No. 645,031. Patented Mar. 6, 1900.

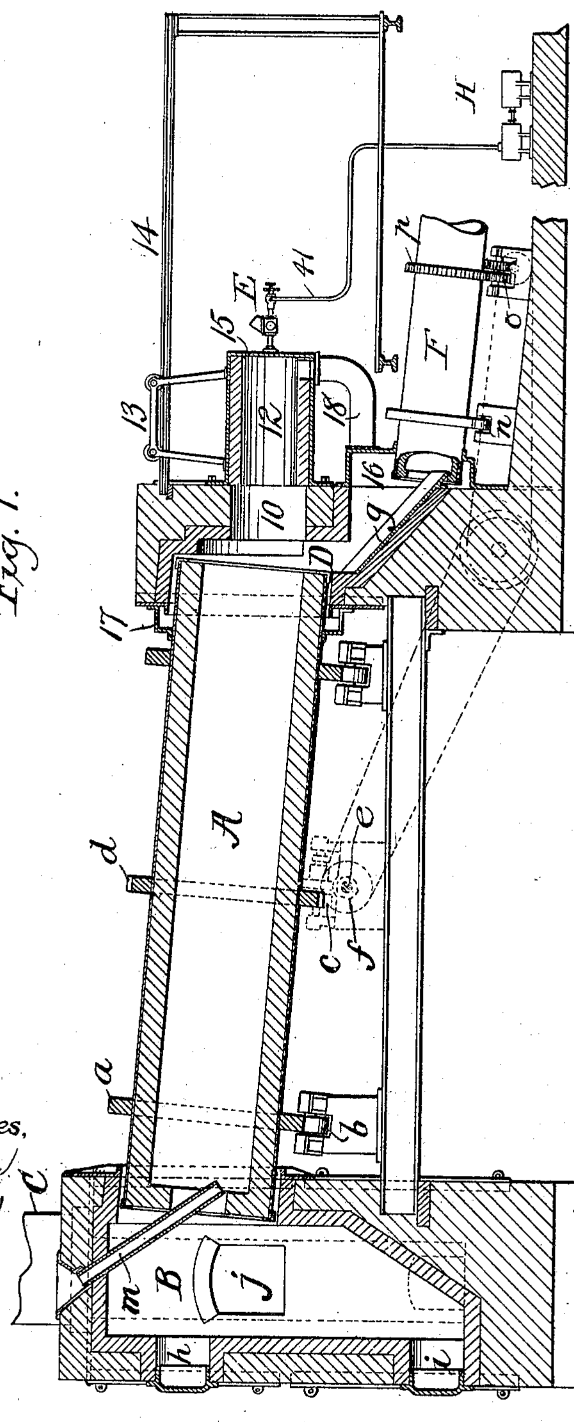
E. H. HURRY & H. J. SEAMAN.

APPARATUS FOR BURNING PULVERIZED FUEL.

(Application filed Feb. 12, 1896.)

(No Model.) 3 Sheets—Sheet I.

Fig. 1.



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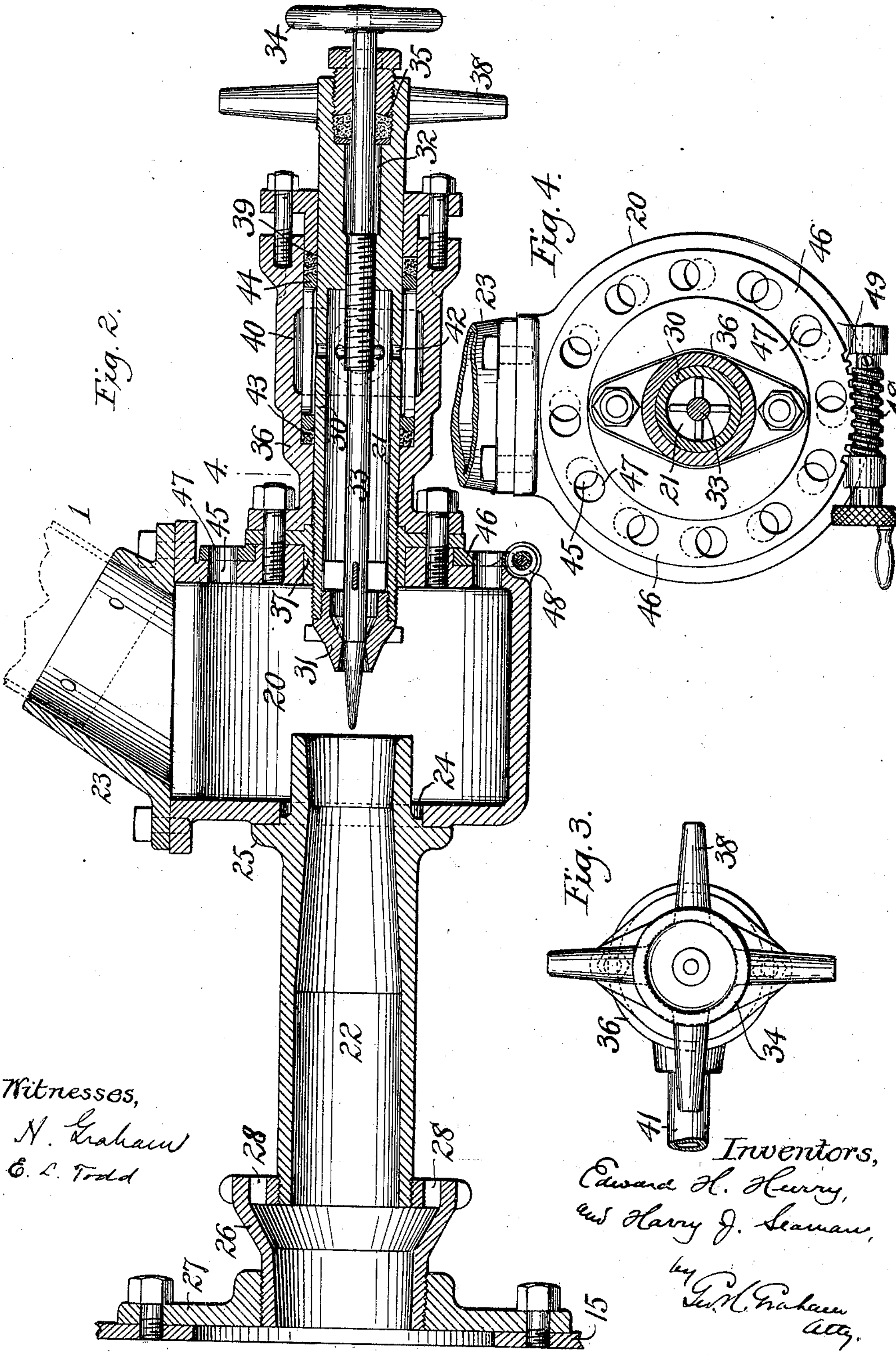

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Fig. 5.

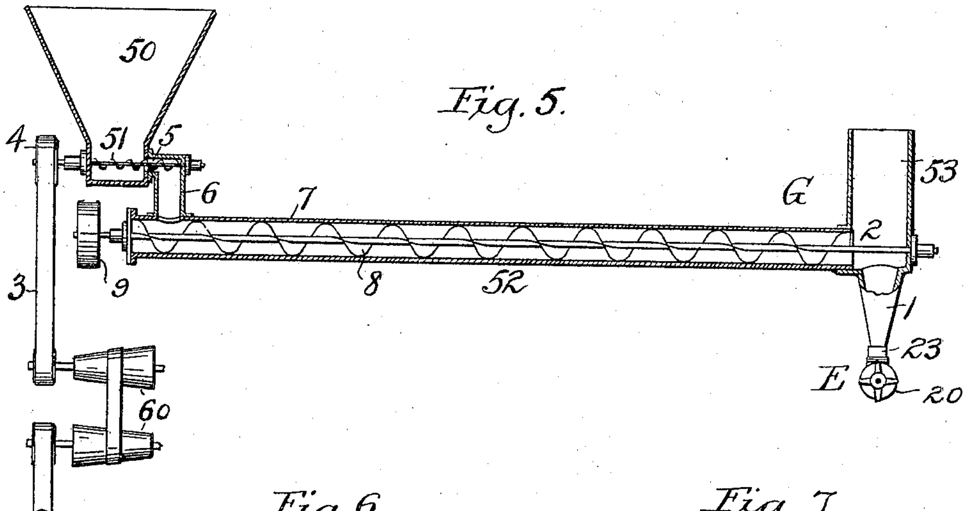


Fig. 6.

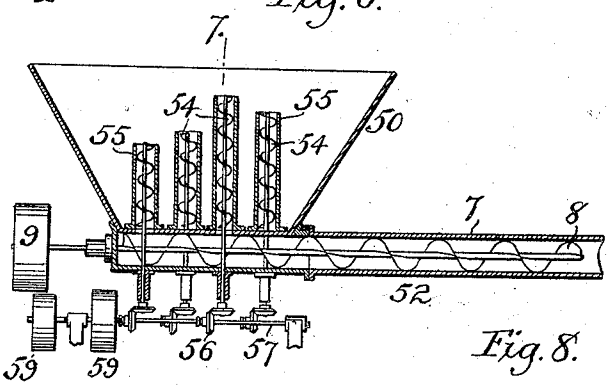


Fig. 7.

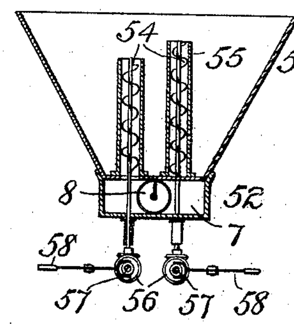


Fig. 8.

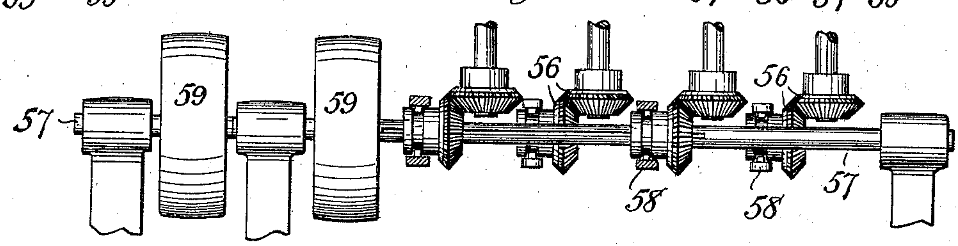
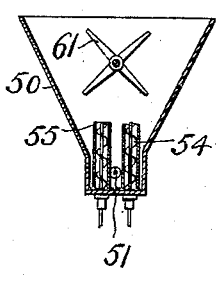


Fig. 9.



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UNITED STATES PATENT OFFICE.

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APPARATUS FOR BURNING PULVERIZED FUEL.

SPECIFICATION forming part of Letters Patent No. 645,031, dated March 6, 1900.

Application filed February 12, 1896. Serial No. 579,049. (No model.)

To all whom it may concern:

Be it known that we, EDWARD HENRY HURRY, a subject of the Queen of England, formerly residing at New York city, (New Brighton, Staten Island,) State of New York, but now residing at Bethlehem, county of Northampton, State of Pennsylvania, and HARRY JOHN SEAMAN, a citizen of the United States, residing at Catasauqua, county of Lehigh, State of Pennsylvania, have invented certain new and useful Improvements in Apparatus for Burning Pulverized Fuel, of which the following is a specification.

The invention relates generally to the burning of cement material to produce cement-clinker, and particularly to the burning of such material in rotary furnaces by means of pulverized carbonaceous fuel. The solid fuel, as coal, which we have used is pulverized to a considerable degree of fineness. In our regular practice on a large scale we reduce it to the condition of coarse flour, and in all cases it should be pulverized to such a degree of fineness that the particles tend to remain suspended in the furnace and will be consumed therein. The ash or solid residue will then be of such character that it is adapted to be carried out of the furnace with the gaseous products of combustion. The fuel so pulverized is carried into the furnace by an air-jet discharged from an injector at the delivery end of the furnace so arranged that the air-jet to which the pulverized carbonaceous fuel is supplied is located axially, or substantially so, with reference to the furnace, and the fuel is carried into the furnace in the form of a stream or core, occupying the central or axial portion of the furnace and around which additional air is supplied to maintain a perfect or substantially perfect combustion. This mode of operation is advantageous and beneficial results in the burning of cement into clinker are obtained for the following, among other reasons: The stream or core of fuel which is carried into the furnace by the air-jet and around which air is supplied to support combustion produces a core of fuel in combustion which by radiation heats the surrounding interior walls of the furnace equally, or substantially so, at all points. Similarly the cement material which is constantly descending through the rotary furnace upon the changing lower interior surface thereof is uniformly heated by radiation to the high temperature required to burn the cement material into cement-clinker. The jet of flame does not impinge upon the wall of the furnace, and destructive action thereupon for that reason does not occur, and similarly the jet of flame does not impinge upon the cement material in process of transformation into clinker, and the material or clinker is not injured by having driven or deposited into it any considerable amount of the unconsumed or solid residue of combustion, the presence of which would impair the quality of the cement.

So far as we are aware we are the first to successfully and practically burn cement material into cement-clinker by the use of pulverized carbonaceous fuel injected into the rotary furnace by means of an air-jet.

Prior to our invention in those instances where the attempt has been made to burn pulverized carbonaceous fuel in non-analogous arts the fuel has been blown into the furnace in a diffused cloud, which has been thrown directly against some one of the interior walls of the furnace and which has been diffused, so as to fill the combustion-chamber. To so introduce the fuel into a rotary cement-furnace would be objectionable and results equally as good as those attained by us could not be produced. We have demonstrated by constant practice on a large scale that the best results are produced by introducing the pulverized fuel by means of a jet of air of small volume and relatively-high pressure—say, for instance, twenty pounds to the square inch, or thereabout—furnished by a suitable compressor, and by supplying around the centrally-disposed stream or core of fuel in combustion additional air to support perfect combustion. In this way we obtain an intense heat, by which the cement material is uniformly and thoroughly burned to cement-clinker. The walls of the furnace are not injured, since this intense jet or stream of fuel in combustion does not impinge against them, while they are by radiation substantially uniformly heated. At the same time the quality of resulting cement-clinker is not injured by being irregularly burned or by having the solid residue of combustion driven into or mixed with it. The velocity or pressure of the jet of air which carries the fuel into the furnace is such that, together with the natural or additional draft of the furnace, the unconsumed solid residue of combustion substantially all passes out of the furnace with the gaseous products. At least this occurs to such extent that the presence of such solid residue, if any, in the cement-clinker is not observable.

In the organization set out in detail in the drawings and hereinafter described the axis of the pulverized-fuel injector forms a slight angle with the axis of the rotary furnace and the jet of air carries the pulverized fuel into the furnace in the form of a stream or centrally-disposed core that extends a considerable distance, if not throughout the length of the furnace. The effect of the draft and the conditions of the additional surrounding air-supply are, however, such that the jet or stream does not impinge against the lower wall of the furnace, but rises slightly and is maintained in general axial relation thereto.

While our experience demonstrates that the core or stream of fuel in combustion is most effective of beneficial results when it occupies a central position in the furnace, variations to an extent from these conditions are not fatal to good operation and the production of quite good results, nor would such variations constitute a departure from the principles of our invention as hereinafter claimed.

In naming a pressure of twenty pounds for the air-jet by which the pulverized fuel is introduced into the furnace, as described, and by the expression "high pressure" in our claims we do not intend to confine ourselves to that particular pressure, because the pressure may be less or greater.

The manner above described of burning cement material into cement-clinker in a rotary furnace with pulverized carbonaceous fuel is new. The high-pressure air is employed to forcibly carry the powdered fuel in a long compact stream into the axial or central portion of the furnace. The volume of air so used need be but a small percentage of that required to support combustion—say two (2) per centum or less—and at the same time it causes the small high-pressure injector to draw in sufficient air, with that supplied by the natural draft through the furnace, to make up the deficiency to produce perfect combustion of the fuel. By using this small percentage of high-pressure air for injecting the finely-pulverized fuel the mixture in the burner or injector is non-explosive, and hence its use is perfectly safe. Furthermore, the use of this high-pressure air produces an effective vacuum at a point in the burner where the fuel is introduced, and hence all danger of the fuel clogging is obviated. In this manner we have found from continued daily practical use that it is entirely practicable to produce an intense flame through substantially the whole length of a rotary roasting-furnace sixty feet long and maintain the walls of the furnace at the white heat necessary to produce a high grade of cement containing so small a percentage of the solid residue of the products of combustion as to require no change in the proportions of the mixture to form the same grade of cement as might be made in the absence of the solid residue.

The feed of the pulverized fuel to the injector, the effectiveness of which depends so much upon the substantially-unvarying supply of such fuel, is obtained in the present instance from a hopper forming a fuel-supply from which a constant, compact, and limited quantity is taken by a primary feeder, which continuously discharges such limited quantity into a larger compartment or conduit and thence taken by a secondary feeder, which simultaneous with its onward carrying movement subjects the powdered fuel to a violent agitating or tossing action, so that it issues from said conduit in an unvarying cloud and is in such condition taken by the injector. Means are also provided for preventing the bridging of the fuel in the hopper, and in consequence its failure to feed. The quantity of fuel fed from the hopper or conveyed to the secondary feeder may by novel means be regulated to a nicety.

In order to aid a more complete understanding of the nature and scope of the improvements, we have illustrated in the accompanying drawings an improved apparatus for roasting the cement material and conducting the clinker onward, embodying also an apparatus adapted to the practical carrying out of the improved process, the apparatus chosen for illustration being the preferred form, but which is obviously capable of modification without departing from the essentials of the invention.

In said drawings, Figure 1 is a sectional elevation of a roasting plant embodying a portion of the present improvements and adapted to the carrying out of the novel process. Fig. 2 is a longitudinal sectional elevation of the improved burner or injector. Fig. 3 is an end elevation of a portion of the burner. Fig. 4 is a cross-section of the burner on the line 4 of Fig. 2. Fig. 5 is a longitudinal sectional elevation of the fuel-feeder, showing a rear view of the burner and the changeable-speed driver for the primary feeder. Fig. 6 is a like section of a modified form of the primary feeder. Fig. 7 is a cross-section of the same on the line 7 of Fig. 6. Fig. 8 is an enlarged elevation of the gearing for driving the primary feeder. Fig. 9 is a cross-section of a further modification.

Before entering into a detailed description of the apparatus for roasting cement material it may be premised that in the manufacture of cement, so far as the apparatus as herein shown is concerned, the cement material is fed in a continuous stream into the roasting-furnace, preferably an inclined rotary furnace, with the inflammable mixture or flame entering the furnace at its exit end and projected therethrough toward the entrance end of the material or stack in a direction opposed to the onward travel of the material being roasted. In its passage through the furnace the material gets hotter and hotter until it gets within the hottest zone of the flame, when the particles of the raw material combine and form the cement-clinker, in which condition the red or white hot clinker masses pass, preferably, into a conduit consisting of a rotary cylinder for further treatment. A natural current of air passes through the conduit, becomes highly heated by the presence of the hot clinker therein, and passes thence to the furnace to support combustion of the carbonaceous fuel injected therein by the burner hereinafter described.

The apparatus in the preferred, but not necessary, embodiment of the invention, as shown in Fig. 1, consists of a rotary cylindrical furnace A, comprising an exterior metallic shell or casing lined with fire-brick and mounted in a horizontally-inclined position having tracks *a*, which bear upon roller-bearings *b*, rotary motion being imparted to the furnace by a pinion *c*, meshing with a toothed wheel *d* on the furnace-shell, the pinion being driven in any proper manner, as from a driven worm-shaft *e* and worm *f*. The upper or entrance end of the furnace A projects into the upper end of a vertical chamber B, forming at its lower portion an ash-pit and having connection with a stack C for the escape of the waste heat and such solid products of combustion as may be carried by the draft, while the opposite or exit end of the furnace projects into an exit-chamber D, having an inclined floor or chute *g* for leading off the hot clinker falling from the furnace. The two chambers B and D are formed by masonry lined with fire-brick to withstand great heat. The chamber B has an opening *h*, closed by a door directly opposite the entrance end of the furnace, to view, if need be, the interior of the furnace, and the lower portion of the chamber below the entrance of the furnace forms the ash-pit, to which access may be had through a lower opening *i*, closed by a door, the communication of the chamber with the stack being had through an opening *j*, preferably at the side of the chamber. This chamber B also has a conduit *m*, water-jacketed, if need be, leading from top of the chamber to the entrance end of the furnace for the feed thereto of the material from any suitable source of supply. The chamber D is formed with an opening 10 in line with the open end of the rotary furnace A, which opening is continued by a cylindrical fire-brick-lined chamber 12, supported by a trolley 13, adapted to travel on the track 14, with the chamber longitudinally away from the chamber-opening 10 for access to the end of the furnace. Normally this combustion-chamber 12 will be bolted to the extreme wall of the chamber D, as shown, to prevent accidental movement and to stop the ingress of cold air to the furnace. The outer end of the chamber 12 is closed by a plate 15, to which the end of the burner E is secured, as is best seen in Fig. 2, which when in operation, as will be presently described, injects the powdered fuel with the small volume of high-pressure air to form and maintain a long intense heating-flame through the rotary furnace A. The inclined floor or chute *g* of this exit-chamber D leads the red-hot and freshly-made clinker directly into the entrance end of a conduit F, consisting of a horizontally-inclined rotatable cylinder, through which the hot clinker is more or less slowly conducted to its exit end against a natural draft of air therethrough and which is thereby intensely heated to pass upward into the furnace to aid and support the combustion of the fuel injected by the burner E. The cylindrical conduit F is mounted like the furnace A to revolve on roller-bearings *n* and rotated by a pinion *o*, meshing with a toothed wheel *p* on the cylinder, the pinion being driven in any proper manner not necessary to describe.

The more or less open connection between the cylindrical conduit F and the exit from the chamber D is closed against ingress of cold air by a fixed shield 16, closely fitting the periphery of said conduit, and in like manner the connection between the exit end of the furnace A and the chamber D is closed by a shield 17, these shields permitting the complete utilization of the very hot air, which under a natural and induced draft passes onward from the conduit F through the rotary furnace to support the combustion of the fuel injected by the burner into such furnace. A portion of this heated air is diverted from passing directly into the chamber D and is conducted by a pipe 18, connected one end to the shield 16 and the other end detachably connected coincident with an opening in the bottom of the chamber 12, so that a portion of the heated air needed to support the combustion of the fuel injected by the burner meets such fuel somewhat earlier than the remainder of the heated air to become more or less intimately mixed with the fuel before it enters the furnace.

An improved form of burner E, capable of injecting and burning pulverized fuel with a limited volume of high-pressure air as the injecting fluid, is shown in detail in Figs. 2, 3, and 4. Said burner consists of a fuel-receiving chamber 20, a high-pressure-air conduit 21, leading to said chamber, and a mixture-directing tube 22, leading from said chamber, the longitudinal axis of the tube being coincident with the axis of the air-conduit. The chamber 20, as shown, is of cylindrical contour with vertical heads and having at its upper end a spout 23, forming a portion of the vertical passage for the fuel from the feeding device G. (See Fig. 5.) Its front wall or head has an opening 24, in which is fitted the rear end of the directing-tube, and in its rear head an opening in which is fitted the forward end of the air-conduit. The mixture-directing tube 22 has its rear end projecting a short distance into the fuel-receiving chamber, the opening of said tube slightly contracting and then gradually enlarging toward the furnace into the full diameter of the tube. The rear portion of this tube has a flange 25 for bolting to the front wall of the chamber 20. The front end of the tube is screw-threaded into an enlarged conical or bell-shaped head 26, whose front end is screw-threaded into a plate 27, secured to the end plate 15 of the chamber 12. The larger rear end of the bell-shaped head is formed with air-openings 28, surrounding the front end of the tube 22, through which openings a limited quantity of atmospheric air is drawn into the bell-shaped head to pass onward with the fuel injected into the combustion-chamber 12.

The air-conduit 21 consists of a tubular shell 30, terminating within the fuel-chamber in a contracted nozzle or nosepiece 31, screw-threaded to the end of the conduit, and the opposite end of the conduit has a smaller central perforation 32, partially screw-threaded to receive a central spindle 33, forming a needle-valve, with its forward portion having radially-projecting guides and its end controlling the size of the orifice through the nosepiece 31 and its outer end passing through a stuffing-box 35 in the outer end of the air-conduit and having a handle 34 for adjusting said valve. The air-conduit is supported by a casing 36, that is flanged at its forward end and bolted to the rear head of the fuel-chamber 20. Intermediate between said end of the casing and the chamber is interposed the flange of an internally-screw-threaded ring or nut 37, the threads of which are engaged by the forward threaded end of the air-conduit, the outer end of the shell 30, forming said conduit, passing through a gland 39 in the casing and having grasping projections 38 to adjust the shell within the casing with respect to said nut to vary the extent of projection of the nosepiece end thereof within the chamber 20.

The casing 36 is formed with an annular chamber 40 in communication with the high-pressure supply-pipe 41, whose end is screwed into the side of the casing, (see Fig. 3,) and said chamber communicates with the air-conduit 21 through openings 42 in the shell 30. In addition to the outer stuffing box or gland 39, which is located at one side of the annular chamber 40, there is provided another packing 43 on the opposite or inner side of said chamber, the two packings being separated by a spacing-ring 44, so that both packings may be tightened by the single outer gland 39 to prevent the escape of the high-pressure air in either direction along the shell 30. The spacing-ring has lantern-openings, which permit free passage of the air from the annular chamber to the air-conduit 21.

In addition to the air admitted through the openings 28 to the bell-shaped head 26 the fuel-receiving chamber is provided in its rear head or wall with a plurality of openings 45 (see Figs. 2 and 4) to admit a limited quantity of atmospheric air to said chamber to intimately mix with the fuel being injected forward through the tube 22. These openings are capable of being varied in size by an adjusting-ring 46, supported on the rear head of the chamber 20 concentric with the axis of the air-conduit 21 and having openings 47, adapted to register with said openings 45 in the chamber. The ring may be turned in any desired manner, as by a worm 48, engaging worm-teeth 49 on the periphery of the ring.

The fuel-feeder G, before referred to, consists of a hopper or source of supply 50, a primary feeder or conveyer 51 for positively feeding a predetermined quantity of fuel from the hopper, and a secondary feeder or conveyer 52 for receiving the fuel from the primary feeder and delivering the fuel in an agitated cloud to the burner E.

The hopper or bin 50 (see Fig. 5) may be of any desired form and capacity and having a closed bottom. Just above the bottom is mounted the primary feeder 51, consisting in this instance of a horizontal worm mounted in suitable bearings and rotated by a belt 3, passing around a pulley 4, fast to the shaft of the worm. The worm passes through a passage 5, (preferably longer than shown,) which extends from the hopper to a vertical chamber 6, that communicates with the secondary conveyer 52. In the rotations of this small worm conveyer 51 a small compact body of pulverized fuel is positively and continuously conveyed from the hopper to the chamber 6, down which it falls by gravity into the secondary conveyer. This secondary conveyer 52 consists of a closed horizontal and longitudinally-arranged chamber or tube 7 and a longitudinal worm 8, extending the length of the chamber 7 and mounted to rotate in suitable bearings in the end walls of the chamber, with a pulley 9, fast to the worm-shaft, to rotate it. The diameter of this worm 8 is, say, six inches to one and one-half inches, the diameter of the worm conveyer 51, and with a much quicker spiral than said worm 51 and much faster rotated, so that immediately the small continuous supply of fuel is received in the chamber 7 it is subjected to a violent tossing action as it is carried along the chamber, with the result that when the agitated fuel arrives at the mouth 2 of the chamber it has been tossed into a thick cloud and in such condition descends the tube 1 and spout 23 into the fuel-chamber 20 of the burner, such descent being materially aided by the partial vacuum induced in the chamber 20 by the injected high-pressure air. The agitation of this cloud of fuel discharged from the mouth of the conveyer 52 is so great that it is requisite to provide a vertical open-ended shield 53 above the discharge end of the conveyer to prevent waste of the fuel.

The speed of the primary conveyer 51 may be varied by driving from a pair of cone-pulleys 60, while the speed of the secondary conveyer may be invariable.

In the modified form of the primary feeder shown in Figs. 6 and 7 such feeder consists of a number of worm conveyers 54, projecting vertically into the lower portion of the hopper 50, each conveyer being inclosed by open-ended tubes 55, which serve to direct a continuous compact body of fuel from the hopper into the chamber 7 of the secondary conveyer 52. These tubes and worm conveyers may be of different heights, so as to feed from different levels of the fuel in the hopper, and thus prevent bridging of the fuel therein. These vertical worm conveyers have their shafts extending through the chamber 7 and are driven by bevel-gears 56 from a pair of horizontal shafts 57, two of the worm conveyers rotated by one shaft and the other two by the other shaft. Each of the bevel-gears on the shafts is adjustable thereon (see Fig. 8) to disconnect any one or more of the worm conveyers therefrom, so as to vary the quantity of fuel fed to the conveyer 7, and for this purpose the gears may be splined to the shafts and each moved thereon by a forked shifting lever 58 of ordinary form. Each shaft will be driven by belts passing around pulleys 59, secured to the end of the shafts.

It is of course apparent that the vertical forms of primary worm conveyers may be combined with the horizontal form, as is indicated in Fig. 9. So, too, the fuel in the hopper may be independently stirred and kept from packing by a rotating arm or blade 61.

With the apparatus thus constituted a continuous uniform quantity of pulverized fuel in the form of a cloud is fed to the burner E. The high-pressure air is supplied by an air-compressor H (see Fig. 1) to the air-conduit 21 of the burner, say, at about the pressure of twenty pounds to the square inch, the volume issuing from the nozzle thereof being limited, and may be still further lessened by the adjustment of the valve 33. From practical use of this apparatus we have found that somewhat less than two per cent. of the air necessary to support complete combustion of the pulverized fuel injected is only needed to cause the fuel to be carried fully into the roasting-furnace. The use of this limited volume of high-pressure air for the injecting fluid causes the fuel to be injected in a long compact body, the particles of which are held suspended in the blast comparatively close together, so that during combustion a long concentrated intense flame is produced capable of most thoroughly maintaining the lining of the furnace at the white heat necessary to form a high grade of cement. The fuel thus being injected into the furnace with simply enough fluid to suspend its particles and carry the fuel onward, the vacuum induced by the force of the jet may cause independent supplies of atmospheric air to move onward with the fuel, such supplies being added at separate points along the travel of the injected fuel until finally when the fuel reaches the furnace and is in the presence of the natural draft of heated air therethrough sufficient air will be present to support perfect combustion. The vacuum produced in the fuel-chamber by the jet of high-pressure air passing from the nozzle 31 into the tube 22 is such as to carry every particle of fuel fed to the fuel-chamber by the feeding device described into said tube, so that after long use no fuel has been found to remain in the bottom of said chamber. This vacuum, which has been found to be equal to from five to six pounds, serves to hasten the feed of the fuel down the feed-tube 1 into the fuel-chamber, prevent clogging in said tube, and also serves to draw in such air behind the fuel as will be permitted to enter through the openings 45. The air, it should be understood, admitted by the openings 45 and 28 is only a small percentage of the total amount of air needed to support combustion of the quantity of fuel injected by the burner into the furnace, it being the intention to rely upon the natural current of heated air passing from the conduit F into the rotary furnace for sufficient air to support combustion. In addition to the effect of this limited volume of high-pressure air in forming a long intense flame it is apparent that in the use of the burner there is at all times insufficient air combined with the pulverized fuel while in the burner and its adjuncts to form an explosive mixture, so that its use is never unsafe. The force of the injected fuel, together with the natural draft through the roasting-furnace toward the chamber B, is such that we have found practically all of the solid residue of combustion to be carried into said chamber B to either escape up the stack C or to fall into the ash-pit, and hence no change in proportions of the cement materials fed to the furnace has been found necessary.

What is claimed is—

1. The combination with a furnace having an elongated combustion-chamber, of means for injecting axially thereinto a jet of air of high pressure and small volume, means for feeding to such air-jet pulverized carbonaceous fuel which is carried by and with the air-jet into the furnace in a long and relatively-compact stream of less cross-section than the combustion-chamber, and means for supplying an additional volume of air to the furnace whereby a core of pulverized fuel in combustion surrounded by air to support com-

bustion is produced in the furnace to uniformly heat the walls of the furnace by radiation without impinging thereupon.

2. The combination with a furnace having an elongated combustion-chamber, of means for injecting axially thereinto a jet of air of high pressure and small volume, means for feeding to such air-jet pulverized carbonaceous fuel which is carried by and with the air-jet into the furnace in a long and relatively-compact stream of less cross-section than the combustion-chamber, means for supplying around said air-jet on its way to the furnace an additional volume of air, and means for supplying a further volume of air to the furnace, whereby a core of pulverized fuel in combustion surrounded by air to support combustion is produced in the furnace to uniformly heat the walls of the furnace by radiation without impinging thereupon.

3. The combination with a rotary cement-furnace having an elongated combustion-chamber, of means for injecting axially thereinto a jet of air of high pressure and small volume, means for feeding into the path of said air-jet pulverized carbonaceous fuel suspended in air so as to form a fuel-cloud of uniform or substantially-uniform density, which is carried by and with the air-jet into the furnace in a long and relatively-compact stream of less cross-section than the combustion-chamber, and means for supplying a further volume of air to the furnace, whereby a core of pulverized fuel in combustion surrounded by air to support combustion is produced in the furnace to uniformly heat the walls of the furnace by radiation without impinging thereupon.

4. The combination with a rotary cement-furnace having an elongated combustion-chamber, of means for axially injecting thereinto a jet of air of high pressure and small volume, means for feeding into the path of said air-jet pulverized carbonaceous fuel suspended in the air so as to form a fuel-cloud of uniform or substantially-uniform density which is carried by and with the air-jet into the furnace in a long and relatively-compact stream of less cross-section than the combustion-chamber, means for supplying around said air-jet on its way to the furnace an additional volume of air and means for supplying a further volume of air to the furnace whereby a core of pulverized fuel in combustion surrounded by air to support combustion is produced in the furnace to uniformly heat the walls of the furnace by radiation without impinging thereupon.

5. The combination with a rotary cement-furnace having an elongated combustion-chamber, of means for feeding material to be treated therein at one end thereof, a conduit connected with the other or delivery end through which the material discharged from the furnace passes, means for axially injecting into the delivery end of the furnace a jet of air, means for feeding to said air-jet pulverized carbonaceous fuel which is carried by and with the jet into the furnace, and a stack or draft device connected with the feed end of the furnace by which air is drawn into the furnace through the discharge-conduit in contact with the heated material therein, whereby a core of pulverized fuel in combustion surrounded by air to support combustion is produced in the furnace to uniformly heat the walls of the furnace by radiation without impinging thereupon.

6. The combination with a rotary cement-furnace having an elongated combustion-chamber, of means for feeding material to be treated therein at one end thereof, a conduit connected with the other or delivery end through which the material discharged from the furnace passes, means for injecting axially into the delivery end of the furnace a jet of air of high pressure and small volume, means for feeding to said air-jet pulverized carbonaceous fuel which is carried by and with the jet into the furnace in a long and relatively-compact stream, and a stack or draft device connected with the feed end of the furnace by which air is drawn into the furnace through the discharge-conduit in contact with the heated material therein, whereby a core of pulverized fuel in combustion surrounded by air to support combustion is produced in the furnace to uniformly heat the walls of the furnace by radiation without impinging thereupon.

7. The combination with a rotary cement-furnace having an elongated combustion-chamber, of means for feeding material to be treated therein at one end thereof, a conduit connected with the other or delivery end through which the material discharged from the furnace passes, means for injecting axially into the delivery end of the furnace a jet of air of high pressure and small volume, means for feeding to said air-jet pulverized carbonaceous fuel which is carried by and with the jet into the furnace in a long and relatively-compact stream, means for supplying around said jet on its way to the furnace a further volume of air to support combustion in the furnace, and a stack or draft device connected with the feed end of the furnace by which air is drawn into the furnace through the discharge-conduit in contact with the heated material therein, whereby a core of pulverized fuel in combustion surrounded by air to support combustion is produced in the furnace to uniformly heat the walls of the furnace by radiation without impinging thereupon.

8. The combination with a rotary cement-furnace having at one end a draft device or stack and means for feeding material to be burned into the furnace, and at the other end a delivery-opening for the discharge of the material, of means for axially injecting into the delivery end of the furnace a jet of air and means for feeding to said jet pulverized carbonaceous fuel, whereby a core of pulver-

ized fuel in combustion is produced in the furnace to by radiation and without impingement thereupon uniformly heat the walls of the furnace and the material passing therethrough.

9. The combination with a rotary cement-furnace, of means for axially injecting into its delivery end a jet of air, means for feeding to said jet pulverized carbonaceous fuel which is carried by and with the air-jet axially into the furnace, and means for supplying around the jet or stream of air and pulverized fuel additional air to support combustion, whereby a core of pulverized fuel in combustion is produced in the furnace to by radiation and without impingement thereupon heat the walls of the furnace.

10. The herein-described means for feeding pulverized fuel to a burner, consisting of means for continuously supplying determined uniform quantities of pulverized fuel, means for receiving and violently mechanically agitating such received uniform quantities of said fuel into a fuel-cloud and for simultaneously positively conveying the fuel-cloud onward toward the burner.

11. The herein-described means for feeding and burning pulverized fuel, consisting of means for continuously supplying determined uniform quantities of pulverized fuel, means for receiving and violently mechanically agitating such received uniform quantities of said fuel into a fuel-cloud and for simultaneously positively conveying the fuel-cloud onward, a vertical conduit down which the fuel-cloud passes, and an injector for directing high-pressure air across the downward-passing fuel-cloud to convey it to the place of combustion, as set forth.

12. The combination with a pulverized-fuel burner, of a pulverized-fuel feed therefor, consisting of a small primary conveyer for continuously feeding limited compact quantities of pulverized fuel, a longer secondary conveyer receiving said fuel from the primary conveyer and positively conveying it to the burner, and means for rotating the secondary conveyer at a speed to violently agitate the fuel and deliver it in a cloud to the burner, as set forth.

13. The combination with a pulverized-fuel burner, of a fuel-feed therefor, consisting of a hopper having an opening, a worm conveyer in said opening to convey a limited compact quantity of pulverized fuel from the hopper, a secondary conveyer to receive such fuel to positively carry it forward to the burner, and means for rotating the secondary conveyer at a speed to violently agitate the fuel as it is carried forward, as set forth.

14. The combination with a pulverized-fuel burner, of a fuel-feed therefor, consisting of a hopper having a plurality of vertical tubes, a worm conveyer mounted vertically in each tube to convey limited compact quantities of fuel from the hopper, a driver for said worm conveyers having means for connecting and disconnecting one or more of the worm conveyers therefrom, and a secondary conveyer receiving the fuel from said worm conveyers to carry it forward to the burner, as set forth.

In witness whereof we have hereunto signed our names in the presence of two witnesses.

EDWARD HENRY HURRY.
HARRY JOHN SEAMAN.

Witnesses:
JNO. W. SEPP,
DANIEL W. SITLER.