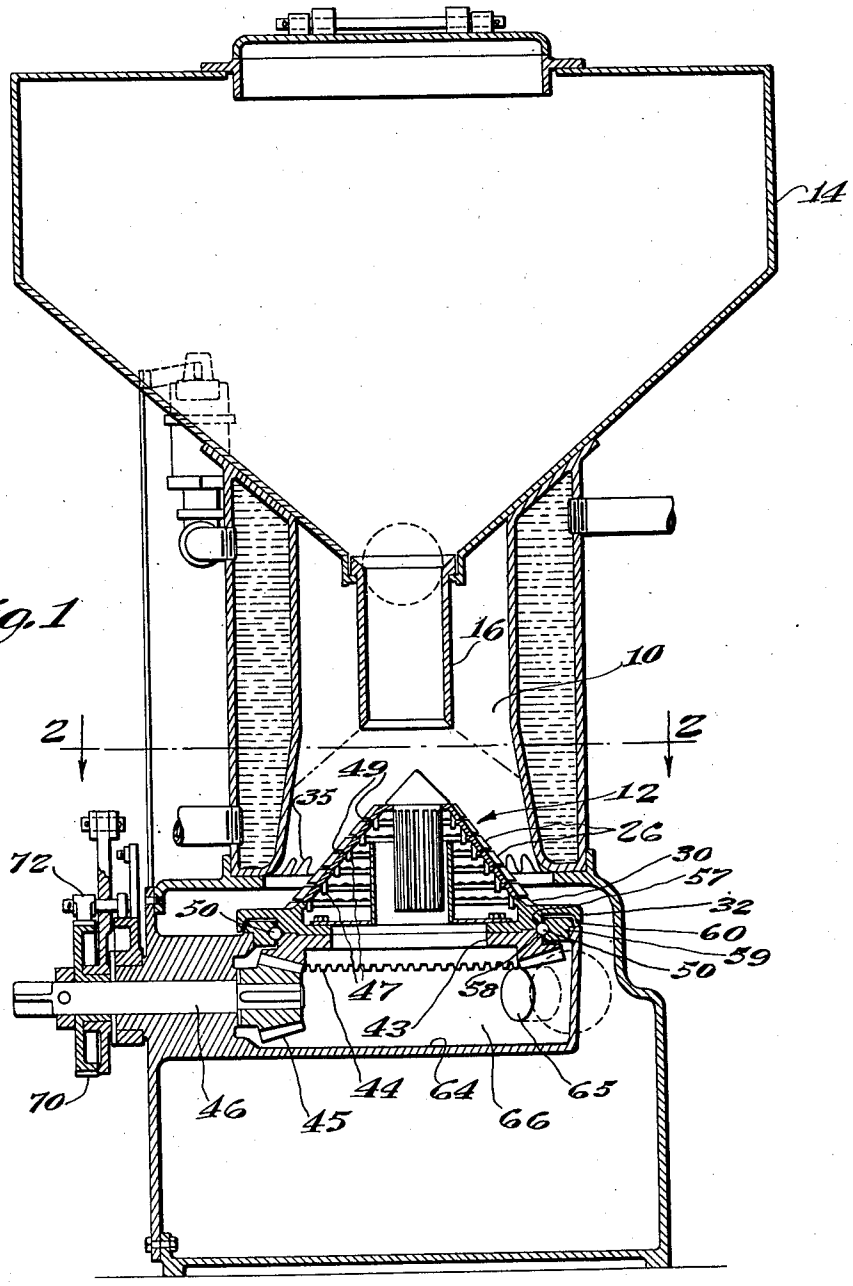
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METHOD OF AND APPARATUS FOR BURNING LOW-VOLATILE FUEL

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Fig. 1



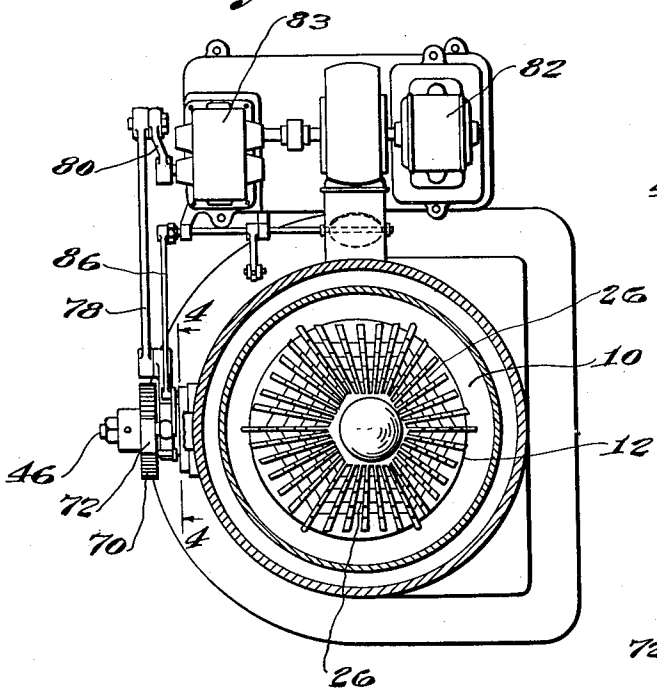
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METHOD OF AND APPARATUS FOR BURNING LOW-VOLATILE FUEL

Filed Oct. 6, 1936 2 Sheets-Sheet 2

Fig. 2



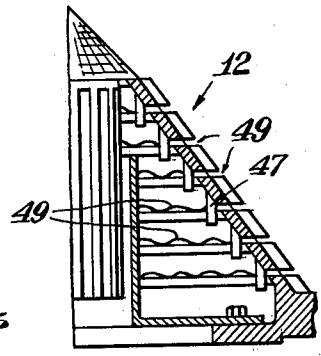


Fig. 5

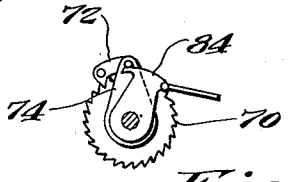
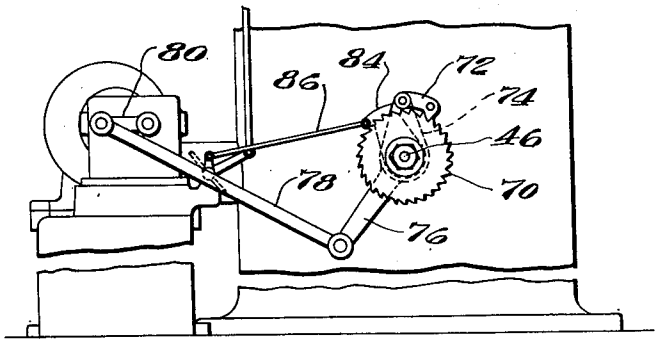


Fig. 4

Fig. 3



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Patented Nov. 14, 1939 2,180,196

UNITED STATES PATENT OFFICE

2,180,196

METHOD OF AND APPARATUS FOR BURNING LOW-VOLATILE FUEL

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Application October 6, 1936, Serial No. 104,210

12 Claims. (Cl. 110—36)

This invention relates to a method of and apparatus for burning low-volatile fuel.

This invention has for its object the provision of a novel and improved method of and apparatus for burning solid low-volatile fuel suitable for such uses as domestic heating or the provision of a hot-water supply.

With this general object in view and such others as may hereinafter appear, the invention consists in the method of and in the apparatus for burning low-volatile fuel hereinafter described and particularly defined in the claims at the end of this specification.

In the drawings, Fig. 1 is a vertical section of the preferred apparatus; Fig. 2 is a sectional plan view on the line 2—2 of Fig. 1; Fig. 3 is a side elevation of a portion of the apparatus shown in Fig. 1; Fig. 4 is a detail on the line 4—4 of Fig. 2, and Fig. 5 is an enlarged sectional detail of the grate structure illustrating the air passages therethrough.

In the burning of solid fuel for central house-heating the best performance is that which combines minimum personal attention to the fire with minimum fuel consumption, which latter in turn requires a high average thermal efficiency of combustion of the fuel. Since periodic operation involves wide variations in efficiency the conventional method of trying to maintain the average efficiency high is by maintaining it uniform, by the continuous addition of fuel and of air; but the problems arising in attempting to combine continuity of feed with freedom from manual attention have not heretofore been completely solved.

The normal overfeed combustion of solid fuel on a grate can be divided into several fairly distinct steps occurring simultaneously but in different parts of the bed. What is known as primary air comes through the bed and (*a*) burns the carbon in the fuel to carbon dioxide in the lower portion of the bed, liberating heat. (*b*) This carbon dioxide rising through the upper portion of the bed reacts with redhot carbon to form gaseous carbon monoxide with attendant absorption of a portion of the previously liberated heat. (*c*) This carbon monoxide gas, rising from the top of the bed with the volatile products distilled out of the green coal, requires additional air to burn it back to carbon dioxide and recover the heat absorbed in the second step. Such additional air must be brought in over the top of the bed, and is called secondary air. The rate at which fuel is consumed depends almost wholly on the rate of addition of primary air; the efficiency of the combustion process, on the other hand, depends on the secondary air supply. The maintenance of the right proportion of secondary to primary air over a wide range of operating rates requires complicated control devices which are practicable only on large industrial furnace installations.

Fuel engineers have known for many years that if the use of a very thin fuel bed were feasible the second step in the combustion process could be eliminated, i. e., the carbon dioxide formed in the bottom of the bed would not be reduced to carbon monoxide, and there would consequently be no need for a secondary air supply to burn the carbon monoxide back to carbon dioxide. This elimination of the need for secondary air would make the maintenance of a high thermal efficiency independent of any control of the ratio of two air supplies, which ratio tends to vary with fuel-bed condition.

The elimination of secondary air would furthermore improve the efficiency of heat transmission in the furnace chamber for the following reasons: The transfer of useful heat to the water-cooled walls of the furnace occurs chiefly by two mechanisms, radiation from the fuel bed directly to those surfaces which are exposed thereto, and convection from the gases above the bed to those surfaces over which the gases sweep. Approximately half the total transfer of heat is by each of these mechanisms. The need for heat-receiving surfaces beyond the combustion chamber and out of view of the fuel bed, such as tubes through which the hot gases pass, is dictated by the desire to get as much heat out of the gases by convection as possible. When a conventional fuel bed is used, the upper part of the bed is cooled by the heat-absorbing chemical reaction between the coke and the rising carbon dioxide as explained above. Although this chemical energy is later reconverted to heat by combustion of the gas in the space above the fuel bed, the subsequent transfer of that heat is largely by convection. In the thin-bed firing contemplated by this invention, the absence of the heat-absorbing reaction between carbon dioxide and carbon to form carbon monoxide causes the top of the bed to operate at a considerably higher temperature, for the same rate of fuel consumption. This increases the portion of the heat transferred by radiation from the bed, a rise in temperature of the bed of one per cent producing about four-per cent increase in radiation from it. There is consequently less heat to be taken out of the gases by convection; in the

gas space there is less last-minute production of heat which must be transferred from the gas to the surfaces by contact, and consequently less need for so-called convection heat transfer surfaces out of view of the fire pot.

The failure in the past to successfully exploit this principle of using a very thin bed and no secondary air, has been due to the inability to maintain a thin bed in a stable condition. If an attempt is made to maintain a thin bed on conventional fuel-burning equipment and a slight increase in rate of air flow occurs at some point in the bed, that increase is followed by an augmented local rate of combustion and a consequent enlargement of apertures between lumps which aggravates the situation by allowing still more air to flow through the bed at that point; this vicious cycle results ultimately in a so-called "chimney" or open spot in the bed through which an excess of air can flow and produce thereby a loss of furnace efficiency. Another difficulty arises when attempt is made to use a thin bed, and is the result of the tendency of adjacent lumps of fuel to fuse together and produce thereby inequalities in condition of various parts of the bed, which inequalities are rapidly magnified in the manner previously described.

In the present invention I have been able to realize the advantages of use of a thin fuel bed by constructing the grate in such a manner that the pressure drop from the air chamber to the stack-base occurs largely in the grate rather than in the fuel bed; as a consequence the distribution of air to various parts of the bed is uniform and insensitive to changes in condition of the bed. To further assist in maintenance of uniformity of flow of air in spite of thinness of the bed, the latter is given a gentle agitation just sufficient to prevent agglomeration of lumps of fuel in a state of incipient fusion, but not enough to mix the fuel and cause interchange of red-hot and green coal lumps with consequent aggravation of clinker formation. An additional feature of the grate construction is the ash seal around its edge, designed to prevent any air from reaching the chamber above the fuel bed without having passed through the live bed itself.

The method of achieving these results will become apparent in the detailed description of my device which follows:

In accordance with the method, a mass of solid fuel is supported within the combustion chamber in the form of a thin cone having its apex uppermost, and a controlled air supply is passed through substantially the entire active fuel bed in amount sufficient to maintain the bed at incandescence during the entire period of combustion, with the exception of banked firing periods; and during such period of combustion, motion is imparted to the conical fuel bed to effect gradual and progressive movement of the burning fuel and ash toward the base of the cone. Unburned fuel feeds in a self-controlled stream onto the upper portion of the conical fuel bed, and the ash is removed from the lower portion of the bed substantially as fast as it accumulates therein. The invention contemplates the feeding of the unburned fuel and the supporting of the mass of solid fuel in a cone of such character that an active fuel bed having a thickness between two and six inches, dependent on the lump size, is maintained during the entire period of combustion. The motion imparted to the conical fuel bed is, in the preferred method, of such character as to effect not only the gradual and progressive movement of the burning fuel and ash down the surface of the cone, but also to agitate or gently undulate the central and upper portions of the fuel bed to prevent the latter from fusing together and thereby to permit uniform flow of air through all parts of the bed.

Referring now to the drawings, solid fuel of low-volatile content, such as anthracite, or coke, is stored in a hopper 14, the lower portion of which forms the top of the furnace chamber 10. The bottom of the hopper 14 slopes downward to the open discharge tube 16 through which the fuel discharges onto the apex of the more or less conical fuel bed supported by the grate 12. The discharge tube 16 is preferably constructed to permit its being disengaged from the hopper 14 in order that it may be replaced at will by one of a length suitable to produce a fuel bed of a thickness appropriate to the particular size of fuel being burned; proper choice of fuel bed thickness will be considered later.

The conical grate 12 is constructed so that the angle of the conical surface thereof with a horizontal plane through the base is sufficient to insure a gradual and progressive traverse of the fuel bed supported thereon downwardly over the surface of the grate under the influence of gravity, when the grate is moved, and from experience I have found that this angle should be at least 35°, and in practice may and preferably vary between 35 and 50°.

It is preferred to construct the grate of a plurality of sections 26 arranged to interlock and to be capable of being rotated as a unit; and the lower section 30 is preferably cast to provide a skirt 32, the upper surface of which is substantially horizontal and of sufficient width to extend outwardly a substantial distance beyond and spaced from the inner wall of the lower portion of the combustion chamber. The latter is preferably provided with ribs 35 for cooperation with the rotary grate in grinding the ash and such clinker as may be formed. The skirt 32 offers a resistance to the immediate discharge of ash from the lower portion of the fuel bed supported upon the grate and in this manner cooperates with the grate as it is rotated in controlling the discharge of ash to insure a minimum amount of unburned fuel in the ash. An ash seal is provided by the ash upon the skirt 32 to prevent air from passing from the ash pit into the combustion chamber.

The grate 12 is, as herein shown, made up of a plurality of sections, and each section is provided with depending lugs 47 which cooperate with recesses in the next succeeding section to lock the sections together and to space one section a short distance from the next lower section so as to provide a series of downwardly and outwardly extending air channels 49 through which the air for effecting combustion may be caused to pass through the fuel bed supported upon the grate. These channels should be sufficiently small to offer a resistance to the flow of air through them comparable in magnitude with that offered by the fuel bed itself, in order that the distribution of air will not be affected unduly by local variations in resistance of the fuel bed. I have found that for a furnace unit intended for small house heating, a clearance of about one-thirty-second of an inch between successive sections of the grate forms an air

passage of suitable resistance. The lower section 30 of the grate is bolted or otherwise secured to a ring 43 having a ring gear 44 cooperating with a driving pinion 45 secured upon the end of a drive shaft 46 rotated by a suitable mechanism, as will be described. The grate is supported upon a series of ball-bearings 50 within a raceway formed by cooperative surfaces 57 and 58 of portions of the lower section 30 of the grate and ring 43 respectively, and the remaining side of the raceway is formed by an annular recess in a supporting ring 59 mounted upon the frame, as shown. The skirt 32 projecting from the lower section 30 of the grate is provided with a downwardly turned lip 60 extended over the supporting ring 59, illustrated in detail in Fig. 1, to thereby assist in protecting the bearings against the entrance of ash and dirt.

Because the use of a thin fuel bed in accompanied by greater difficulty in maintaining uniformity of air distribution than is common in the use of fuel beds of normal thickness, prevention of local agglomeration of fuel lumps is particularly necessary. This is accomplished, when the character of the fuel demands it, either by the use of a grate which is pyramidal in form or by constructing the grate assymetrically so that its apex is not on its axis of rotation although the circle of its base is concentric with the axis of rotation, or by combining both of these features of pyramidal form and assymetric construction. The consequence of this construction is that, while the upper part of the fuel bed facing the combustion chamber is hindered in its rotation by its anchorage with the fuel supply in the discharge tube 16, the underside of the same portion of the bed is subjected to a gentle undulatory motion, upon sedatively slow rotation of the grate. In consequence the fuel bed is periodically subjected to a local bending which is just sufficient to prevent fusion together of lumps of fuel, thereby maintaining the desired uniformity of flow of air through all parts of the bed.

The conical grate 12 is hollow and, as herein shown, cooperates with the bottom wall 64 of the burner pot to form a closed chamber 66 to which air is admitted under pressure through an air inlet pipe 65 from a convenient source of supply, as for example a blower or fan 67 driven by the motor 82. During the operation of the apparatus the air under pressure from within the closed air chamber 66 passes through the narrow air passages 49 between successive sections of the grate to supply air for the combustion of the fuel. The construction of the air pressure chamber 66 formed within the grate and burner pot serves to assist in preventing the entrance of ash or dirt into the bearings 50 by reason of the pressure through the bearings and outwardly under the projecting skirt.

In accordance with the present method, provision is made for imparting rotary movement to the fuel bed to assist in effecting a gradual and progressive and downward traverse of the incandescent fuel bed toward the base of the grate during combustion and, in practice, I prefer to effect a step by step rotary movement of the fuel bed at a relatively slow rate, such, for example, as between the limits of ¼ revolution of the grate per hour when the fire is idling and one revolution per hour as a maximum. The best rate of movement depends upon the ash content of the fuel and upon that quality of the ash which determines its ease of passage through an opening; that rate of movement is chosen which prevents excessive accumulation of ash in the fire but which corresponds to a minimum loss of unburned fuel. As herein shown, provision is made for rotating the grate from the driving shaft 46 upon which the driving gear 45 is mounted, and has affixed to its outer end a ratchet 70 with which a pawl 72 cooperates to advance the ratchet and consequently to effect rotation of the conical grate when the pawl is advanced. The pawl is carried upon a part of a pawl arm 74, as best shown in Fig. 3, which forms a part of an arm 76, the latter being connected by a link 78 to a crank 80. The crank 80 is arranged to be revolved from an electric motor 82 through the medium of a reduction gearing 83 of any usual or preferred form now upon the market. Provision is made for controlling the effective throw of the pawl 72 to control the extent of grate movement at each revolution of the crank 80, and as herein shown, a shield member 84 pivoted upon the shaft 46 is arranged to be moved relative to the pawl so as to slide under a pin projecting from the pawl to maintain the nose of the pawl disengaged from the teeth of the ratchet for the desired portion of the normal stroke of the pawl to thereby prevent it from picking up any desired number of teeth. The pivoted shield is preferably connected to a control link 86 running from a thermostat or from a manual control.

In the operation of the above described device, green fuel enters the fuel bed at its apex, is rapidly brought to incandescence, and moves slowly down the sides of the cone under the combined action of gravity and the agitation provided by rotation of the grate. The thickness of the fuel bed is established by the combination of length of the discharge tube 16, angle of inclination of the conical or pyramidal grate, rate of rotation of the grate, and the size of the fuel lumps. That combination should be chosen which produces a fuel bed thin enough not to cause excessive reaction of carbon dioxide with carbon in the upper part of the bed to form carbon monoxide with consequent need for a secondary air supply if thermal efficiency is to be maintained high, and thick enough not to allow oxygen to come through the bed unconsumed. In practice I have found a two-inch bed thickness satisfactory for pea-size fuel and six to eight inches satisfactory for stove-size fuel. One method of determining what constitutes the best thickness of fuel bed is to withdraw samples of combustion products through a water-cooled sampling tube from various points at the surface of the bed. The presence of appreciably large quantities of carbon monoxide in the gas is an indication that the bed thickness is excessive; presence of a high percentage of oxygen indicates that the bed is too thin, or that the air distribution is not uniform. I have found at the surface of the bed consistently high percentages of carbon dioxide, up to nineteen per cent, with carbon monoxide less than one per cent, when the furnace is properly adjusted; such values indicate that the amount of additional combustion necessary in the gas space above the bed is negligibly small.

As used throughout the specification and claims, the term "undulating" is intended to define motion imparted to the fuel bed. This motion is difficult to describe, resulting from the cooperation of the grate motion and the fuel feeding mechanism and it might be regarded as a motion that could be defined as a periodic bend-

ing if the fuel bed were elastic, but which functions to separate or pull apart the lumps of fuel without substantially changing their positions to thereby break up incipient fusion and maintain the desired uniformity of flow of air through the different parts of the fuel bed. The term "thin" as used throughout the claims, is intended to define fuel beds of thicknesses within the limits above set forth.

Having thus described the invention, what is claimed is:

1. In the method of burning low-volatile solid fuel in domestic heaters substantially completely without the use of a secondary air supply, the steps comprising feeding the fuel by gravity to the apex of a conical fuel bed in such a manner as to establish and maintain a thin fuel bed, producing a gentle undulating motion in the fuel bed sufficient to prevent agglomeration without effecting substantial interchanges of green and hot fuel lumps, supplying air under pressure to the under side of the fuel bed through a resistance whereby the distribution of air supply is rendered substantially independent of the character of the bed, and removing the ash from the edges of the conical fuel bed.

2. In the method of burning solid fuel, the steps comprising supplying fuel in such a manner as to maintain a conical "thin" fuel bed, gently agitating the conical thin fuel bed to break up incipient bonding of adjacent lumps of fuel without effecting appreciable interchanges in the position of the green and hot lumps of fuel in the bed, and distributing the entire air for combustion through the conical thin fuel bed through a resistance such as to insure that the rate of flow of air at any point in the active fuel bed is substantially independent of the condition of the bed at such point, and removing ash on the edge portion of the conical fuel bed substantially as fast as it accumulates therein.

3. Apparatus for burning solid fuel having, in combination, a movable conical grate, fuel supply means arranged with respect to the conical grate to maintain thereon a conical "thin" fuel bed, means for imparting to the conical grate a motion such as to effect gentle agitation of the conical thin fuel bed to break up incipient bonding of adjacent lumps of fuel in the bed without effecting appreciable interchanges in the position of the green and hot lumps of fuel therein, said grate being provided with air passages distributed over the surface thereof and of a size sufficiently small so that the rate of flow of the air through any portion of the bed is rendered substantially independent of the condition of the bed at such point, and means for supplying air under pressure beneath the conical grate.

4. In the method of burning low-volatile solid fuel substantially completely without the use of a secondary air supply, the steps comprising feeding the fuel by gravity to the apex of a conical fuel bed in such a manner as to establish and maintain a thin bed, producing a gentle undulating motion in the fuel bed sufficient to prevent agglomeration without effecting interchanges of green and hot fuel lumps by intermittently rotating the fuel bed within rates of speed from one-quarter to one revolution per hour, supplying air under pressure to the under side of the fuel bed through a resistance whereby the distribution of air supply is rendered substantially independent of the character of the bed, and removing the ash from the edges of the conical fuel bed.

5. In the method of burning solid fuel, the steps comprising supplying fuel in such manner as to maintain a conical thin fuel bed, gently agitating the bed sufficiently to break up incipient bonding of adjacent lumps of fuel without effecting appreciable interchanges in the position of the green and hot lumps of fuel in the bed, distributing the entire air for combustion through the thin conical fuel bed, and maintaining a resistance to the passage of air prior to passage through the fuel bed comparable to the resistance offered by the thin fuel bed whereby the rate of flow of air at any point in the active fuel bed is rendered relatively insensitive to the condition of the bed at such point.

6. Apparatus for burning solid fuel having, in combination, a fuel supply means including a fuel discharge tube, a grate of substantially conical shape for supporting a substantially conical fuel bed, said grate being positioned beneath the fuel discharge tube at such a distance therefrom such as to maintain upon the grate a thin fuel bed, means for preventing agglomeration of fuel lumps by imparting to the fuel bed a bending motion, said means including a grate of such construction and character of motion that the distance from any point of anchorage of the upper surface of the fuel bed at the lip of the discharge tube to the bottom of the bed immediately thereunder continually varies, said grate having a series of openings proportioned to offer a major resistance to the flow of air therethrough as compared to the resistance offered by the fuel bed itself, air supply means for distributing the air for combustion through said grate and bed, and means for imparting movement to the grate.

7. Apparatus for burning solid fuel having, in combination, a fuel supply means including a fuel discharge tube, a grate of substantially conical shape for supporting a substantially conical fuel bed, said grate being positioned beneath the fuel discharge tube at such a distance therefrom such as to maintain upon the grate a thin fuel bed, said grate having a series of openings proportioned to offer a major resistance to the flow of air therethrough as compared to the resistance offered by the fuel bed itself, means for preventing agglomeration of fuel lumps by imparting to the fuel bed a bending motion, air supply means for distributing the air for combustion through said grate and bed, and means for imparting movement to the grate.

8. In the method of burning low-volatile solid fuel substantially completely without the use of a secondary air supply, the steps comprising feeding the fuel by gravity to the apex of a conical fuel bed; maintaining the fuel bed in a "thin" condition; agitating the bed by a motion which combines a disintegrating action on the lumps to prevent incipient fusion with a crushing action at the periphery of the bed where the ash is discharged; supplying air under pressure, the distribution of which is made substantially independent of local variations in bed thickness or state of agglomeration of the lumps by maintaining a major resistance to airflow prior to the passage of air through the bed as compared to the resistance offered by the bed itself; and removing the ash from the edge of the bed in such a manner as to prevent flow therethrough of any additional air.

9. Apparatus for burning solid fuel substantially completely without the use of a secondary air supply having, in combination, means for

feeding the fuel to the apex of a conical fuel bed to establish and maintain a thin bed, a rotatable grate for supporting the fuel bed, means for rotating the grate within rates of speed from one-quarter to one revolution per hour, said grate being constructed to cooperate with the fuel feeding means and produce a gentle undulating motion in the fuel bed sufficient to prevent agglomeration without effecting interchanges of green and hot fuel lumps, said grate having a series of openings proportioned to offer a major resistance to the flow of air therethrough as compared to the resistance offered by the fuel bed itself, and air supply means for supplying air under pressure to the under side of the grate and fuel bed.

10. Apparatus for burning solid fuel substantially completely without the use of a secondary air supply having, in combination, fuel feeding means for feeding fuel to a conical fuel bed constructed and arranged to establish and maintain a thin bed, means for supplying air under pressure to the under side of the fuel bed, and means constructed and arranged to produce a gentle undulating motion in the fuel bed sufficient to prevent agglomeration without effecting interchanges of green and hot fuel lumps, said means including a pyramidal shape grate, said grate having a series of openings proportioned to offer a major resistance to the flow of air therethrough as compared to the resistance offered by the fuel bed itself, and means for intermittently rotating the grate.

11. Apparatus for burning solid fuel substantially completely without the use of a secondary air supply having, in combination, fuel feeding means for feeding fuel to a conical fuel bed in such a manner as to establish and maintain a thin bed, means constructed and arranged to produce a gentle undulating motion in the fuel bed sufficient to prevent agglomeration without effecting interchanges of green and hot fuel lumps, said means including an eccentrically mounted conical grate, said grate having a series of openings proportioned to offer a major resistance to the flow of air therethrough as compared to the resistance offered by the fuel bed itself, means for revolving said grate, and means for supplying air under pressure to the under side of said grate and fuel bed.

12. Apparatus for burning solid fuel substantially completely without the use of a secondary air supply having, in combination, fuel feeding means, a grate cooperating therewith to maintain a thin fuel bed thereon, said grate having a series of openings proportioned to offer a major resistance to the flow of air therethrough as compared to the resistance offered by the fuel bed itself, means for supplying air to the under side of the grate and fuel bed, and means constructed and arranged to produce a gentle undulating motion in the fuel bed sufficient to prevent agglomeration without effecting interchanges of green and hot fuel lumps.

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