

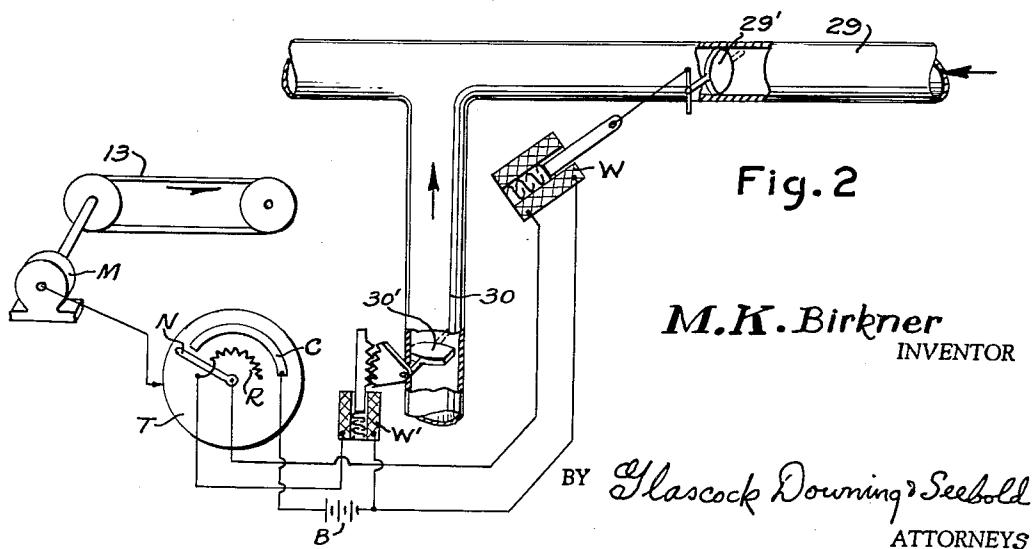
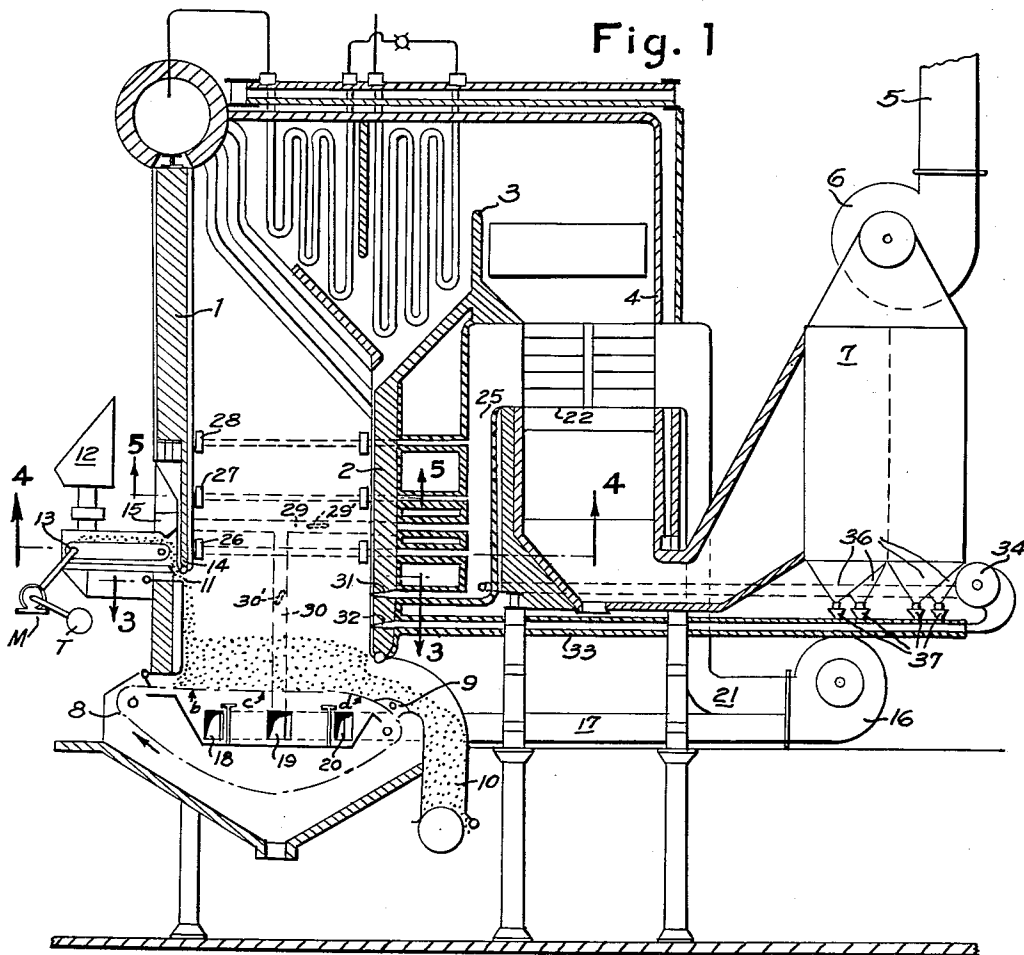
Jan. 17, 1956

M. K. BIRKNER
BURNING SOLID FUEL

2,730,997

Filed Oct. 25, 1949

2 Sheets-Sheet 1



M.K. Birkner
INVENTOR

BY *Glascok Downing & Seebold*
ATTORNEYS

Jan. 17, 1956

M. K. BIRKNER
BURNING SOLID FUEL

2,730,997

Filed Oct. 25, 1949

2 Sheets-Sheet 2

Fig. 3

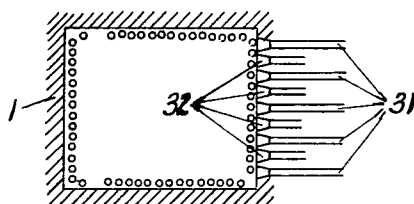


Fig. 4

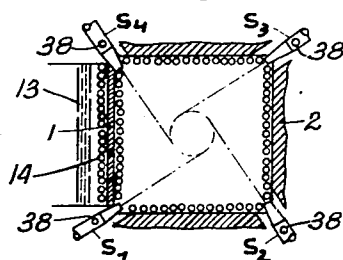
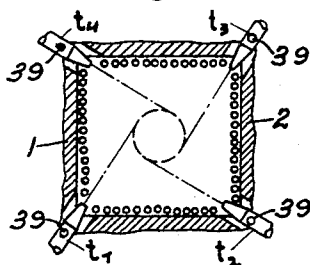


Fig. 5



Inventor:
M. K. Birkner
by
Glascock Downing & Kelle
Attorneys

1

2,730,997

BURNING SOLID FUEL

Max Karl Birkner, Kohn-Dellbruck, Germany

Application October 25, 1949, Serial No. 123,515

Claims priority, application Germany November 1, 1948

19 Claims. (Cl. 122—4)

This invention relates to a method of burning solid fuel which makes it possible to attain greater rates of combustion per unit area of grate than have hitherto been usual, and also to apparatus for use in burning fuel by this method. Besides giving a higher fuel consumption the method dispenses with preliminary reduction of the fuel to coal dust, and makes it possible to utilise the heat of the flue gases for heating air, which the use of grate furnaces with regenerative pre-heating of the feed water excludes. Through good utilisation of the grate space and fire space the method is suitable for use in very high duty boilers, and they can be made substantially smaller.

The invention makes use in part of known features and in part of features newly devised, from which either alone, or in combination with each other or with other elements new results are obtained.

Thus use is made of the known method of allowing entering fuel to fall freely upon a grate to promote drying and ignition of the coal, as well as of what is known as "fuel fluidisation," the maintenance of the fuel particles upon the grate in hovering movement by a powerful under-grate blast.

Use is made also of combustion of fuel in a state of suspension, as has been proposed for gas suspension combustion and as occurs in suspension gas producers.

For this purpose use is made of highly heated air in manner in part already known, but so as to attain new effects.

The new method also makes use of under-grate blast increasing towards the fire bridge end, such as is known in zoned travelling grates, but in a more powerful form to attain a new effect.

Use is also made of the returning of gas-borne coke to the grate, but again with a new effect.

Such new effects also result from the employment of higher air temperatures, different steps of air temperature, and substantially greater under-grate air pressures than were hitherto usual in the burning of fuel on grates or as dust.

The burning of fuel according to the new method is grate-burning combined with burning in suspension. It is preferable to use travelling grates or other grates which forward the fuel. Hitherto only a small part of such grates has been effectively utilised. The front third of the length of the grate has served more for drying the fuel and gradually igniting it throughout, and as a rule the rear third is but lightly loaded in order that combustion may be complete. These two sections are missing in grates operating on the method of this invention; the grates are intensively utilised throughout their length, even more intensively than is the middle third of existing grates.

The basis of the new method is the production of a mixture of fresh fuel entering the fire box with already burning particles of fuel. To bring this about the amount of pressure of the under-grate blast beneath a travelling grate or other grate which forwards the fuel is so much

2

increased towards the end of the grate that burning particles of coal are lifted from the grate and flung into the combustion space. They are then projected toward the front into the incoming fuel to fall simultaneously with the freely falling pre-dried fresh fuel which is strewn over the whole width of the front end of the grate, and interspersed with flame, so charging the grate that vigorous combustion at once ensues.

According to the invention combustion in suspension is accelerated by the use of air at a high temperature. The grate, on the other hand, may be fed with a cold under blast. This has two advantages; the grate is well cooled even when most intensively utilised, and the part of the total air for combustion to be supplied above the grate can be heated to a far higher temperature than would be possible if the whole of the air were pre-heated.

Combustion in suspension results in a great enrichment of the furnace fumes with fume-borne coke and ash, which are separated in the boiler flues and in a fume filter following the furnace. In the method of the invention fume-borne coke and ash are separated and blown by hot air over the travelling grate towards the front end of the grate. The consequence of using air at high temperature is that the combustible constituents begin to be gasified while still within the conduit through which they are blown forward; so quite different, and much better, conditions of combustion are obtained than by simple return of fume-borne coke as hitherto known, which leads to a large part of the separated coke blown in falling upon the grate still unburnt, and generally to a still larger part having to be repeatedly circulated with the fumes. In the new method only the coarsest constituents of the separated coke are flung into the fresh fuel falling upon the grate, where they contribute to increase the flame. Also the return of fume-borne combustible, which may also be effected in known manner with furnace fumes as the carrier, gives rise to an initial turbulence in the furnace gases, which brings about complete combustion.

Therefore this invention has for a principal object to provide a method and apparatus for burning solid fuel in a vertically extending combustion zone having an upper outlet and a fire bed travelling from front to rear of the zone at the bottom thereof. The fire bed embodies plural aligned portions including at least front, middle and rear portions. All fuel to be burned is continuously dropped solely by gravity upon the front portion of the fire bed from an inlet in the front of the zone at a height substantially midway of the height of the zone. A primary oxidizing medium is introduced under pressure from beneath the bed under all portions thereof to flow upwardly therethrough with the pressure increasing toward the rear of the grate. An additional oxidizing medium is supplied above the rear portion of the bed in the form of a substantially horizontal blanketing stream of medium directed toward the front of the zone and extending throughout substantially the width of the zone at a level beneath the fuel inlet and under pressure sufficient to entrain and project the fuel and incandescent particles elevated from the bed across the bed to the front of the zone to intermingle the same with the incoming curtain of fuel.

Further modifications of the method bring about a great diminution in the amount of particles in suspension carried off to the flues by the fumes, notwithstanding that there is a great increase in the amount of combustion occurring in suspension. To this end air supplied above the grate is directed from various points upon a point over the middle of the grate, or is directed tangentially to a circle of greater or less radius about a point over the middle of the grate. The air nozzles or tuyeres are preferably mounted to swing, so that they

can be adjusted to direct the air in the best possible way from time to time.

The air is blown in at a comparatively high speed and at a high temperature. For good distribution it may be blown in in several planes one above the other. When it is blown in tangentially a whirl is set up in the furnace gases such as is known in coal dust burning, and this greatly prolongs the path of the suspended particles in the traversing of which they may be completely burnt. By arranging the nozzles in successive planes spaced one above the other to impart whirl in opposite directions the turbulence may be intensified and the total combustion greatly increased.

It is preferable to provide for blowing in some air above the grate, in a direction opposite to that of grate travel, into the return flame zone beneath the fuel entry, while further air is supplied above the grate for producing turbulence directed centrally or tangentially as above described; for thus a comparatively short zone of complete combustion is produced which makes it possible to build a high duty boiler of small height.

Fuel is fed in at about mid height of the fire box, in known manner over the whole width of the grate by a Redler belt, a chain conveyor or the like. The entry is screened by a wall of cooling or heat absorbing tubes to minimize radiation effects. To further protect the conveyor from radiation from the fire box and to prevent back firing, an additional supply of warm air is provided to flow downwardly from above and past the end of the conveyor, and its temperature is adjusted according to the rate of fuel delivery by mixing cold air with it. This additional warm air also promotes drying of the fuel and ignition and combustion of the volatiles which are set free in quantity in the front zone of combustion.

This additional air supply, acting chiefly to afford protection, is controlled according to a further feature of the invention by the fuel feeding conveyor drive, the arrangement being such that a decrease in the speed of the conveyor, such as occurs when the boiler is lightly loaded, increases the admixture of cold air; while when the conveyor stops the supply of hot air is cut off and the current of cold air throttled down to what is necessary for the protection of the fuel supply apparatus.

In this method of burning, the whole of the residue from the combustion, save for the trifling amount in the clean fumes from the filter, is carried away by the grate. On account of the great rise of temperature in the fire box due to combustion with a small excess of air, the ash is to a large extent molten, and on the rear part of the grate is more or less granulated, while the coke-like unburnt particles are lifted by the air blast and flung into the fire space. The consequence is an automatic sifting, in known manner, of the combustible from the incombustible particles. To ensure complete combustion under all circumstances the residue on the grate may be led over a doctor or stripper into a complete combustion shaft behind the grate.

With many fuels it may be of advantage if the slope of the grate increases towards the rear in known manner.

The new method of burning solid fuel and the apparatus by which it may be carried out are further explained below with reference to the accompanying illustration of a construction of such apparatus. The grate chosen for illustration in this example of construction is a zoned travelling grate.

Figure 1 is a view partly in longitudinal section and partly in elevation of a boiler installation embodying the invention.

Figure 2 is a fragmentary view partly in perspective and partly in section diagrammatically illustrating the control of the valves that govern the flow of air past the fuel forwarding conveyor.

Figure 3 is a fragmentary cross sectional view of the fire box on a reduced scale and taken along lines 3—3 of Figure 1.

Figures 4 and 5 are further fragmentary cross sectional

views on a reduced scale taken along lines 4—4 and 5—5 respectively of Figure 1 and at different levels in the combustion zone.

As shown in Figure 1, the boiler for burning solid fuel is constructed of suitably formed wall means that define a combustion zone and include a front wall 1 and a rear wall 2. The combustion zone is vertically extended and includes an upper outlet through which fumes and products of combustion flow past the boiler tubes, thence over a baffle 3 and downwardly through a conduit 4 from whence they change their direction and are drawn out through the stack 5 by a fan 6 after passing through a fume filter means 7. At the bottom of the combustion zone is a travelling grate 8. The grate includes plural aligned portions including a front portion or zone *b* on which is initiated intensive combustion, a middle portion or zone *c* that has greater longitudinal extent than the front portion and upon which main combustion occurs and a comparatively short rear and separating portion or zone *d* from which unburned fuel particles are separated from slag and flung upwardly into the lower portion of the combustion zone. Through omission of the hitherto usual front drying and igniting zone and of the rear complete combustion zone the grate is made substantially shorter; hence there is no need to guide its return length, and since the return length or run of the grate hangs freely, grate-tensioning means are not required. This makes the grate more reliable in working. At the end of the grate there may be a doctor blade or scraper 9 which facilitates the enclosure of the grate and directs slag to a combustion completing or slag shaft 10. This shaft is of advantage when burning fuels of high ash content, for it may then happen that particles of coke adhere to burnt-out slag and might pass out unconsumed with the slag.

The vertically extending combustion zone extends from the top of the grate to the point above the uppermost bank of tuyeres referred to hereinafter. The front wall 1 is provided with a fuel feed opening 11 at a height substantially midway of the height of the combustion zone. This opening extends substantially coextensive in width with the width of the zone. Operatively associated with this opening are fuel feed means including a bunker 12 which supplies fuel to an endless conveyor 13 and includes a delivery end which forwards all fuel to drop down through the opening 11 in the form of a falling curtain of fuel of narrow extent in relation to the length of the fire bed or travelling upon the front portion of the grate. Between the delivery end of the conveyor and the adjacent portion of the front wall 1 of the fire box is a wall of relatively cold tubes 14. These tubes constitute heat absorbing means for minimizing radiation effects on the conveyor. Above this delivery end of the conveyor are nozzle means 15 which direct air downwardly past the delivery end of the conveyor and through the opening 11 with the fuel. This downwardly directed current of air, supplied and controlled as hereinafter set forth, also minimizes radiation effect or damage, prevents backfire of fuel through the opening and constitutes a further supply of oxidizing medium.

The inner walls of the fire box or combustion chamber are clad with the cold tube system of the boiler.

Means are provided for establishing an under-grate blast beneath the grate including a fan 16 which draws in what can be termed ambient or relatively cold air, and directs it through a conduit 17 to a plurality of damper controlled outlet means 18, 19 and 20. The supply of under-grate air which flows upwardly through the grate is such that the under-grate pressure increases toward the rear of the grate with the greatest pressure existing beneath the rear portion of the grate. Pressure conditions are such that the air supplied beneath the middle portion *c* of the grate is sufficient to fluidize fuel upon the grate and to elevate fine incandescent particles therefrom and the pressure of the air supplied beneath the rear portion *d* of the grate is still higher than that pressure required for fluidization so as to pick up and fling larger incandescent

5

6

particles upwardly from the grate. The under-grate supply of air constitutes the supply of the primary oxidizing means. The fan 16 also delivers through a conduit 21 which extends up to an air heater 22 mounted in the downwardly extending portion 4 of the flue or stack. This air heater is of conventional construction and the air after passing through the air heater enters the conduit 25 from which it is discharged through the superposed banks of tuyeres or nozzles 26, 27 and 28 referred to hereinafter. Hot air from the air heater is also directed through conduit 29 that feeds the nozzle means 15. A conduit 30 communicates between the conduit means 17 and the conduit 29 so that the air supplied to the nozzle means 15 is a mixture of the cold air flowing through the conduit 30 and the hot air flowing through conduit 29. The hot air conduit 25 further communicates with a bank of nozzles 31 which as shown in Figure 3, are arranged in the rear wall 2 of the fire box portion of the boiler and directed toward the front wall. The nozzles 31 project a horizontal stream of hot oxidizing medium across the grate at a level below the fuel inlet opening 11. As indicated in Figure 3, the nozzles extend across the back wall 2 of the fire box so that the horizontal blanketing stream of oxidizing medium extends throughout substantially the width of the combustion zone. This medium is supplied under pressure so that it impinges upon the particles of fuel and incandescent particles that have been lifted upwardly from the fire bed by the under-grate blast particularly at the rear portion of the combustion zone and projects these particles toward and into the curtain of incoming fuel.

Beneath the bank of nozzles 31 is another bank of nozzles 32 and these nozzles are fed by an elongated conduit means 33 suitably communicating with the discharge side of a fan 34. A conduit 35 communicates with the inlet side of the fan at one end and with the lower portion of downwardly extending hot air conduit 25 at its other end. Thus hot air is drawn through conduit 35 and forced by the fan through the elongated conduit means 33. The fume-borne coke and ash that deposits in the boiler flues and are entrained in the fume filter means 7, settle into the lower portion of the fume filter means as at 36 and pass through nozzles 37 which provide communication between the fume filter means and the conduit means 33. The hot carrier air stream delivered by the fan 34 picks up separated coke and ash since the nozzles 37 work injector fashion and project the same through the nozzle means 32 in the lower part of the rear wall 2 of the fire box and thus blow gas-borne coke and ash toward the inlet end of the grate. Since conduit means 33 is elongated and is fed by a hot air stream, the coke entrained therein is at least partially gasified before it is discharged into the combustion zone so as to produce an initial turbulence in the gases within the combustion zone to enhance complete combustion. Thus the gas-borne coke and ash return nozzle means are arranged in the rear wall of the tube below the nozzle means 31 which constitute the secondary air supply nozzle means. All of these nozzle means are supplied with air at high temperature and are directed toward the front end of the grate and thus toward the incoming curtain of fuel.

Higher up, above this secondary air supply is a group, or a plurality of groups one above the other, of nozzles s_1, s_2, s_3, s_4 (Figure 4) t_1, t_2, t_3, t_4 (Figure 5) and a similar group of nozzles embodied in the bank of tuyeres or nozzles 28. These nozzles and those illustrated in Figures 4 and 5 constitute a third air supply. The jets from these nozzles are directed from different sides—preferably from the corners of the fire box—towards a single point, namely the point at which the vertical axis of the fire box intersects the plane of the jets. The nozzles for the third air supply, which are also fed with air at high temperatures, are preferably mounted on pivot means indicated diagrammatically at 38 and 39, Figures 4 and 5, so that they can swing in a horizontal plane. This makes it possible to adjust the jets to directions tangential to a circle of greater or less radius having its

centre on the axis of the fire box, and thus produce the known whirl in the furnace gases. The setting of the nozzles may be such that the direction of whirl produced by one group is opposite to that produced by the next above it.

As stated, to shield the fuel supply apparatus from radiation from the fire box and to prevent back firing of the fuel towards the bunker, a downwardly directed stream of air is produced by nozzles 15 behind the wall of heat absorbing tubes 14. This air may be preheated though not to the highest temperature. Its temperature may be the higher the poorer the fuel is in volatiles. The temperature of this air stream is adjusted by mixing cold air with hot air coming from the air heater. So long as the conveyor or fuel forwarding device is running; the highest temperature permissible for the fuel may be maintained without damage to the structure. But when the fuel supply is much reduced the temperature of the protecting stream of air should be reduced in dependence on the speed of the conveyor. This can be arranged in simple fashion by using a thermostat to operate throttle valves in the hot and cold air pipes.

Upon the supply of fuel being wholly interrupted the hot air supply is automatically shut off altogether and at the same time the amount of air supplied is reduced to a minimum. The conveyor 13 is driven by an electric motor M. This motor M also drives a tachometer device T which controls valves 29' and 30' in the respective hot and cold air pipes 29 and 30. Such valve control means are known and operate in accordance with the speed of movement of the conveyor and so control the valves that when the conveyor slows down the valve 30' is opened wider to increase the amount of cold air that is fed to the nozzles 15 while when the conveyor stops, the control impulse in the tachometer device is such that the valve 29' is closed to shut off the hot air and the valve 30' is turned to a position where a reduced supply of cold air enters and flows through the nozzle means 15. The details of the controls for the valves 29' and 30' form no part of the present invention. The speed of the motor that drives the conveyor and thus the speed of the conveyor movement and rate of fuel delivery as stated previously, can be controlled in accordance with the load on the boiler by conventional motor controls.

The arrangement shown diagrammatically in Figure 2 illustrates valve 29' closed, or crosswise of duct 29, to shut off the hot air completely; valve 30' is also crosswise of its duct 30, but as shown is truncated to allow a certain minimum cold air flow. When coil W is energized, its armature is drawn in against a coil spring to open valve 29'. The other coil W' has an armature formed with rack teeth engaging a toothed sector on the shaft of valve 30', and when energized pulls down the armature to open this valve (from its most nearly closed condition) also against a coil spring. The degree of opening will be governed by the current strength in this coil.

In Figure 2 the conveyor is presumed to be stationary, and needle N of tachometer T in its zero position, so neither coil is energized, and the valves have the positions shown. At low conveyor speeds needle N will move clockwise and complete a circuit from battery B to a sector-shaped contact C and needle N to coil W, opening valve 29'. Also, from contact C and needle N a circuit is completed to the sector resistor R and coil W' to open valve 30'. The faster the conveyor moves, the more of resistance R is included in this circuit, so that the current in coil W' falls off to allow valve 30' to close more and more, resulting in less and less cold air being admitted via duct 30. As the conveyor slows down, the effective resistance of R drops, coil W' becomes stronger, and valve 30' opens to admit more cold air and lower the temperature of the mixture. When the conveyor stops needle N is out of contact with bar C and resistance R, so valve 29' is closed to shut off the hot air completely

and valve 30' is as fully closed as possible to allow only the minimum of cold air to enter.

The operation and working of the boiler and furnace installation above described are as follows:

To set the boiler going the grate is charged with fire-lighting material, or gas or oil burners provided for fire lighting are lit. By these means the fuel delivered by the forwarding device to the front end of the grate is ignited so that upon the grate being started up its two front sections are soon charged with a burning body of coal. The undergrate blast in the middle section is now so much strengthened that "fluidisation" or pneumatic stirring of fuel begins. As soon as the rear section of the grate is charged the air pressure upon this section is slowly increased beyond the level for fluidisation of the fuel, and at the same time the separated coke and ash return and the secondary air supply are set going, and soon after that the third and fourth air supplies are turned on.

Because of the increase in air supply and pressure from front to back in the three sections of the grate a flight of sparks or incandescent granules sets in from the back to the front of the grate. This back flow effect is known, but in the conditions of operation according to the invention it is much increased. The effect is further greatly increased by the action of the gas-borne dust return, and the similarly directed secondary air supply. So from this time on incandescent particles will be flung on the front end of the grate together with the fresh fuel, and the grate will be charged with a mixture of fresh coal and incandescent material. This mixture is so fanned by the blast from beneath the grate that it at once begins to burn in vigorous fashion; so there is vigorous combustion even at the front end of the grate, of the bed of coal resting on the first section of the grate.

Under the action of the highly heated air, at a temperature of about 350 to 450° C., extremely vigorous combustion occurs in the lower zone of suspension burning both on the grate and in the suspension. The lighter particles of fuel which are carried into the upper complete-combustion zone of suspension burning are burnt to a very large extent by the third supply of air in the course of traversing the long path along which the incoming air drives them. Because the grate is fed with cold air, and at much higher pressures than hitherto, it suffers hardly any wear. Also it is practically impossible for anything to fall through the grate.

The fresh fuel is already dried and in part freed of volatiles by radiation from the very high temperature of the fire box while it is falling freely. The volatiles are burnt by the fourth air supply led in from above through nozzle means 15 to protect the fuel forwarding device. But this fourth air supply has yet another effect; it hinders particles of fuel dust from being driven upward immediately they enter the fire box by the lively uprush of gas, and reaching the upper zone of the fire box where they cannot contribute to combustion on the grate. The fourth air supply completes this "dust burning" immediately above the front end of the grate and close to the body of fresh and incandescent fuel upon the grate. Thus it helps further to raise the capacity of the grate.

The capacity of a boiler and furnace built as above described and operated according to the method of the invention is considerably greater than that of known boilers employing grate burning or coal dust burning. The fire box can be of much less height, so the boiler has not to be so high, and the total cost of a boiler installation, including a boiler house of reduced height, is greatly lessened. Notwithstanding the use of considerably higher air pressures and higher speeds of flue gases, which cause great loss of draught the operation on the whole is much more economical. There is no great expenditure of energy in grinding fuel as in coal dust burning, nor any wear of grinding mills. Only very large coal need be broken up beforehand; save for this fuels may be burnt

as they are, moist or dry. It is not necessary to damp too dry coal as usually required in grate burning, so there is no loss of heat in vapourising of the added water. Neither the water-tube-clad fire box nor the grate operating under the most favourable conditions is subject to wear. Good combustion of the gases with small excess of air and lower loss of combustible matter in the ash result in high efficiency. Complete combustion at the highest temperature makes an advantageous change in the fume-borne ash, and this together with the return of fume-borne ash and the high gas speeds prevents the much feared sooting-up of after heating surfaces and makes it possible to operate the boiler for very long periods.

It is therefore clear that the present invention provides an association with a vertically extending wall means that defines a combustion zone, a travelling grate movable from front to rear, a fuel feed means comprising a conveyor operatively associated with the front wall of the combustion zone for delivering fuel through an opening substantially midway of the height of the zone to fall upon the front portion of the travelling grate. A primary oxidizing supply means are provided for introducing preferably cold air under pressure from beneath the grate to flow upwardly therethrough, the area beneath the grate being divided into at least front, middle and rear portions with the air supplied to these respective portions being of progressively increasing pressure from front to rear. The pressure beneath the middle portion of the grate fluidizing or stirring the fuel upon the grate while a greater pressure is supplied from beneath the rear portion of the grate, elevates incandescent particles of fuel above the fire bed. A secondary oxidizing medium in the form of hot air is supplied through a bank of nozzles associated with the rear wall and directed toward the front wall at a level below the fuel inlet opening. Additionally, nozzle means are located below the last mentioned nozzle means for returning separated coke and ash through the combustion zone. Thus the secondary air supply means provides a horizontal blanketing stream that impinges upon and flings elevated incandescent particles into the falling fuel. Above the level of the feed opening are superposed banks of tuyeres or nozzles which preferably are directed into the combustion zone tangentially of a circle about a common point lying above the middle of the fire bed. These banks or nozzles elongate the flame path to ensure complete combustion. The oxidizing medium supplied through these last mentioned banks of nozzles is hot since it is air coming from an air heater located in the flue. A fourth air supply includes nozzle means located above the delivery end of the conveyor and directed downwardly to project a current of air past the delivery end and through the fuel opening together with the fuel. This current of air constitutes warm air supplied from a hot air conduit into which a cold air conduit communicates. The respective conduits are valve controlled with the control means for the valve coordinated with the drive for the conveyor so that when the conveyor slows down and thus the rate of fuel delivery decreases, the amount of cold air is increased, whereas upon cessation of movement of the conveyor the valve in the hot air conduit is closed and the valve in the cold air conduit moves to a position where only a reduced quantity of cold air is forced through the nozzle means above the conveyor.

It is clear therefore that the arrangement provides for the construction of a highly efficient boiler for burning solid fuel which can be of reduced vertical dimensions compared with known constructions which includes plural oxidizing medium supply means so coordinated and arranged relative to the introduction of medium into the combustion zone as to facilitate combustion.

I claim:

1. A boiler for burning solid fuel comprising wall means including front and rear walls defining a vertically

9

10

extending combustion zone, a travelling grate moving from front to rear within the confines of said zone, fuel feed means consisting of a conveyor above the level of said grate and disposed substantially midway the height of said zone, said front wall having an opening adjacent said conveyor, said conveyor including a delivery end forwarding all fuel through said opening to fall freely into said zone and upon said grate at the front portion thereof in a falling curtain of fuel of narrow extent with relation to the direction of grate travel, heat absorbing means between the delivery end of said conveyor and the adjacent portion of the front wall for minimizing radiation effects on the conveyor, means for supplying oxidizing medium under pressure to flow from beneath said grate upwardly therethrough at a pressure increasing toward the rear of said grate with the greatest pressure existing beneath the rear of the grate so as to lift fuel particles above the rear of the grate and means for supplying oxidizing medium under pressure to flow through the rear wall in a direction toward the front wall to project lifted fuel particles into the falling curtain of fuel, said last named means being below the level of the grate and beneath the level of the opening in the front wall.

2. A boiler for burning solid fuel including walls defining a vertically extending combustion zone, and incorporating front and rear walls, a travelling grate moving from front to rear within the confines of said zone, fuel feed means consisting of a conveyor above the level of said grate, operatively associated with the front wall substantially midway the height of said zone and extending substantially across the width of said zone, said front wall having an opening adjacent and coextensive in width with the width of said conveyor, said conveyor including a delivery end for forwarding all fuel to fall freely into said zone throughout substantially the width of the zone and upon said grate at the front portion thereof in a falling curtain of fuel of narrow extent with relation to the direction of grate travel, means for supplying oxidizing medium under pressure to flow from beneath said grate upwardly therethrough at a pressure increasing toward the rear of said grate with the greatest pressure existing beneath the rear of the grate to lift fuel particles above the rear of the grate, means for supplying oxidizing medium under pressure to flow through the rear wall in a direction toward the front wall to project lifted fuel particles into the falling curtain of fuel, said last named means being above the level of the grate and beneath the level of the opening in the front wall, and means for supplying downwardly directed air from above the conveyor and through said opening past the delivery end of the conveyor and thus adjacent the zone at which said conveyor delivers fuel to the combustion zone so that the air enters the combustion zone with the fuel and in substantially the same direction of flow so as to minimize radiation effects on the conveyor, prevent backfiring of fuel through the opening in the front wall and to constitute a further supply of oxidizing medium.

3. A boiler for burning solid fuel including walls defining a vertically extending combustion zone, and incorporating front and rear walls, a travelling grate moving from front to rear within the confines of said zone, fuel feed means consisting of a conveyor above the level of said grate, operatively associated with the front wall substantially midway the height of said zone and extending substantially across the width of said zone, said front wall having an opening adjacent and coextensive in width with the width of said conveyor, said conveyor including a delivery end for forwarding all fuel to fall freely into said zone throughout substantially the width of the zone and upon said grate at the front portion thereof in a falling curtain of fuel of narrow extent with relation to the direction of grate travel, means for supplying oxidizing medium under pressure from beneath said grate to move upwardly therethrough at a pressure increasing toward the rear of said grate with the greatest pressure existing

beneath the rear of the grate to lift fuel particles above the rear of the grate, means for supplying oxidizing medium under pressure to flow through the rear wall in a direction toward the front wall to project lifted fuel particles into the falling curtain of fuel, said last named means being above the level of the grate and beneath the level of the opening in the front wall, and means for supplying downwardly directed air from above the conveyor and through said opening past the delivery end of the conveyor and thus adjacent the zone at which said conveyor delivers fuel to the combustion zone so that the air enters the combustion zone with the fuel and in substantially the same direction of flow so as to minimize radiation effects on the conveyor, prevent backfiring of fuel through the opening in the front wall and to constitute a further supply of oxidizing medium, said last named air supply means including means for varying the temperature of said downwardly directed supply of air automatically in dependence upon the speed of the conveyor.

4. A boiler for burning solid fuel including walls defining a vertically extending combustion zone, and incorporating front and rear walls, a travelling grate moving from front to rear within the confines of said zone, fuel feed means consisting of a conveyor above the level of said grate, operatively associated with the front wall substantially midway the height of said zone and extending substantially across the width of said zone, said front wall having an opening adjacent and coextensive in width with the width of said conveyor, said conveyor including a delivery end for forwarding all fuel to fall freely into said zone throughout substantially the width of the zone and upon said grate at the front portion thereof in a falling curtain of fuel of narrow extent with relation to the direction of grate travel, means for supplying oxidizing medium under pressure from beneath said grate to move upwardly therethrough at a pressure increasing toward the rear of said grate with the greatest pressure existing beneath the rear of the grate to lift fuel particles above the rear of the grate, means for supplying oxidizing medium under pressure to flow through the rear wall in a direction toward the front wall to project lifted fuel particles into the falling curtain of fuel, said last named means being above the level of the grate and beneath the level of the opening in the front wall, means for supplying downwardly directed air from above the conveyor and through said opening past the delivery end of the conveyor and thus adjacent the zone at which said conveyor delivers fuel to the combustion zone so that the air enters the combustion zone with the fuel and in substantially the same direction of flow so as to minimize radiation effects on the conveyor, prevent backfiring of fuel through the opening in the front wall and to constitute a further supply of oxidizing medium and means for varying the temperature of said downwardly directed supply of air in dependence upon the speed of the conveyor including means responsive to cessation of movement of said conveyor and operative to direct a reduced supply of cold air past the delivery end of the conveyor upon cessation of movement of said conveyor.

5. A boiler for burning solid fuel including walls defining a combustion zone and incorporating spaced front and rear walls, a travelling grate for supporting a fire bed at the bottom of said zone and moving from front to rear therein, said front wall having an opening substantially midway of the height of the zone and extending substantially coextensive in width with the zone, fuel feed means consisting of an endless conveyor adjacent said opening and substantially coextensive in width with said opening for forwarding all fuel regardless of particle size to fall by gravity, with the falling fuel providing a downwardly flowing curtain of fuel extending substantially coextensive in width with the zone so that fuel falls upon the grate adjacent the front wall of the zone in a restricted area of narrow extent with relation

11

to the grate travel, means dividing the area beneath the grate into at least a front portion subjacent said falling fuel, a middle portion of greater longitudinal extent than said front portion and a rear portion of less longitudinal extent than said middle portion and said rear portion being disposed adjacent the rear wall of said zone, means for supplying air beneath said front portion, means for supplying air beneath said middle portion at a pressure greater than the pressure in said front portion and sufficient to fluidize the fuel upon the grate at said middle portion and to elevate fine incandescent particles therefrom, means for supplying air beneath said rear portion at a pressure greater than the pressure required for fluidization to pick up and fling larger incandescent particles upwardly from the grate, pressurized means for supplying additional and hot air through the rear wall of said zone in a horizontal blanketing stream extending throughout substantially the width of the zone and disposed in a substantially horizontal plane above said conveyor and under such pressure that said hot air impinges upon and projects said incandescent particles toward and into the curtain of falling fuel, and means for supplying additional air to said zone in vertically spaced planes above the opening in the front wall of said zone including a plurality of air jets disposed for projecting a tangential air flow within the zone in each plane, the jets in one plane being directed to provide a tangential air flow counter-current to the air flow from the jets in the adjacent plane.

6. A boiler for burning solid fuel including walls defining a combustion zone and incorporating spaced front and rear walls, a travelling grate for supporting a fire bed at the bottom of said zone and moving from front to rear therein, said front wall having an opening substantially midway of the height of the zone and extending substantially coextensive in width with the zone, fuel feed means consisting of a conveyor including a delivery end adjacent said opening and substantially coextensive in width with said opening for forwarding all fuel to fall by gravity, with the falling fuel providing a downwardly flowing curtain of fuel extending substantially coextensive in width with the zone and the fuel falling upon the grate adjacent the front wall of the zone in a restricted area of narrow extent with relation to the direction of grate travel, means dividing the area beneath the grate into at least a front portion subjacent said falling fuel, a middle portion of greater longitudinal extent than said front portion and a rear portion of less longitudinal extent than said middle portion and said rear portion being disposed adjacent the rear wall of said zone, means for supplying air beneath said front portion, means for supplying air beneath said middle portion at a pressure greater than the pressure in said front portion and sufficient to fluidize the fuel upon the grate superjacent said middle portion, means for supplying air beneath said rear portion at a pressure greater than the pressure required for fluidization to pick up and fling incandescent particles upwardly from the grate, means for supplying additional and hot air through the rear wall of said zone in the form of a blanketing stream extending throughout substantially the width thereof in a substantially horizontal plane lying above said conveyor so that said air impinges upon and projects said incandescent particles toward and into the falling curtain of falling fuel, means for supplying additional air to said zone in vertically spaced planes above the opening in the front wall of said zone including a plurality of air jets disposed for projecting a tangential air flow within the zone in each plane, the jets in one plane being directed to provide a tangential air flow counter-current to the air flow from the jets in the adjacent plane, heat absorbing means disposed between the delivery end of the conveyor and the adjacent portion of the front wall for minimizing radiation effects on the conveyor, means for supplying air to flow in a downward direction from above the conveyor and past the delivery end and through the opening in the front

12

wall adjacent the zone at which said conveyor delivers the curtain of fuel, and fly ash return means including at least one jet in the rear wall of the zone beneath the means for supplying the additional and hot air and said jet being above the fire bed at the rear portion of the grate for returning fly ash to the combustion zone.

7. A boiler for burning solid fuel including walls defining a combustion zone and incorporating spaced front and rear walls, a travelling grate for supporting a fire bed at the bottom of said zone and moving from front to rear therein, said front wall having an opening substantially midway of the height of the zone and extending substantially coextensive in width with the zone, fuel feed means consisting of a conveyor adjacent said opening and substantially coextensive in width with said opening for forwarding all fuel to fall by gravity, with the falling fuel providing a downwardly flowing curtain of fuel extending substantially coextensive in width with the zone and the fuel falling upon the grate adjacent the front wall of the zone in a restricted area of narrow extent with relation to the direction of grate travel, means dividing the area beneath the grate into at least a front portion subjacent said falling fuel, a middle portion of greater longitudinal extent than said front portion and a rear portion of less longitudinal extent than said middle portion and said rear portion being disposed adjacent the rear wall of said zone, means for supplying primary air beneath said front portion, means for supplying primary air beneath said middle portion at a pressure greater than the pressure in said front portion and sufficient to fluidize the fuel upon the grate of said middle portion, means for supplying primary air beneath said rear portion at a pressure greater than the pressure required for fluidization to pick up and fling incandescent particles upwardly from the grate, means for supplying a blanketing stream of secondary and hot air through the rear wall of said zone said stream extending throughout substantially the width thereof in a substantially horizontal plane above said conveyor so that said hot secondary air impinges upon and projects said incandescent particles toward and into the curtain of falling fuel, and means for supplying tertiary air to said zone in vertically spaced substantially horizontal planes above the opening in the front wall of said zone including a plurality of air jets disposed for projecting a tangential air flow within the zone in each plane for elongating the flame path and completing combustion, the jets in one plane being directed to provide a tangential air flow counter-current to the air flow from the jets in the adjacent plane, fume filter means for separating fume-borne coke and fly ash from the products discharged from said combustion zone, elongated air conduit means terminating in at least one nozzle in the rear wall of the zone, disposed beneath the means for supplying secondary hot air and directed toward the front wall, means providing communication between said fume-filter means and the air conduit means, and means for supplying a stream of hot air through said conduit means to pick up separated coke passing from the fume-filter means to the conduit means and ash and carry the coke and ash through the conduit means and discharge the same into the combustion zone above the rear portion of the grate in a direction toward the falling curtain of fuel, the combination of the last mentioned hot air and the length of the conduit means at least partially gasifying the coke before it is discharged into the zone to produce an initial turbulence in the gases within the zone to enhance complete combustion therein.

8. A boiler for burning solid fuel including walls defining a combustion zone and incorporating spaced front and rear walls, a travelling grate for supporting a fire bed at the bottom of said zone and moving from front to rear therein, said front wall having an opening therein substantially midway of the height of the zone and extending substantially coextensive in width with the zone, fuel feed means consisting of an endless conveyor ad-

13

14

5 jacent said opening and substantially coextensive in width
with said opening for forwarding all fuel to fall by
gravity, with the falling fuel providing a downwardly
flowing curtain of fuel extending substantially coexten-
sive in width with the zone and the fuel falling only
upon the grate adjacent the front wall of the zone in
a restricted area of narrow extent with relation to the
grate travel, means dividing the area beneath the grate
into plural longitudinally aligned portions, means for sup-
plying primary air beneath all said portions at a pres-
sure increasing from front to rear so that the increasing
air pressure first fluidizes the fuel upon the grate and
elevates incandescent and other particles of fuel from
the bed with larger particles being elevated at the area
adjacent the rear wall of the zone, and means for sup-
plying a pressurized horizontal blanketing stream of
secondary oxidizing medium through the rear wall of
the zone, said stream extending throughout substantially
the width of the zone in a plane above said conveyor
and under such pressure that said secondary oxidizing
medium impinges upon and projects the elevated par-
ticles across the zone toward and into the curtain of
falling fuel.

9. A boiler for burning solid fuel including walls de-
fining a vertically extending combustion zone, and incor-
porating front and rear walls, a travelling grate moving
from front to rear within the confines of said zone, fuel
feed means consisting of a conveyor above the level of
said grate, operatively associated with the front wall sub-
stantially midway the height of said zone and extending
substantially across the width of said zone, said front wall
having an opening adjacent and coextensive in width with
the width of said conveyor, said conveyor including a de-
livery end for forwarding all fuel to fall freely into said
zone throughout substantially the width of the zone and
upon said grate at the front portion thereof in a falling
curtain of fuel of narrow extent with relation to the direc-
tion of grate travel, means for supplying oxidizing medium
under pressure beneath said grate at a pressure increasing
toward the rear of said grate, means for supplying a
blanketing stream of secondary oxidizing medium ex-
tending substantially throughout the width of the zone
and through the rear wall in a substantially horizontal
plane at a level below the opening for projecting fuel and
incandescent particles elevated from the grate by the
medium introduced beneath the same toward and into
the falling curtain of fuel, means for supplying a tertiary
supply of oxidizing medium in vertically spaced, substan-
tially horizontal planes above the opening including in
each plane a plurality of spaced jets directed tangentially
of a circle within the zone for facilitating completion of
combustion above the opening, and means for supplying
downwardly directed air to flow from above the con-
veyor and through said opening and past the delivery end
of the conveyor and thus adjacent the zone at which said
conveyor delivers fuel to said combustion zone so that
the air enters the zone with the fuel and in substantially
the same direction of flow.

10. A boiler for burning solid fuel including walls de-
fining a combustion zone and incorporating spaced front
and rear walls, a travelling grate for supporting a fire bed
at the bottom of said zone and moving from front to rear
therein, said front wall having an opening therein substan-
tially midway of the height of the zone and extending
substantially coextensive in width with the zone, fuel feed
means consisting of an endless conveyor adjacent said
opening and substantially coextensive in width with said
opening for forwarding all fuel to fall by gravity, with
the falling fuel providing a downwardly flowing curtain of
fuel extending substantially coextensive in width with the
zone and the fuel falling only upon the grate adjacent
the front wall of the zone in a restricted area of narrow
extent with relation to the grate travel, means dividing
the area beneath the grate into plural longitudinally
aligned portions, means for supplying primary air beneath

all said portions at a pressure increasing from front to
rear so that the increasing air pressure first fluidizes the
fuel upon the grate and elevates incandescent and other
particles of fuel from the bed with the larger particles
being elevated at the area adjacent the rear wall of the
zone, means for supplying a pressurized horizontal
blanketing stream of secondary oxidizing medium through
the rear wall of the zone, said stream extending through-
out substantially the width of the zone in a plane beneath
said conveyor and under such pressure that said secondary
oxidizing medium impinges upon and projects the ele-
vated particles across the zone toward and into the cur-
tain of falling fuel, and means for supplying additional
oxidizing medium in at least one substantially horizontal
plane lying above the conveyor so that the flame path is
elongated and the blanketing stream of secondary oxidiz-
ing medium at least partially separating the combustion
zone into a coarse combustion zone portion beneath the
stream and a combustion completing portion above the
stream.

11. A boiler as defined in and by claim 10, in which
the means for supplying the additional oxidizing medium
includes at least one group of spaced jets directed tan-
gentially to a circle within the zone and lying in a hori-
zontal plane above the level of the opening.

12. A boiler as defined in and by claim 11, in which
the means for supplying additional oxidizing medium in-
clude plural groups of spaced jets with the jets of each
group directed tangentially to a circle within the zone and
lying in vertically spaced substantially horizontal planes
all above the level of the opening and with the jets of one
group directed to provide a turbulent flow of medium
counter-current to the flow from the jets of an adjacent
group.

13. A method of burning solid fuel in a vertically ex-
tending combustion zone having an upper outlet and a fire
bed travelling from front to rear thereof at the bottom
of the zone and which fire bed embodies plural aligned
portions including at least front, middle and rear portions,
said method comprising continuously dropping solely by
gravity all fuel to be burnt, upon the front portion of the
fire bed from an inlet in the front of the zone at a height
substantially midway of the height of the zone in the
form of a falling curtain of fuel of narrow extent with
relation to the direction of travel of the bed and of a
width substantially coextensive in width with the width
of the zone, introducing primary oxidizing medium under
pressure from beneath the bed under all portions thereof,
increasing the pressure of the medium introduced under
the middle portion of the bed to a pressure sufficient to
fluidize and stir the fuel thereon and to elevate fine in-
candescent particles therefrom, increasing the pressure of
the medium introduced under the rear portion of the bed
to a pressure higher than that required for fluidization
and sufficient to elevate and fling fuel particles and larger
incandescent particles upwardly from the bed, and sup-
plying additional oxidizing medium above the rear por-
tion of the bed in the form of a substantially horizontal
blanketing stream of medium directed toward the front
of the zone and extending throughout substantially the
width of the zone at a level beneath the fuel inlet and
under a pressure sufficient to entrain and project the fuel
and incandescent particles elevated from the bed across
the bed to the front of the zone to intermingle the same
with the incoming curtain of fuel.

14. A method of burning solid fuel in a vertically ex-
tending combustion zone having an upper outlet and a
fire bed travelling from front to rear thereof at the bottom
of the zone and which fire bed embodies plural aligned
portions including at least front, middle and rear portions,
said method comprising continuously dropping solely by
gravity all fuel to be burnt, upon the front portion of the
fire bed from an inlet in the front of the zone at a height
substantially midway of the height of the zone in the
form of a falling curtain of fuel of narrow extent with

15

relation to the direction of travel of the bed and of a width substantially coextensive in width with the width of the zone, introducing cold primary oxidizing medium under pressure from beneath the bed under all portions thereof, increasing the pressure of the medium introduced under the middle portion of the bed to a pressure sufficient to fluidize and stir the fuel thereon and to elevate fine incandescent particles therefrom, increasing the pressure of the medium introduced under the rear portion of the bed to pressure higher than that required for fluidization and sufficient to elevate and fling fuel particles and larger incandescent particles upwardly from the bed, and supplying hot additional oxidizing medium above the rear portion of the bed in the form of a substantially horizontal blanketing stream of medium directed toward the front of the zone and extending throughout substantially the width of the zone at a level beneath the fuel inlet and under a pressure sufficient to entrain and project the fuel and incandescent particles elevated from the bed across the bed to the front of the zone to intermingle the same with the incoming curtain of fuel.

15. A method of burning solid fuel in a vertically extending combustion zone having an upper outlet and a fire bed travelling from front to rear thereof at the bottom of the zone and which fire bed embodies plural aligned portions including at least front, middle and rear portions, said method comprising continuously dropping solely by gravity all fuel to be burnt, upon the front portion of the fire bed from an inlet in the front of the zone at a height substantially midway of the height of the zone in the form of a falling curtain of fuel of narrow extent with relation to the direction of travel of the bed and of a width substantially coextensive in width with the width of the zone, introducing primary oxidizing medium under pressure from beneath the bed under all portions thereof, increasing the pressure of the medium introduced under the middle portion of the bed to a pressure sufficient to fluidize and stir the fuel thereon and to elevate fine incandescent particles therefrom, increasing the pressure of the medium introduced under the rear portion of the bed to a pressure higher than that required for fluidization and sufficient to elevate and fling fuel particles and larger incandescent particles upwardly from the bed, supplying additional oxidizing medium above the rear portion of the bed in the form of a substantially horizontal blanketing stream of medium directed toward the front of the zone and extending throughout substantially the width of the zone at a level beneath the fuel inlet and under a pressure sufficient to entrain and project the fuel and incandescent particles elevated from the bed across the bed to the front of the zone to intermingle the same with the incoming curtain of fuel, and to provide a horizontal stream substantially throughout the zone separating the same into a coarse combustion zone portion beneath the stream and a combustion completing portion above the stream and supplying still additional hot oxidizing medium above the bed and above the fuel inlet for completing combustion of any fuel in suspension and for combustion of evolved gases.

16. A method as defined in and by claim 13, further comprising separating fume-borne fuel particles and fly ash particles from fumes leaving the combustion zone, entraining the separated particles in an elongated stream of hot oxidizing medium, projecting the stream of hot medium and entrained particles into the zone above the rear portion of the bed and in a direction toward the front of the zone at a level beneath said horizontal blanketing stream of oxidizing medium to initiate turbulence above the bed and assist the projection of rising fuel and incandescent particles into the incoming curtain of fuel.

17. A method of burning solid fuel in a vertically extending combustion zone having an upper outlet and a fire bed travelling from front to rear thereof at the bottom of the zone and which fire bed embodies plural aligned

16

portions including at least front, middle and rear portions, said method comprising continuously dropping solely by gravity all fuel to be burnt, upon the front portion of the fire bed from an inlet in the front of the zone at a height substantially midway of the height of the zone in the form of a falling curtain of fuel of narrow extent with relation to the direction of travel of the bed and of a width substantially coextensive in width with the width of the zone, introducing primary oxidizing medium under pressure from beneath the bed under all portions thereof, increasing the pressure of the medium introduced under the middle portion of the bed to a pressure sufficient to fluidize and stir the fuel thereon and to elevate fine incandescent particles therefrom, increasing the pressure of the medium introduced under the rear portion of the bed to a pressure higher than that required for fluidization and sufficient to elevate and fling fuel particles and larger incandescent particles upwardly from the bed, supplying additional oxidizing medium above the rear portion of the bed in the form of a substantially horizontal blanketing stream of medium directed toward the front of the zone and extending throughout substantially the width of the zone at a level beneath the fuel inlet and under a pressure sufficient to entrain and project the fuel and incandescent particles elevated from the bed across the bed to the front of the zone to intermingle the same with the incoming curtain of fuel, and introducing still additional oxidizing medium above the inlet and under pressure and in the form of horizontally directed jets and directing the jets from spaced points tangentially of a circle about a point over the middle portion of the bed to complete combustion of fuel, increase turbulence in the zone and thus provide an elongated flame path.

18. A method of burning solid fuel in a vertically extending combustion zone having an upper outlet and a fire bed travelling from front to rear thereof at the bottom of the zone and which fire bed embodies plural aligned portions including at least front, middle and rear portions, said method comprising continuously dropping solely by gravity all fuel to be burnt, upon the front portion of the fire bed from an inlet in the front of the zone at a height substantially midway of the height of the zone in the form of a falling curtain of fuel of narrow extent with relation to the direction of travel of the bed and of a width substantially coextensive in width with the width of the zone, introducing primary oxidizing medium under pressure from beneath the bed under all portions thereof, increasing the pressure of the medium introduced under the middle portion of the bed to a pressure sufficient to fluidize and stir the fuel thereon and to elevate fine incandescent particles therefrom, increasing the pressure of the medium introduced under the rear portion of the bed to a pressure higher than that required for fluidization and sufficient to elevate and fling fuel particles and larger incandescent particles upwardly from the bed, supplying additional oxidizing medium above the rear portion of the bed in the form of a substantially horizontal blanketing stream of medium directed toward the front of the zone and extending throughout substantially the width of the zone at a level beneath the fuel inlet and under a pressure sufficient to entrain and project the fuel and incandescent particles elevated from the bed across the bed to the front of the zone to intermingle the same with the incoming curtain of fuel, and introducing still additional oxidizing medium above the inlet and under pressure in the form of horizontally directed jets lying in a plurality of vertically spaced planes and directing the jets in each plane from spaced points tangentially of a vertical cylinder about a point above the middle of the bed.

19. A method of burning solid fuel as claimed in claim 18, and introducing the still additional oxidizing medium under pressure through the jets of one plane in a direction counter-current to the supply issuing from the jets in an adjacent plane.

17

References Cited in the file of this patent

UNITED STATES PATENTS

708,240	Mace	Sept. 2, 1902	1,943,949
1,095,489	Alford	May 5, 1914	1,970,109
1,298,530	Mann	Mar. 25, 1919	2,386,336
1,369,200	Stephens	Feb. 22, 1921	2,483,728
1,678,827	Schillinger	July 31, 1928	2,493,960
1,719,416	Bailey	July 2, 1929	127,062
1,898,479	Coghlan et al.	Feb. 21, 1933	940,023

10

18

Coghlan et al.	Jan. 16, 1934
Stratton	Aug. 14, 1934
Mosshart	Oct. 9, 1945
Glaeser	Oct. 4, 1949
Gladden	Jan. 10, 1950

FOREIGN PATENTS

Australia	Feb. 25, 1932
France	May 10, 1948