

Nov. 28, 1950

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KILN

2,532,077

Filed Sept. 8, 1947

4 Sheets-Sheet 1

FIG. 1.

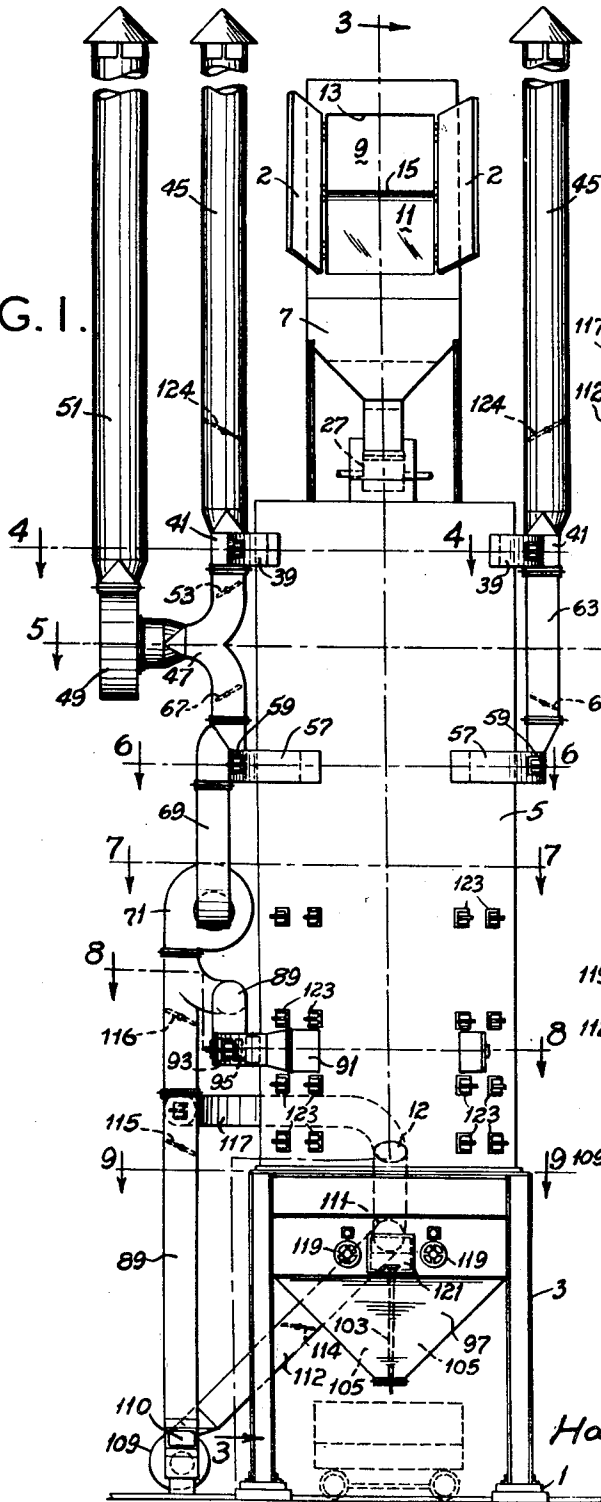


FIG. 8.

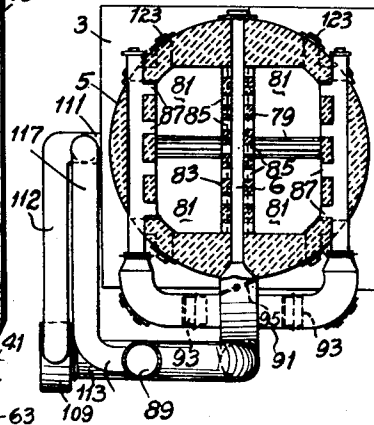
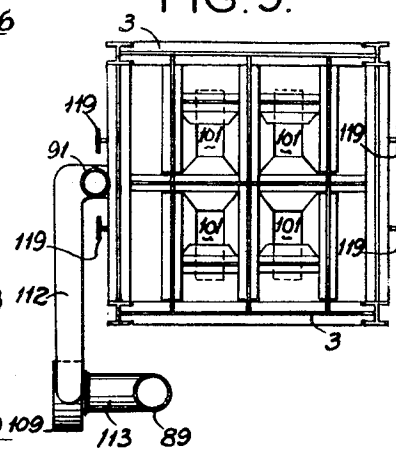


FIG. 9.



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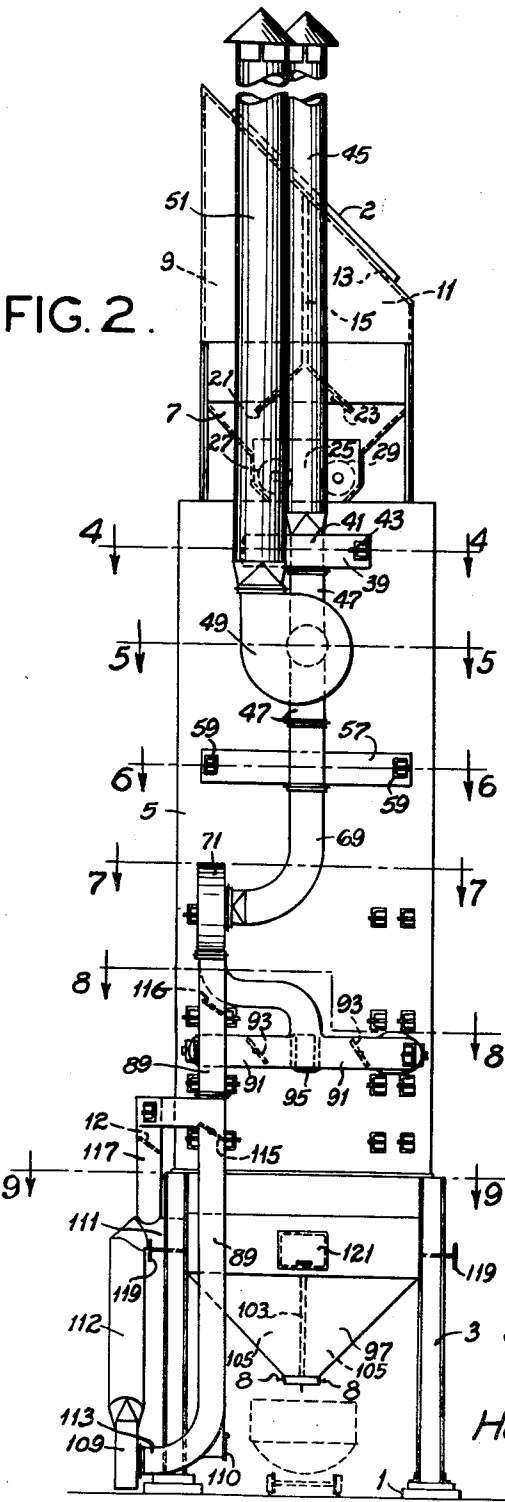


FIG. 6.

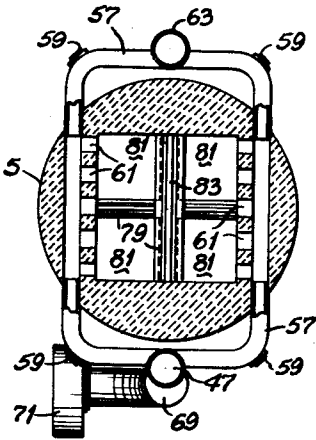
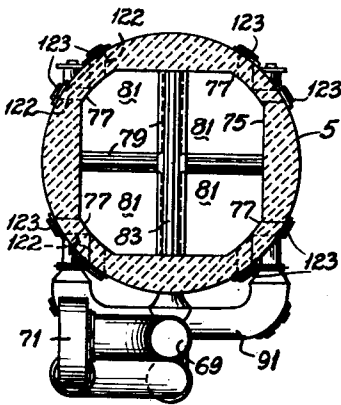


FIG. 7.



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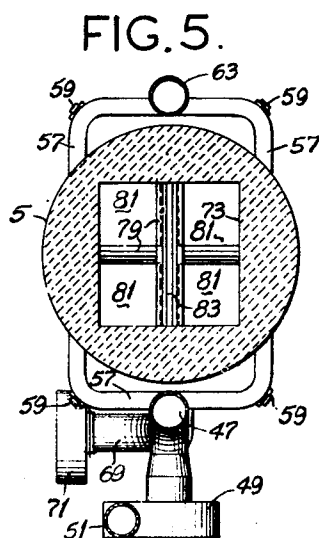
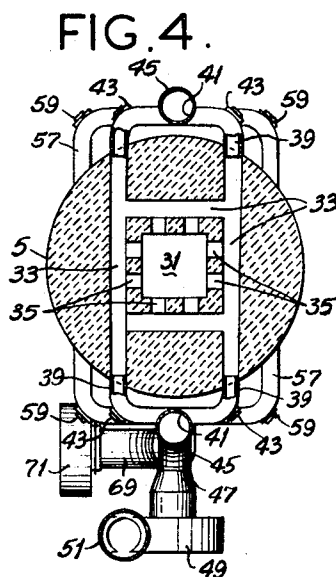
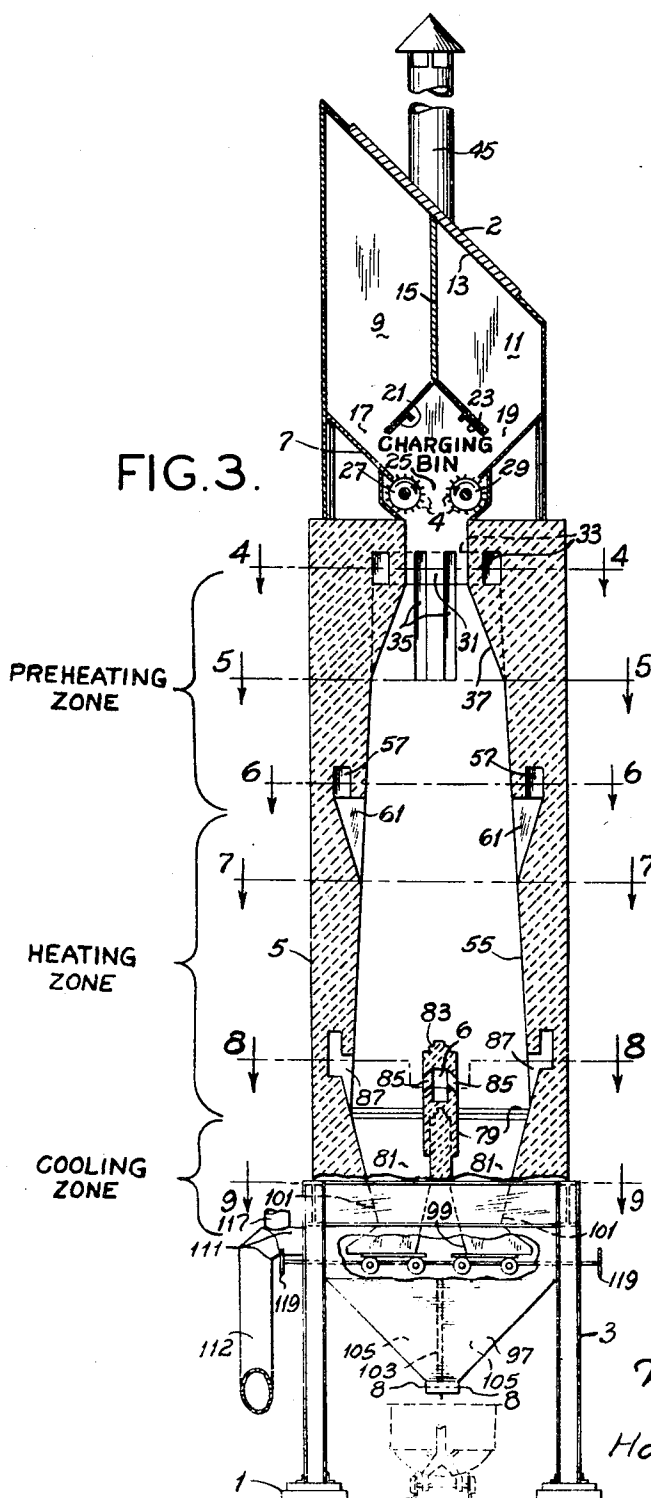
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FIG. 10.

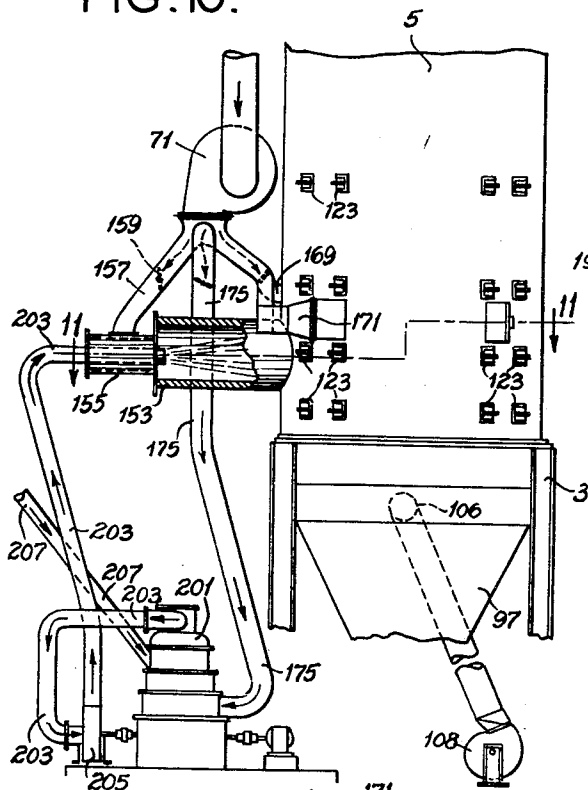


FIG. 14.

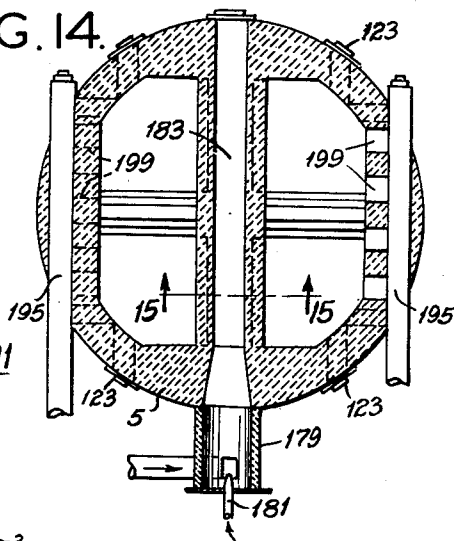


FIG. 13.

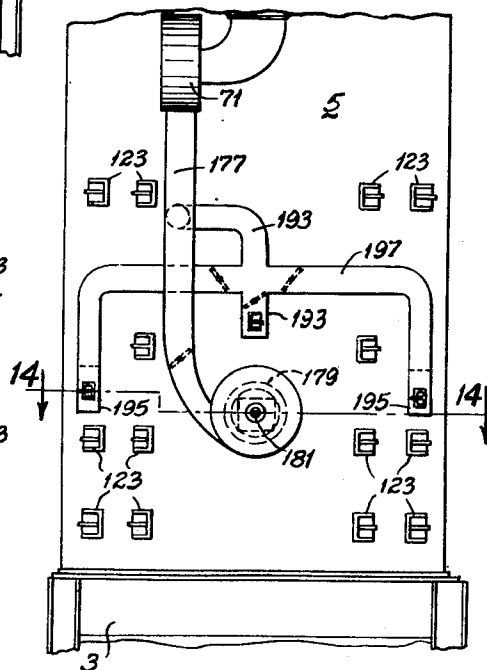


FIG. 11.

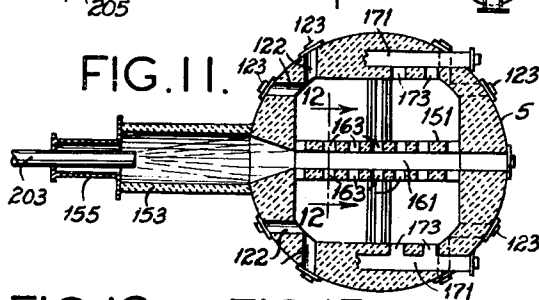


FIG. 12.

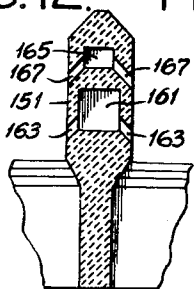
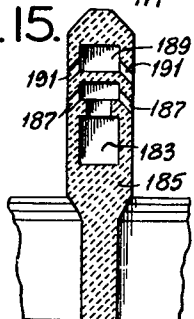


FIG. 15.



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UNITED STATES PATENT OFFICE

2,532,077

KILN

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Application September 8, 1947, Serial No. 772,660

9 Claims. (Cl. 263-29)

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This invention relates to kilns, and with regard to certain more specific features, to mixed-feed kilns and to those alternately firing gaseous, liquid or pulverized fuels.

Among the several objects of the invention may be noted the provision of a mixed-feed kiln in which the components of the charge are homogeneously distributed and in which these components are subjected to a uniform temperature treatment; the provision of a kiln of the class described which will accept and process at high efficiency both coarsely and finely divided charges; the provision of a kiln of the class described which will properly accept not only fuel as a part of a mixed charge, but also separately injected fuels such as oil or powdered coal, with or without mixed-feed operation; the provision of a kiln of the class described which is fully controlled in order to meet various desired operating and output requirements; and the provision of such a kiln which is relatively trouble-proof, compact and efficient. Other objects will be in part apparent and in part pointed out hereinafter.

The invention accordingly comprises the elements and combinations of elements, features of construction, and arrangements of parts which will be exemplified in the structures hereinafter described, and the scope of the application of which will be indicated in the following claims.

In the accompanying drawings, in which several of various possible embodiments of the invention are illustrated:

Fig. 1 is a front elevation of my new kiln;

Fig. 2 is a left-end view of Fig. 1;

Fig. 3 is a diagrammatic vertical section taken on line 3-3 of Fig. 1, parts being shown in elevation at the bottom.

Figs. 4, 5, 6, 7, 8 and 9 are horizontal sections taken on line 4-4, 5-5, 6-6, 7-7, 8-8 and 9-9, respectively, of Figs. 1-3, their angular positions being according to Figs. 2 and 3.

Fig. 10 is a fragmentary side elevation similar to parts of Fig. 2 but showing an alternative powdered-coal-burning structure;

Fig. 11 is a horizontal section taken on line 11-11 of Fig. 10;

Fig. 12 is a vertical enlarged section taken on line 12-12 of Fig. 11;

Fig. 13 is a view similar to Fig. 10 but showing somewhat enlarged an alternative oil-burning structure;

Fig. 14 is a horizontal section taken on line 14-14 of Fig. 13; and,

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Fig. 15 is an enlarged cross section taken on line 15-15 of Fig. 14.

Similar reference characters indicate corresponding parts throughout the several views of the drawings.

In the following, my new kiln is described as being applied to lime calcining operation, but it is to be understood that the principles involved are applicable to kilns for any purposes in which lump materials are to be treated at substantial temperatures.

At present three different types of kilns are generally used for calcining or the like. These are the gas-fired vertical kiln, the rotary kiln and the mixed-feed type of kiln. The vertical type has been preferred for larger lump material and the rotary type for smaller lumps. The mixed-feed type has usually been employed only for larger lumps. This type of kiln failed to produce a uniform product because of its inherent tendency towards improper distribution and flow of material therethrough, improper fuel distribution and lack of arrangements for proper temperature control. By means of the present invention I overcome the stated defects of the mixed-feed type of kiln, and make it effective to be operable on both large and small lumps, and alternatively as a vertical gas, oil or powdered-coal-fired kiln, besides making it more compact, reliable and efficient.

Referring now to the drawings, there is shown at numeral 1 a foundation for a structural steel base 3, the latter supporting the kiln shaft 5 which is made of suitable refractory materials. At the upper end of the shaft 5 is a charging bin 7. The bin has two inlet compartments 9 and 11 into which material may be inserted through an opening 13. Doors are indicated at 2, adapted to be closed after charging. The usual skip hoist or the like for charging is not shown. Such a hoist is ordinarily mechanically co-ordinated with the doors for closing the latter after a charge. These features are known and since they form no part of the invention per se, are not shown.

The compartment 9 is for receiving lump material to be heated, such as, for example, limestone in the case of a limekiln. The compartment 11 is for the purpose of receiving lump fuel, such as, for example, coke, charcoal or the like. A wall 15 divides the compartments 9 and 11. At the bottom of the wall 15 are throats 17 and 19, controlled by adjustable gates 21 and 23, respectively. The control throats 17 and 19 lead to a common entrance 25. In the entrance are opposite-

ly rotary feeding drums 27 and 29. These have protuberances 4 upon their surfaces adapted to mix and forward the flows of stone (roller 27) and fuel (roller 29) when the rollers are rotated. The amount of one material or the other that is fed depends upon the speed of rotation of its respective feeding roller. The speed may be controlled manually or automatically. In any event, the relative speeds of the rollers 27 and 29 determines the proportions of materials that are mixed at the inlet 25. An additional proportioning effect is obtained by adjustment of the gates 21 and 23, but it is preferred that these remain open as far as possible in attaining a given proportion. It is to be understood that other charging means may be employed, provided uniform flow and mixing of the materials takes place.

Below the rollers 27 and 29 the mixed material, without substantial fall, enters a square throat 31 (see also Fig. 4). This throat is of limited size relative to the remainder of the shaft to be described. Around the throat 31 is a primary gas exhaust passage 33. Exhaust ports 35 communicate with this passage 33, said ports being in a downwardly flaring head portion 37 in the shaft 5. Off-take passages 39 lead to exhaust pipes 41 on the sides of the kiln. Natural-draft stacks 45 are connected with the pipes 41. The passages 33 and the off-take passages 39 are arranged upon a rectangular basis, as shown, so that by placing clean-out openings 43 at the corners, as indicated, all passages may readily be cleaned out. The left-hand pipe 41 (Fig. 1) is connected to the upper leg of a vertical T 47. The stem of the T 47 is connected to the inlet of an exhaust fan 49 blowing into an exhaust stack 51. A damper 53 controls flow through the upper leg of the T 47. Thus the head of the shaft 5 may be exhausted by natural-draft action from the stacks 45 or by mechanical exhaustion into the stack 51, depending upon the position of the damper 53.

Below the region 37 the shaft is further gradually flared outward and downward, as indicated at numeral 55. This proceeds to a maximum cross section. This tapered portion 55 is divided into two zones; an upper pre-heating zone, as indicated, and a heating zone, as indicated. The zones are established by a secondary exhaust arrangement constituted by a second exhaust ring of rectangular form, indicated at numeral 57 (Fig. 6), having connecting ducts 61. Clean-out ports 59 are installed at the corners of ring 57. The exhaust ring 57 communicates on the right side with the ring 39, as indicated by pipes 63 in Fig. 1, so that a natural-draft effect may be induced in the ring 57. This connecting pipe 63 includes a control damper 65. On the other side of the shaft the ring 57 is connected to the other branch of the T 47, whereby mechanical draft may also be induced in the ring 57 by the exhaust fan 49. A damper 67 controls this draft action. Ring 57 is also connected by means of pipe 69 with a recirculating fan 71 for purposes to be described.

As indicated in Fig. 5, a typical cross section of the pre-heating zone is square (see numeral 73). A typical cross section of the heating zone is indicated in Fig. 7, which is also essentially square (see numeral 75), except for fillet portions 77 at the corners. Such an internal cross section is different from the usual round section used heretofore, and has certain advantages to be made clear.

The lower end of the heating zone is determined by tops of cross walls 79, indicated more clearly in Figs. 5 and 8. These walls 79 divide 75

the lower inwardly tapered square portion of the shaft into four chutes 81 which constitute a cooling zone, as indicated. One of these walls 79, as indicated in Fig. 3, extends upward to form a single bridge wall 83 having therein a cross-passage 8 and outlet ducts 85. Opposite the bridge wall 83, in the sides of the shaft 5, are inlet ports 87. The ducts 85 and 87 are for recirculating spent gas from the top of the kiln. They receive this gas from the recirculating fan 71 via pipes 89 and 91. Dampers 93 control the flow in pipes 91 and a damper 95 controls flow to the passage 8.

Below the cooling zone is located a storage hopper 97, which is carried by the kiln foundation steel framework 3. This hopper is different than those usually employed. It is an integral part of the kiln, and entirely encloses the bottom below the cooling zone to form a plenum chamber which will carry gas pressure. It also encloses an outlet shaker and control mechanism indicated in general by the numeral 99. Further details of this mechanism will not be given, since it is made substantially along the lines of the mechanism shown in my United States Patent 2,300,860, dated November 3, 1942, or its equivalent. There are four conical boot-like outlets 101, one leading from each of the chutes 81. Beneath each outlet 101 is a reciprocating discharge mechanism for controllably letting out material from the respective chute and into the hopper per se. The mechanism is of the type in which all units reciprocate together but the flow through each is controllable from an individual control wheel 119 (see said patent). The hopper 97 at the bottom is divided by walls 103 into four compartments 105, into each of which passes material from a respective chute 81. Individually controlled outlets or releasing means 8 are shown for the respective compartments 105. Any stored material above the releasing means 8 prevents outflow of gas therefrom.

An openable port 121 allows inspection of the amount of material in the compartments of the hopper 97 and if one is receiving too much or too little material, a proper adjustment may be made on the respective discharge feeder by controlling its wheel 119. Door 121 also provides for air inlet when natural draft operation alone is used.

Forced circulation through the cooling zone is effected from a fan 109 to an inlet 111 in the closed hopper 97. This is accomplished through pipe 112 having a damper 114. Fan 109 supplies air if an air port 110 is open. It may receive spent gases of combustion from recirculating fan 71 via pipes 89. This places the inside of the hopper under pressure and gas will seek to escape through the reciprocating discharge feeder mechanism 99 into the boots 101 and up through the cooling chutes 81. Tempering gas is supplied from pipes 89, provided dampers 115 and 116 are open. At 117 is shown a connection from pipes 89 to the inlet 111 in which is a damper 12. This allows gas to be brought down from fan 71 to the inlet 111 when desired; or air may be supplied from the inlet 110. Thus it is apparent that the fans 109 and 71 with their connecting pipes and dampers constitute controlled compressor means for supplying a gaseous medium at superatmospheric pressure to the plenum chamber formed by the closed hopper 97.

The kiln section is essentially square (rec-

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tangular) throughout. The advantage of this will be seen by reference to Figs. 7, 8 and 11. In each of these there is shown at each corner of the square section a set of covered but openable portholes 122, each of which is more or less parallel to a flat inner wall of the shaft. There are a number of levels of these holes, as indicated in Figs. 1 and 2 wherein each is shown as being covered by an openable door 123. By this means, convenient inspection of conditions in the kiln may be made during operation and poke tools introduced for relieving any hanging of the charge. This poking is much more effective when applied to flat inner walls, as compared to the old-style round inner kiln walls. Visual inspection of the operating conditions within the kiln is considerably improved.

Operation is as follows, assuming, for example, that the kiln is to be used as a limekiln:

A suitable hoist (not shown) is used for intermittently loading stone into the inlet compartment 9 and coke into the compartment 11. The doors 2 are open only during charging. The gates 21 are adjusted, as are also the speed rates of the feeders 27, so that there will be a proper ratio of stone to coke in the charge. The lumps of stone and coke become homogeneously distributed in passing between the feeders 27, after which they enter the throat 31. This throat, being relatively short and small in cross section (Fig. 4) and having non-flaring side walls, assures that the material in entering the kiln proper will be maintained in a state of homogeneous distribution. This would not be true if the material were allowed to drop for any substantial distance from the feeders into the kiln because during such a drop the heavier lumps tend to segregate out from the lighter ones. It is the intention that the charge shall never fall below the throat 31 but it may fluctuate within it, the feeders 27 and the gates B being accordingly adjusted for this result. The mixed lumps having once been deposited in proper homogeneity in the throat 31, will not thereafter tend to segregate, even though the cross section of the column of material increases in size as it descends through the kiln. Thus there is avoided the segregation which would result in hot and cold spots during the flow downward, which would give rise to uneven burning. The relatively small cross section and length of the throat 31 is illustrated by the fact that it is only three feet square by three feet long in a kiln six and a quarter feet in diameter just above the Fig. 5 section where the taper 37 starts.

As the mixed charge proceeds downward, it passes through the pre-heating zone and then the heating or calcining zone, the fuel becoming ignited and thus in the case of limestone driving off carbon dioxide. In the cooling zone the material (fuel burned out) separates into four channels and becomes cooled and shaken into the four sections of the hopper 97 by operation of the discharge shaker feeders 99. The feed rate of each feeder 99 is controlled from a wheel 119. Since the kiln is at all times operated practically full up through the throat 31, there are no deep drops. This results in the ability to handle fragile materials to be heated and to use even such fuels as charcoal. The flat tapering walls of the square cross section lend themselves to effective release of hung material by insertion of tools in the poke and inspection holes 122. The strategically located doors also permit of breaking up of undesirable masses.

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For large lumps of stone, in the case of a limekiln (3 inch by 6 inch lumps, for example) the dampers are adjusted to apply the suction of the exhaust fan 49 and of the natural-draft stacks 45 to the primary exhaust 33. These are also applied to the secondary exhaust 57.

For small-stone operation (1 inch by 3 inches, for example) the primary exhaust 33 is generally cut off from the exhaust fan 49, the effect of the latter being applied only to the secondary exhaust 57. This eliminates the undesirable mechanical dragging of gases through an excessive height of fine stone, thus avoiding power waste and making operation practical. However, the controls to the stacks 45 and to fan 49 may be arranged for maintaining some circulation above the secondary exhaust 57, if desired.

Whether the exhaust fan 49 operates upon one or both of the exhausts 33 or 57, in either case recirculation of spent gas by means of the fan 71 is provided for. This gas may be sent to the recirculation ports 85, 87 and 111, or any one or combination of these, with or without air at the inlet 110. The purpose is to obtain even combustion throughout the column of material in the kiln; also the proper rate of cooling. Visual inspection through ports 121 will indicate when damper controls are to be used for the purpose.

Air alone may also be introduced into the port 111 from the fan 109, if desired. A breakdown of any one, or for that matter, all of the fans would not shut down the kiln, as compensating damper adjustments may be made. Also, natural-draft operation alone may be employed through port 121 and is sufficient to carry over a repair period. In the case of natural-draft operation, the door of opening 121 would be opened. Air would then rise through the discharge feeders 99 and into the cooling passages 81; thence through the shaft per se up to the primary exhaust 33 and out through the exhaust stacks 45. For control under such conditions, dampers 124 are used in the natural-draft stacks 45. Also some natural draft may occur through ports 61 by opening dampers 65, 67 and 53.

For forced-draft operation, the fan 109 is relied upon to deliver air from opening 110 to the connection 111, which places the draw chamber enclosed by the hopper 97 under pressure, consequently placing the entire shaft under draft pressure. The gas will escape through the exhausts 33 or 61 or both, depending upon the settings of dampers 65, 67, 53 and 122. Control of air under pressure is effected by means of a damper 114.

Induced-draft is effected by causing the gas to leave the kiln through the ducts 33 and to pass to the exhaust fan 49, instead of passing to the stacks 45. Under these conditions, control would be by means of the damper 53, dampers 65 and 67 being closed.

In the event that balanced-draft operation is desired, both of the fans 109 and 49 are operated and dampers 53 and 67 controlled in a manner such that in the heating zone there will be little unbalanced pressure but still there will exist a high rate of gas flow.

An advantage of the kiln is that it may with few changes be used as a gas-fired kiln or oil or powdered coal fired. In this event both chambers 9 and 11 may be used to charge the material to be treated, such as stone for example.

Atomized-fuel, gas-firing arrangements are shown in the alternative embodiments of Figs. 10-15. Figs. 10-12 show a powdered-coal-firing

arrangement. In this form the firing bridge wall (Fig. 3) has been renumbered at 151 in Figs. 11 and 12. This wall 151 receives powdered coal from an injection device 153, wherein turbulence is maintained by the introduction into a sleeve 155 of some recirculating gas from the recirculating fan 71. This is done by a pipe 157 wherein is a damper 159. The injection device nozzle 153 feeds powdered coal into a passage 161 in the wall 151 and enters the kiln through outlets 163. Additional recirculating gas is supplied to the wall 151 through a cross passage 165 having outlets 167. The passage 165 is supplied with recirculating gas by a pipe 169 from the fan 71. Lateral passages 171, also supplied from the recirculating fan 71, send recirculating gas into the shaft through lateral ports 173.

Air for supporting combustion from the outlets 163 is supplied from the bottom of the shaft at 186 by a fan 188. In Fig. 10 pipe 175 is for furnishing recirculating gas to a powdered-coal pulverizer 201, which gas serves to carry the powdered coal to the injection device 153 via pipes 203 and fan 205. The raw coal inlet for the pulverizer is shown at 207. In this form of the invention no connection is needed between the recirculating fan 71 and the lower part of the shaft, although such may be used if desired.

In Figs. 13-15 is shown an oil-fired arrangement wherein the recirculating fan 71 supplies highly heated recirculating gas through a duct 177 to an oil burner nozzle 179. The pipe 177 connects tangentially with the nozzle 179 to cause a swirl in the nozzle. The oil-injection pipe is shown at 181. The nozzle 179 is connected with a passage 183 of a firing bridge wall 185 which in this case also constitutes a gas generator. As in the case of all oil burner nozzles, the fuel is mechanically atomized into extremely small droplets, but of itself such a burner cannot gasify the fuel. By means of the present construction, the introduction of sufficiently highly heated recirculating gas into the firing bridge passage 183, wherein the vaporized oil becomes suspended, gasifies the vapor particles before they leave the bridge. Thus the firing bridge becomes a gas producer per se and the hot air present causes some to burn, thus raising the temperature and cracking any unburned parts. This gas escapes at high velocity into the kiln through the lateral openings 187 with improved firing action. This gasifying action is aided by the fact that the firing bridge is completely surrounded by hot lime, its walls being hot and radiant. The carbon resulting from the hydrocarbon cracking of the oil is, while in suspension, in a considerable degree rapidly oxidized. The remainder of the suspended carbon is carried by the gas stream through the ports 187 into the voids among the line particles. Outlets from passage 183 are shown at 187. Recirculating gas for tempering purposes is supplied to a passage 189 in the wall 185 and enters the shaft through ports 191. The connections to passage 189 for the recirculating gas are shown at numerals 193. Connections for side recirculating ducts 195 are shown at 197. The inlets to the shaft from side recirculating ducts 195 are shown at 199. In this case, as in the powdered-coal-firing case, air is introduced into the bottom of the kiln by the fan and lower inlet as in the powdered-coal form, but not shown again in Figs. 13 and 14. In this case no connections are used between the recirculating fan 71 and the lower end of the kiln, although such may be used if desired.

An advantage of the construction shown in Figs. 10-15 is that the spent gases which come from above the heating zone are used not only as a carrier and gasifier or vaporizer for introducing the atomized fuel (powdered coal or oil) into the lower portion of the shaft, but also as a diluent for the combustible constituted by the fuel and the air rising from the cooling zone. Thus the combustion is tempered. This ensures not only effective tempered combustion but an evenly distributed combustible in the shaft. This prevents localized overheating. In this connection it should be understood that although the recirculating gas is relatively cool, it is nevertheless hot enough for vaporizing and gasifying atomized oil and for starting some gasification of powdered coal. Although being spent or relatively inert, it may be blended with some fuel to support partial combustion in the firing bridge.

From the above it will be seen that general structural features of the kiln may be used advantageously not only with mixed-feed combustion, but by merely feeding from the top material to be treated and introducing the combustible (powdered coal or oil) at the lower end of the heating zone. In any of these constructions, full advantage is obtained of the tempering effect of the recirculating gases, together with the effect that they have of better distributing combustion and rendering temperatures more even throughout the kiln sections.

In view of the above, it will be seen that the several objects of the invention are achieved and other advantageous results attained.

As many changes could be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

I claim:

1. A mixed-feed kiln comprising an upright hollow shaft having an upper material inlet and successively lower pre-heating, heating and cooling zones, apparatus near the material inlet adapted to mix fuel with material to be treated and to introduce the mixture into the inlet, a central spent gas inlet near the base of the heating zone and above the cooling zone having distributing ports central and lateral with respect to the shaft, spent gas off-takes respectively near the top and bottom of the pre-heating zone and having connections with said gas inlet, gas circulating apparatus associated with said connections, control elements in the connections whereby either gas off-take may supply the gas inlet, whereby the kiln may be constantly operated full up to said material inlet whether coarse or fine material is used and an even combustion of the fuel obtained by even distribution and control of the introduction of spent gas, and whereby wasteful passage of spent gas through the pre-heating zone may be substantially eliminated when fine material is treated.

2. A mixed-feed kiln comprising an upright hollow shaft having an upper material inlet and successively lower pre-heating, heating and cooling zones, apparatus near the material inlet adapted to mix fuel with material to be treated and to introduce the mixture into the material inlet, a spent gas inlet near the base of the heating zone and above the cooling zone having distributing ports central and lateral with respect to the shaft, spent gas off-takes respectively near the top and bottom of the pre-heating zone and

having independently controllable forced and natural draft connections and additional connections with said gas inlet, gas circulating apparatus associated with said additional gas inlet connections, control elements in the inlet connections whereby either gas off-take may supply the gas inlet, whereby the kiln may be constantly operated full up to said material inlet whether coarse or fine material is used and an even combustion of the fuel obtained by even distribution and control of the introduction of spent gas, and whereby wasteful passage of spent gas under forced draft through the pre-heating zone may be substantially eliminated when fine material is treated.

3. A mixed-feed kiln comprising an upright hollow shaft having an upper material inlet and successively lower pre-heating, heating and cooling zones, apparatus near the material inlet adapted to mix fuel with material to be treated and to introduce the mixture into the material inlet, a spent gas inlet near the base of the heating zone and above the cooling zone having distributing ports central and lateral with respect to the shaft, spent gas off-takes respectively near the top and bottom of the pre-heating zone and having independently controllable forced and natural draft connections and additional connections with said gas inlet, gas circulating apparatus associated with said additional gas inlet connections, control elements in the inlet connections whereby either gas off-take may supply the gas inlet, controllable material outlet means at the bottom of the shaft, a closed hopper below the shaft and attached thereto around said outlet to form a plenum chamber, a connection from said gas off-takes with said plenum chamber, said plenum chamber having an operable bottom outlet means for the material.

4. A kiln comprising an upright hollow shaft having an upper heating zone and a lower cooling zone which has at least one bottom material outlet, material discharge control means associated with said cooling-zone outlet, a closed substantially gas-tight hopper below the shaft adapted to receive and temporarily store material from said outlet and including means for releasing material from time to time, said hopper being attached to the shaft around and covering said outlet to form a plenum chamber for the introduction of a gaseous medium into said outlet, compressor means connected with the plenum chamber adapted to force said medium into the plenum chamber under superatmospheric pressure, control means for the compressor means, whereby the medium may be forced under control from the plenum chamber and into the cooling zone through said outlet against the flow of material therefrom, stored material above the material releasing means preventing outflow of gas therefrom.

5. A kiln comprising an upright hollow shaft having an upper heating zone and a divided lower cooling zone which has a plurality of bottom material outlets, one outlet being associated with each division, individual material discharge control means associated with the respective cooling zone outlets, a closed substantially gas-tight hopper below the shaft divided into individual compartments adapted to receive materials respectively from the outlets and to store said material as discharged from the cooling zone divisions and including means for releasing materials from time to time, said hopper being attached to the shaft and covering said outlets to

form a common plenum chamber for all outlets for introduction of a gaseous medium into said outlets, compressor means connected with the plenum chamber adapted to force said medium into the plenum chamber under superatmospheric pressure, control means for the compressor means, whereby the medium may be forced under control from the plenum chamber and into the divisions of the cooling zone through said outlets and against the flows of material therefrom, stored materials above the material releasing means preventing outflow of gas therefrom.

6. A kiln comprising a hollow shaft wherein is a heating zone for calcining, a ported hollow firing bridge below the heating zone adapted to be surrounded by hot calcined material descending from said heating zone, oil-injection means connected with said firing bridge adapted to inject particles of oil therein, recirculating means adapted to abstract sufficiently hot gas from the heating zone and to introduce it into the firing bridge along with the injected particles of oil so as to come into direct contact therewith under conditions of suspension of the particles in said gas, the bridge being sufficiently heated by surrounding hot calcined material and the recirculating gas being also sufficiently hot in the firing bridge substantially to gasify said particles, whereby hydrocarbon cracking is effected within the bridge.

7. A kiln comprising a hollow shaft wherein is a heating zone for calcining, a ported hollow firing bridge below the heating zone adapted to be surrounded by hot calcined material descending from said heating zone, oil-injection means connected with said firing bridge adapted to inject particles of oil therein, recirculating means adapted to abstract sufficiently hot gas from above the heating zone and introducing it into the firing bridge along with the injected particles of oil so as to come into direct contact therewith under conditions of suspension of the particles in said gas, means for introducing air into said bridge with said particles, the bridge being sufficiently heated by surrounding hot calcined material and the recirculating gas being also sufficiently hot in the firing bridge substantially to gasify said particles, whereby hydrocarbon cracking and oxidation of resulting suspended carbon particles are effected within the bridge and a high firing velocity effected from the same into the shaft.

8. A kiln comprising a hollow shaft wherein is a heating zone for calcining, a ported hollow firing bridge below the heating zone adapted to be surrounded by hot calcined material descending from said heating zone, powdered-coal injection means connected with said firing bridge adapted to inject solid particles of powdered coal therein, recirculating means for abstracting sufficiently hot gas from above the heating zone and introducing it into the firing bridge along with the injected particles of powdered coal so as to come into direct contact therewith under conditions of suspension of the particles in said gas, the bridge being sufficiently heated by surrounding hot calcined material and the recirculating gas being also sufficiently hot in the firing bridge substantially to volatilize at least some of said solid particles before they escape from the bridge ports.

9. A kiln comprising a hollow shaft wherein is a heating zone for calcining, a hollow firing bridge below the heating zone adapted to be surrounded by hot calcined material descending from

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said heating zone, said bridge having a first and a second passage wherein are independent openings into the shaft, fuel-injection means connected with said first passage adapted to inject solid particles of fuel therein, recirculating means for abstracting sufficiently hot gas from above the heating zone and introducing it into both passages of the firing bridge, the gas entering the first passage being introduced along with the injected fuel particles so as to come into direct contact therewith under conditions of suspension of the particles in said gas, means for introducing air into the first passage, the bridge being sufficiently heated by the surrounding calcined material and the recirculating gas being sufficiently hot in the firing bridge to volatilize at least some of said particles into a gas, whereby, with said air, burning takes place in the bridge and a high firing velocity is effected from the bridge openings into the shaft, exit of recirculating gas from the second gas passage acting as a tempering medium for the burning gas after it leaves its openings.

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