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PULVERIZED FUEL BURNER

Filed Feb. 13, 1929

3 Sheets-Sheet 1

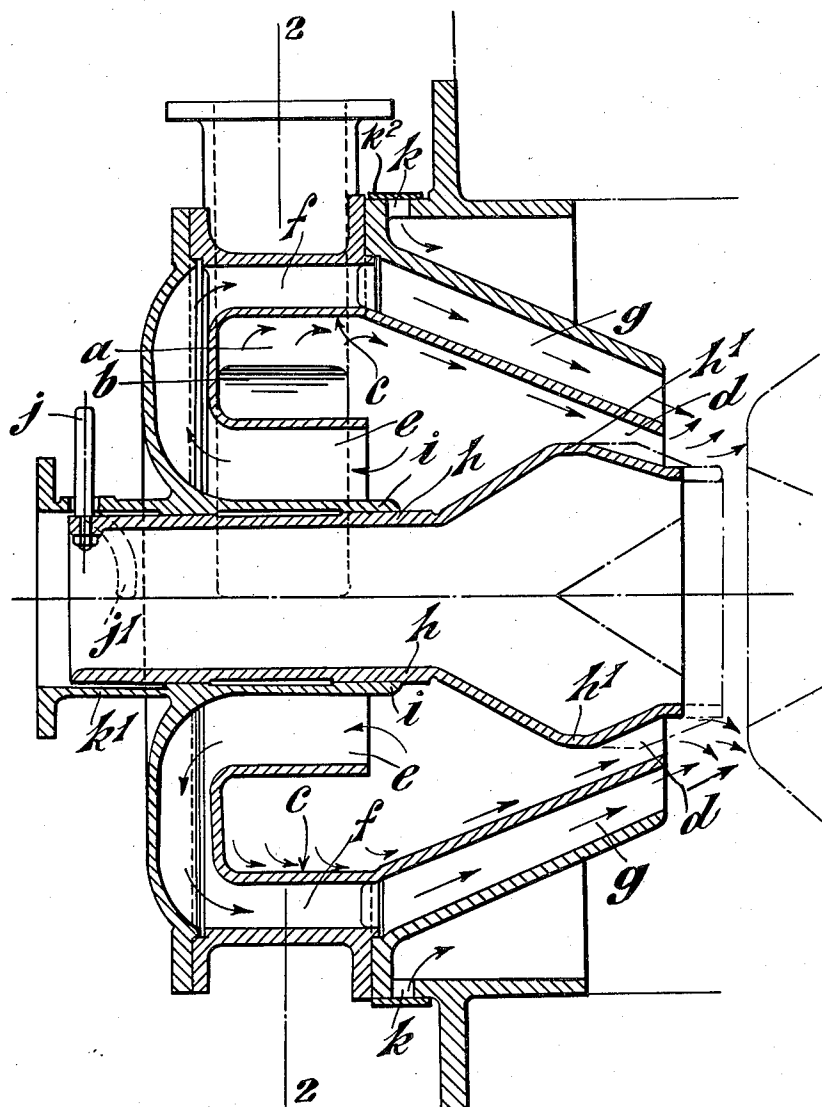


Fig. 1.

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3 Sheets-Sheet 2

Fig. 3.

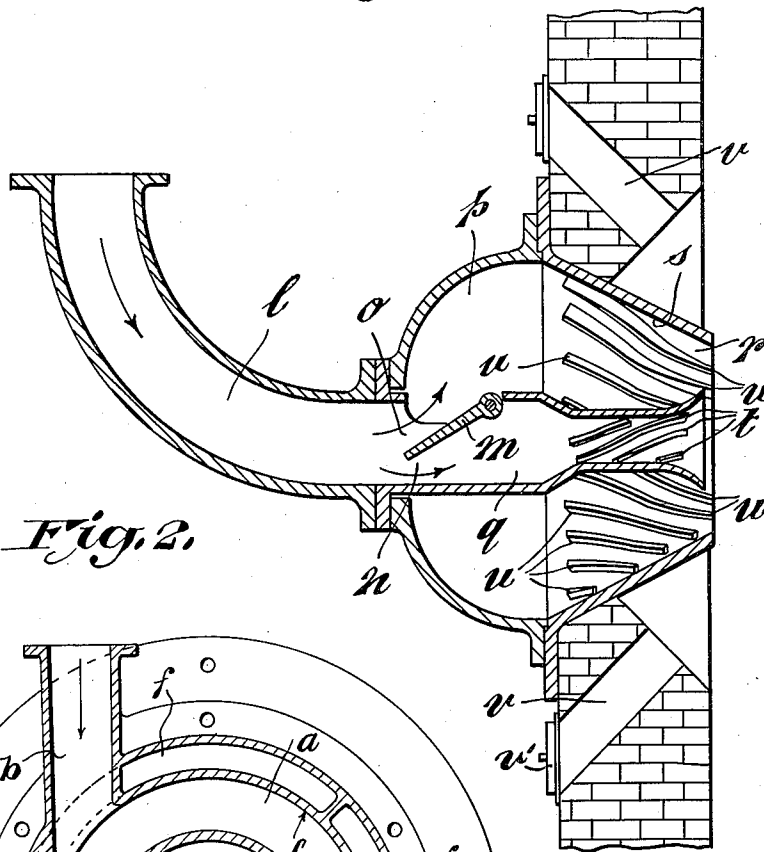
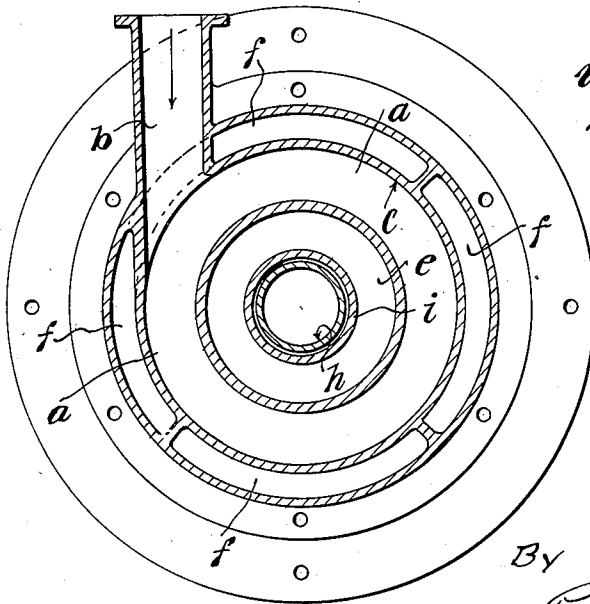


Fig. 2.



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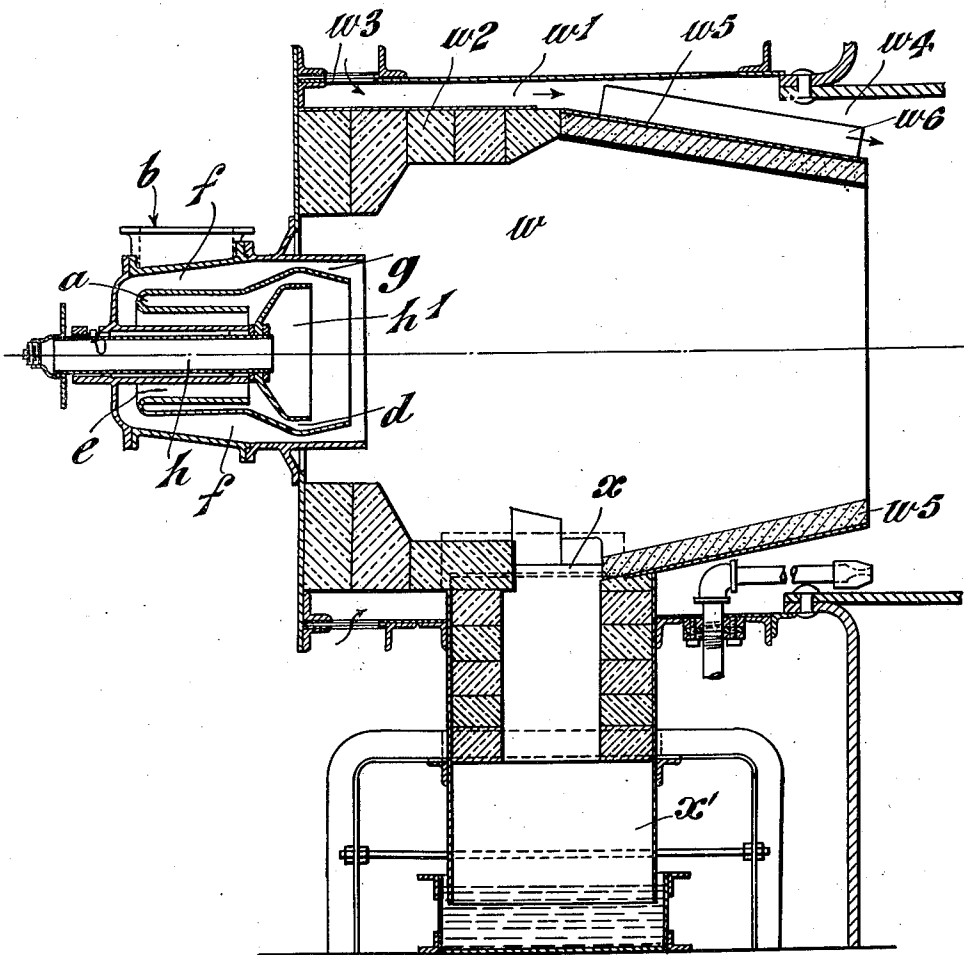


Fig. 4.

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UNITED STATES PATENT OFFICE.

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PULVERIZED FUEL BURNER.

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This invention relates to the burning of fuel and is more particularly concerned with the mixing of the fuel and air for the purpose of ensuring practically complete combustion within a few feet of the burner.

Existing methods of and devices for injecting a mixture of air and powdered fuel into a chamber for the purpose of combustion within the same are generally designed either to affect an admixture of the fuel with all the air required for its combustion within the burner, or to effect an admixture of all the fuel with a portion of the air required for its combustion within the burner, while admitting the remainder of the air at points outside the burner or along the path of the flame or both. In both these cases, turbulent movement of the fuel and air mixture is aimed at because this has been found to be an important factor in attaining rapid combustion. Turbulent motion within the mixture in the first of the two known methods referred to is effected within the burner by a stream, of comparatively high velocity, of a mixture of fuel and air which is dispersed by deflectors or vanes placed in its path and in the path of further high velocity air streams converging on the first, so that the resulting mixture in the nozzle of the burner is in turbulent movement. In the second of the two known methods referred to a mixture of part of the air and of the fuel is blown into the furnace while the remaining air required is admitted at points exterior to the burner, and generally at right angles to the path of the flame in order to maintain and increase the limited turbulent movement in the flame which was set up by the comparatively high velocity of the fuel streams exit from the burner nozzle.

When using powdered fuel it is particularly important to ensure rapid combustion, but at the same time rapid forward movement of the burning fuel cloud is found to result in very serious attrition of any refractory surfaces of the combustion chamber which are in its path, with the result that combustion chambers have been made very large compared to those used with lump fuel firing methods in order that the flame cloud shall not strike the surfaces. Shortness of the combustion zone is therefore greatly desirable, and this cannot be done unless the forward moving velocity of the burning fuel cloud is as low as possible.

In existing methods it has been found im-

practicable to reduce the entering velocity of fuel and air mixture below a value which would allow any part of the jet to be issuing from the nozzle at a slower rate than that of the flame propagation of the mixture in consequence of the resulting tendency of the flame to fire back inside the burner and supply pipes.

One of the objects of the present invention is to effect the introduction of the fuel and air into the combustion chamber in such a manner that the forward velocity of the resulting mixture may safely be less than the rate of flame propagation of that mixture.

In our experiments we have found that the rate of flame propagation of a fuel and air mixture varies with the proportion of air to fuel for a given fineness of the fuel particles. It has been found that a mixture containing less than one-third of the air required for complete combustion has a much lower rate of flame propagation than a mixture with a proportion of between half and all the theoretical air required for combustion. It has also been found that a mixture containing more than one and a half times the theoretical air required for combustion also has a much lower rate of flame propagation than one containing between half and all the air required for combustion.

The present invention, which relates to the burning of powdered fuel by the method which consists in introducing the fuel into a combustion chamber by means of carrying air, consists broadly in effecting a division of the fuel and carrying air, prior to their admission into the combustion chamber into at least two streams having different densities, one of said streams consisting of a weak mixture having substantially sufficient or more than sufficient air for the complete combustion of the fuel contained in it and the other stream consisting of a rich mixture having insufficient air for the combustion of the fuel contained in it, introducing such streams of fuel and air into the combustion chamber, with or without additional secondary air, and effecting the subsequent mixing of the two streams within the combustion chamber preferably by causing the streams to converge one upon the other just in advance of their respective outlets.

By means of the above method a floating cloud of fuel and air is formed which has a turbulent motion within itself but which,

as a body, has a forward motion the velocity of which is less than the rate of flame propagation of the mixture.

In one of these streams the amount of the air may be arranged to be equal to or more than one and a quarter times that required for complete combustion of the fuel contained in it; while in the other stream the amount of air may be arranged to be equal to or less than one third of the air required for complete combustion of the fuel contained in it.

As mentioned above the re-admixture of these two streams is preferably effected at a point immediately beyond the nozzle of the burner or other device used for their introduction into the combustion chamber and within such combustion chamber by converging the streams one upon the other, thus also producing the turbulent motion within the resulting mixture which mixture now contains the best proportion of the air and fuel for complete combustion. In the burner or other passages employed for the introduction of the two streams the velocity of the two streams of different fuel to air density may both be relatively low because the rate of flame propagation of both streams is low compared to that of the subsequent mixture which contains the proportion of air required for complete combustion. As a further result, the forward moving velocity of the mixture made by the recombining streams within the combustion chamber is still lower because the issuing velocity of the two separate streams is largely absorbed in producing turbulent eddy currents in the mixture, due to the converging direction of the streams.

The result obtained therefore by the use of our invention is to produce a floating cloud of fuel and air moving forward in the combustion chamber chiefly by the action of the furnace draught, but moving turbulently within itself due to the sudden mixture of the two converging streams of different densities. It will further be seen that any tendency to fire back into the burner and pipes is impossible in spite of the low forward velocity of the mixture because the velocity in each of the two streams is higher than the rate of flame propagation of both the very weak mixture in the one stream, and the very rich mixture in the other stream.

The division of fuel and carrying air according to the present invention may either be effected before such fuel and air reach the burner or other means for introducing the same into the combustion chamber or such division may be effected within a burner designed for the purpose. We have found that the required division may be satisfactorily effected by utilising centrifugal force such as in a conventional cyclone separator by making the fuel pass through a curved pipe forming the delivery pipe to a suitable burner or by

introducing the fuel and air into a chamber within a burner tangential to the interior circumference of such chamber.

In order that the invention may be clearly understood and carried into effect, examples of suitable burners will now be described by aid of the accompanying drawings in which:—

Fig. 1 is a vertical longitudinal section through a burner in which division of the fuel and carrying air is effected by introducing the same into the burner through a tangentially arranged inlet.

Fig. 2 is a vertical transverse section through the same burner taken on the line 2—2 of Fig. 1.

Fig. 3 is a longitudinal vertical section through another example of a burner suitable for use in carrying the present invention into effect in which the main fuel and carrying air stream is divided into two streams prior to reaching the burner by being passed through a passage in the form of a semi-circular bend.

Fig. 4 is a modified arrangement of the burner illustrated in Figs. 1 and 2.

Referring to the burner illustrated in Figs. 1 and 2, this is circular in cross section and comprises an annular chamber *a* hereafter referred to as a separating chamber, having an inlet *b* for the main stream of fuel and carrying air, which inlet is disposed at a tangent to the interior circumferential wall *c* of the chamber *a*, an outlet *d* for the stream of rich mixture, and an outlet passage *e* for the stream of weak mixture. This latter outlet causes the stream of weak mixture to flow rearwardly, and thereafter forwardly and upwardly into an annular chamber *f* surrounding the separating chamber *a* from whence it flows through an annular inwardly converging passage *g*.

The outlet *d* for the stream of rich mixture is somewhat restricted in area for a purpose hereafter to be explained and is formed on its inner side by the enlarged head *h'* of a central tubular member *h*. This central tubular member *h* is slidably supported in a bearing *i* and is longitudinally adjustable by, for example, a pin *j* carried by the tubular member and a co-acting inclined slot *j'* formed in a forwardly projecting sleeve *h'*. By adjusting the longitudinal position of the tubular member *h* and consequently its enlarged head *h'* relatively to the burner, proper regulation of the proportion of air to coal in the stream of rich mixture is obtainable. Incidentally this adjustment of the position of the head *h'* also has the effect of varying the proportion of air to coal in the stream of weak mixture, the flow of which through the outlet *e* is occasioned by the restriction in the area of the outlet *d* by the position therein of the enlarged head *h'*.

The central tubular member *h* may either

be used for the purpose of introducing secondary air into the combustion chamber or it may be used as a passage either for the insertion of the nozzle of an oil burner or for the introduction of an alternative fuel such as gas. Ports having suitable control elements for the admission of additional secondary air are indicated at k , and k^2 respectively.

By introducing the main stream of powdered fuel and carrying air into the burner by way of a tangentially arranged inlet such as b , the heavier fuel particles are by the action of centrifugal force, caused to travel around the interior circumference of the separating chamber a and out through the outlet d with sufficient air to form a stream of rich mixture, leaving the lighter fuel particles to circulate within the central zone of the chamber a and to pass out through the other outlet e with the remaining air to form a stream of weak mixture. In consequence of the formation of the final outlets from the burner, the two streams are caused to converge onto each other and to mix together within the combustion chamber immediately in advance of the burner.

In consequence of the tangential entry of the main stream of fuel and air into the separating chamber, the two divided streams of weak and rich mixtures are given a swirling or turbulent motion which eventually results in the production of a floating cloud of fuel and air having a turbulent motion within itself but which, as a body, has a forward motion, the velocity of which may be less than the rate of flame propagation of the mixture. This turbulent motion may be accentuated, if desired, by the provision of suitably inclined vanes in the burner outlets for the streams of weak and rich mixtures of fuel and air.

In the second example of burner illustrated in Fig. 3, the main stream of fuel and carrying air is caused to enter the burner through a delivery pipe l in the form of a semicircular bend. The lower or inner end of this pipe is divided by means for example of a hinged flap m to form two openings n and o , the lower opening n forming a continuation of the outer curve of the bend and being adapted to carry away the heavier fuel particles and sufficient air to form the stream of rich mixture, and the upper opening o serving to carry away the lighter fuel particles and the remaining air to form the stream of weak mixture.

The upper opening o leads into an annular chamber p surrounding a central passage q through which central passage is conveyed the stream of rich mixture. The weak mixture discharges from the annular chamber p through an annular passage r , the outer circumferential wall s of which converges towards the outlet from the central passage q , thus causing the two streams to mix in advance of the burner.

The desired turbulent motion is imparted to each stream by means of inclined ribs t and u in the passages q and r respectively. These ribs in the example shown are disposed so as to cause the streams to spin in opposite directions to each other.

Similar ribs or projections (not shown) may be arranged around the outer interior circumference of the separating chamber a for the purpose of effecting efficient mixing of fuel and air. The extremities of these ribs may be bent to check the circulatory motion of the stream of fuel and air within the chamber a . Such ribs may be inserted in the form of a detachable liner.

The openings v having control elements v' are for the admission of secondary air into the combustion chamber. It will be understood that the shape and design of the burner and delivery passages may be modified within the usual limits. In cases where an extremely short flame is not required, the properties of the fuel streams may be varied accordingly, and with the apparatus above described. For example, one of the streams may consist of such a mixture that the rate of flame propagation is low and therefore the velocity of this stream may be low while the second stream may consist of the usual mixture of between half and all the air required for complete combustion and by discharging at a comparatively high velocity either in a stream converging on the first or by being given a swirling motion to disperse its forward moving velocity and to produce turbulence by reason of its contact with the other stream.

In the application of the burner according to the present invention to combustion chambers containing no refractory surfaces, such as the furnaces of "Lancashire" and marine boilers and the water-cooled combustion chambers of water-tube boilers, a considerable amount of difficulty is experienced in lighting up the burner from cold and in maintaining rapid combustion owing to the absence of heat retaining walls and the presence of heat absorbing walls.

This trouble may be overcome by initiating combustion in a small refractory lined chamber associated with the burner outlet the arrangement being such that the ignited fuel leaves such ignition chamber before complete combustion occurs and directly enters the combustion chamber proper together with or at the same time as a quantity of secondary air sufficient to cause combustion to be completed.

One suitable arrangement is illustrated in Fig. 4, the ignition chamber receiving fuel and air from a burner similar to that shown in Fig. 1 being indicated at w . This chamber is formed with a jacket w' surrounding the refractory lining w^2 . The secondary air is preheated by being passed into this jacket through an inlet w^3 , having a suitable control

for the entering air, the preheated air leaving the jacket by way of an annular outlet w^4 surrounding the ignited fuel outlet from the ignition chamber. The ignition chamber is
 5 formed with a conical nose w^5 of carborundum or other suitable conductive material and is provided on its exterior with a plurality of straight or helical ribs w^6 thus causing the pre-heated air to converge and mix
 10 with the ignited fuel at a point beyond the outlet from the ignition chamber.

A port x communicating with a water-sealed extension x' is provided, if necessary, in the bottom of the ignition chamber for the
 15 discharge of deposited incombustible matter from the fuel.

With the arrangement just described ignition is very rapid owing inter alia, to the small mass of the refractory lining of the
 20 ignition chamber and the low forward velocity of the fuel cloud therein. Although the refractory lining is quickly heated up to a suitable ignition temperature dangerously high temperatures cannot be reached owing
 25 to the prevention of complete combustion of the fuel within the ignition chamber by curtailing the quantity of primary air.

To start the burner a small fire may be lighted within the ignition chamber or alternatively a small supplementary oil burner
 30 may be used for the purpose of heating up the walls of the chamber.

Whilst in most cases it is convenient to adapt this invention to cases where the fuel
 35 and air is supplied in a mixture to the burner and therein divided into the required number of rich and weak streams, our invention, where different systems of fuel delivery to the burner or combustion chamber are utilized,
 40 may also be carried into effect by equivalent means and such equivalent means are included within the scope of the present invention.

It will be seen that the several objects of the invention are accomplished and other advantageous results attained. As many changes could be made in carrying out the above invention, without departing from the scope thereof, it is intended that all matter
 50 contained in the above description or shown in the accompanying drawing shall be interpreted as illustrative and not in a limiting sense.

Claims:

55 1. In apparatus for burning powdered fuel, the combination of a combustion chamber, means for supplying a main stream of powdered fuel and carrying air, means for dividing said main stream of fuel and carrying air into a plurality of streams having different densities, one of said streams consisting of a weak mixture of fuel and more than
 60 sufficient air for the combustion of the fuel contained in it and the other stream consisting of a rich mixture having insufficient air

for the combustion of the fuel contained in it, and means for separately introducing said plurality of streams into the combustion chamber, and for causing said streams to mix within the combustion chamber. 70

2. A powdered fuel burner comprising a separating chamber, means in said chamber to divide a main stream of powdered fuel and carrying air into a plurality of streams of different fuel densities, an inlet for admitting
 75 the main stream of powdered fuel and carrying air into said separating chamber, said inlet being arranged tangential to said separating chamber, and a plurality of passages from said separating chamber operative to
 80 carry off the streams of different densities from the separating chamber, the outlets from said passages being disposed to effect the mixing of the streams at a point beyond the burner. 85

3. A powdered fuel burner comprising a separating chamber, means in said chamber to divide a main stream of powdered fuel and carrying air into two streams of different densities, one stream consisting of a weak
 90 mixture and the other stream consisting of a rich mixture, an inlet for said main stream of fuel and carrying air, said inlet being arranged tangentially to said separating chamber, separate passages from said chamber
 95 having outlets respectively for the streams of different densities, the outlet for the stream of rich mixture being of smaller area than the outlet for the stream of weak mixture, said passages separately conveying said streams of
 100 weak and rich mixtures out of the burner, and means for mixing said streams at a point beyond the burner.

4. In apparatus for the burning of powdered fuel, in combination, a burner, means
 105 therein to divide a main stream of fuel and carrying air into streams of different densities, one of said streams consisting of a weak mixture of fuel and air and the other stream consisting of richer mixture, passages for projecting such streams separately thru the
 110 burner, and outlets from said passages operative to converge and mix said streams at a point beyond the burner whereby to form a combustible mixture. 115

5. A powdered fuel burner comprising a main separating chamber, an inlet for admitting a main stream of powdered fuel and carrying air into said separating chamber, said inlet being tangential to said separating
 120 chamber, an annular chamber surrounding said separating chamber, a communicating passage between said separating chamber and said annular chamber arranged to pass a weak mixture of fuel and air from the separating
 125 chamber into the surrounding annular chamber, an outlet from said separating chamber for conveying a richer mixture of fuel and air from the separating chamber to the exterior of the burner, a similar outlet from the 130

annular chamber for conveying the weak mixture to the exterior of the burner, said outlets converging thereby to cause the weak and rich streams to mix outside the burner and form a combustible mixture, and means within the burner for insuring an even distribution of the fuel in the air of the stream of rich mixture.

6. In apparatus for burning powdered fuel, in combination, a refractory lined chamber constituting a mixing and pre-ignition chamber for the fuel of a burner, means associated with the burner to divide a main stream of fuel and carrying air into streams of different densities consisting of rich and weak fuel mixtures, and means for mixing said streams beyond the burner and within said refractory chamber.

7. The combination of a powdered fuel burner comprising a separating chamber, an inlet for admitting a main stream of powdered fuel and carrying air into said separating chamber, said inlet being tangential to said separating chamber, an annular chamber surrounding said separating chamber, a communicating passage between said separating chamber and said annular chamber, a refractory lined chamber, an outlet from said separating chamber having an area smaller than the area of the passage between the separating chamber and said annular chamber, said outlet communicating with said refractory lined chamber and serving to convey into said latter chamber a rich mixture of fuel and air, a similar outlet from said annular chamber also communicating with said refractory lined chamber and serving to convey into said latter chamber the weak mixture of fuel and air, said outlets converging to cause the weak and rich streams to mix within said refractory lined chamber and become ignited therein, and means within the burner for insuring an even distribution of the fuel in the air of the stream of rich mixture.

8. The process of burning pulverized fuel

which consists in dividing a main stream of fuel and carrying air into at least two streams having different densities, of which one consists of a weak mixture having more than sufficient air for the complete combustion of the fuel contained in it, and the other consists of a rich mixture having insufficient air for the combustion of the fuel contained in it, introducing said streams of fuel and air separately into a combustion chamber, and converging the streams one upon the other within the combustion chamber and after discharge from their respective outlets whereby mixing of the streams is effected.

9. The process of burning pulverized fuel, which consists in dividing a main stream of fuel and carrying air into at least two streams having different densities, of which one stream consists of a weak mixture having approximately one and a quarter times sufficient air for the complete combustion of the fuel contained in it, and the other stream consists of a rich mixture having less than one-third of the air required for combustion of the fuel contained in it, introducing said streams of fuel and air separately into a combustion chamber, and converging the streams one upon the other within the combustion chamber and after discharge from their respective outlets, whereby mixing of the streams is effected.

10. The process of burning pulverized fuel which consists in dividing a main stream of fuel and carrying air into at least two streams of different fuel densities, maintaining the velocity in each of the streams higher than the rate of flame propagation of both said streams, introducing such streams separately into a combustion chamber, and mixing said streams within the chamber and after passage from their respective outlets.

In testimony whereof we affix our signatures.

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