substantially horizontally through the ignition and combustion section grates, and one of said cooling section grates, respectively, each conduit having separate means to control the quantity of air received through the respective grates, a second group of separate conduit means for removing hot gases passing through the water tube sections and the opposing cooling section grate, said second group including conduit means for recirculating hot gas from said second group including conduit means for recirculating hot gas from said opposing cooling section grate to said air forcing means, conduit means for removing hot gas from the upper water tube section, conduit means for separately conducting hot gases from the lower water tube section to one of said preheating section grates for passage through the fuel bed, and conduit means for removing the cooler gas from the opposing preheating section grate, means for conducting the said cooler gas to one of the drying section grates, for passage through the fuel bed in order to dry the fuel, means for removing the now relatively cool gas through the opposing drying section grate, means for varying the rate of feed of the fuel, including means for removal of ashes or clinkers from the bottom of the shaft and means including the said separate means to control for varying the rate of admission of gases to the said sections of the said second portion.

9. A furnace as in claim 8, wherein the cross-sectional area of the shaft section is increased at the combustion zone to allow for expansion of the fuel in burning.

10. A furnace as in claim 8, wherein the means for removal of hot ash and clinkers comprises a pair of rollers which acts by rotation to crush the clinkers and cause downward motion of the fuel through the vertical shaft.

11. A furnace as in claim 10, wherein the cross-sectional area of the shaft section is increased at the combustion section to allow for expansion of the fuel in burning.

12. A furnace for crossfeed ignition and combustion of fuel, wherein the fuel travels downwardly through a series of sections, including in descending order a drying section, and a preheating section, followed by an ignition section, a combustion section, and a cooling section; comprising fuel hopper means, a vertical shaft located below said fuel hopper means, a plurality of grates spaced vertically on said shaft below said fuel hopper means, a fifth grate means comprising a pair of opposing grates, located on the shaft at opposite portions thereof at the cooling section, a fourth and third grate means comprising grates located at the combustion and ignition sections, respectively, a plurality of water tube sections located on said shaft opposite said fourth and third grate means, a second grate means comprising a pair of grates located on the shaft opposite portions thereof at the

preheating section, a first grate means comprising a pair of grates located at opposite portions of said shaft at the drying section thereof, means including an arrangement of first, second, and third conduits, each having a control means for determining the supply of cool air to the ignition, combustion, and cooling section respectively, and means for forcing the cool air through the third conduit and one of the grates of the fifth grate means to cool the hot burned fuel in the shaft, a fourth conduit means for removing hot air from the opposing member of said fifth grate means, means for admixing cold air with said hot air to adjust the temperature and produce heated air, means including the first and second conduits for passing the heated air through the third and fourth grate means into said ignition and combustion sections, and additional conduit means for removing hot combustion gas passing through the water tube sections, means for conducting a portion of the gas of said combustion section through one of the second grate means, said additional conduit means and into the preheating zone, further additional conduit means for removing the hot gas passing through the other grate of the second grate means, including means for leading the said hot gas through one of the first grate means to the drying section, and means for removing the spent gas from the opposing grate thereof, said air and gases being introduced horizontally through all the said grate means into the shaft, and removed horizontally therefrom, means for varying the rate of feed including means for removing ashes or clinkers from the bottom of the shaft, and means including the control means of said first, second, and third conduits, for varying the rate of admission of the air gases into the said shaft sections corresponding thereto.

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