Oct. 15, 1946. V. J. AZBE 2,409,527

CALCINING APPARATUS

Filed April 13, 1945 3 Sheets-Sheet 1

FIG. 1.

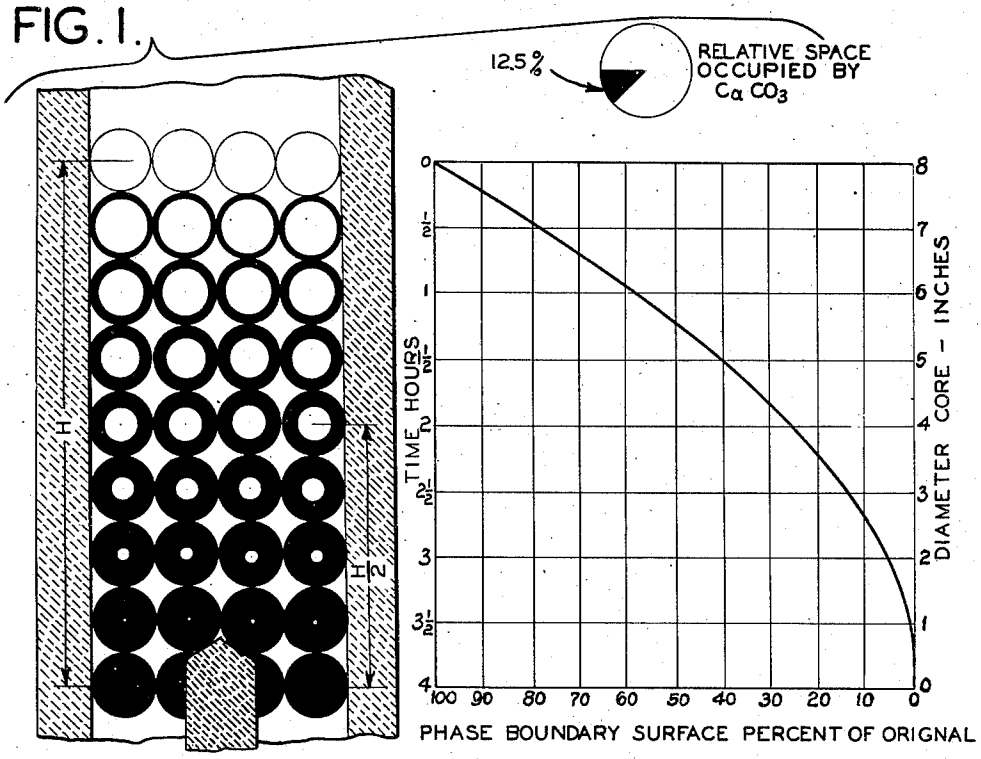
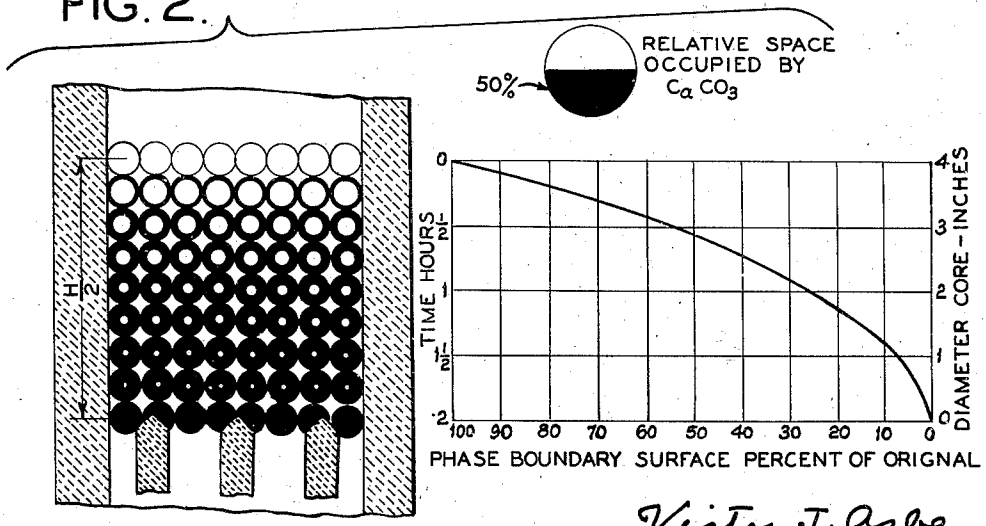


FIG. 2.



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FIG. 3.

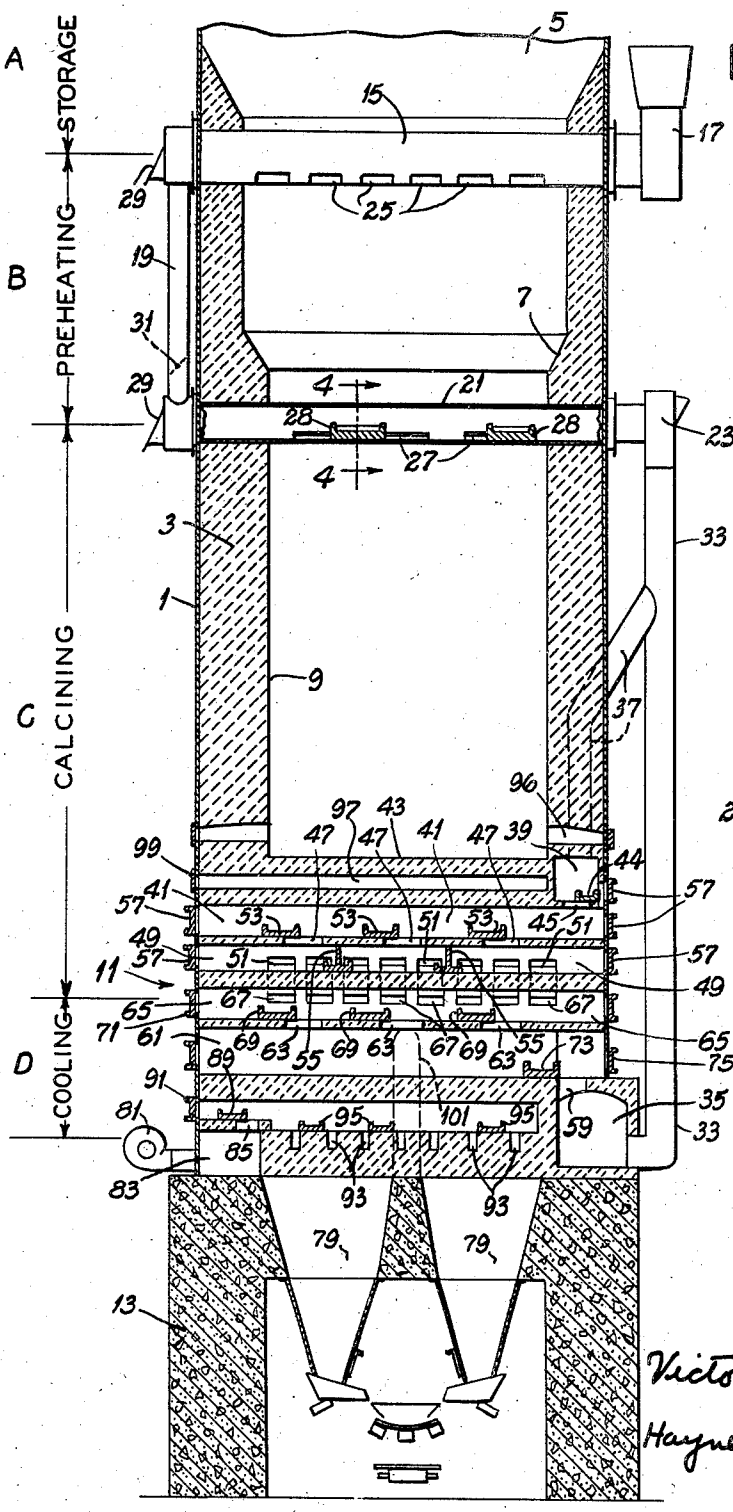
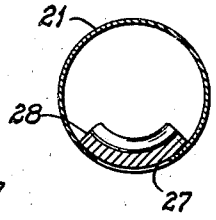


FIG. 4.



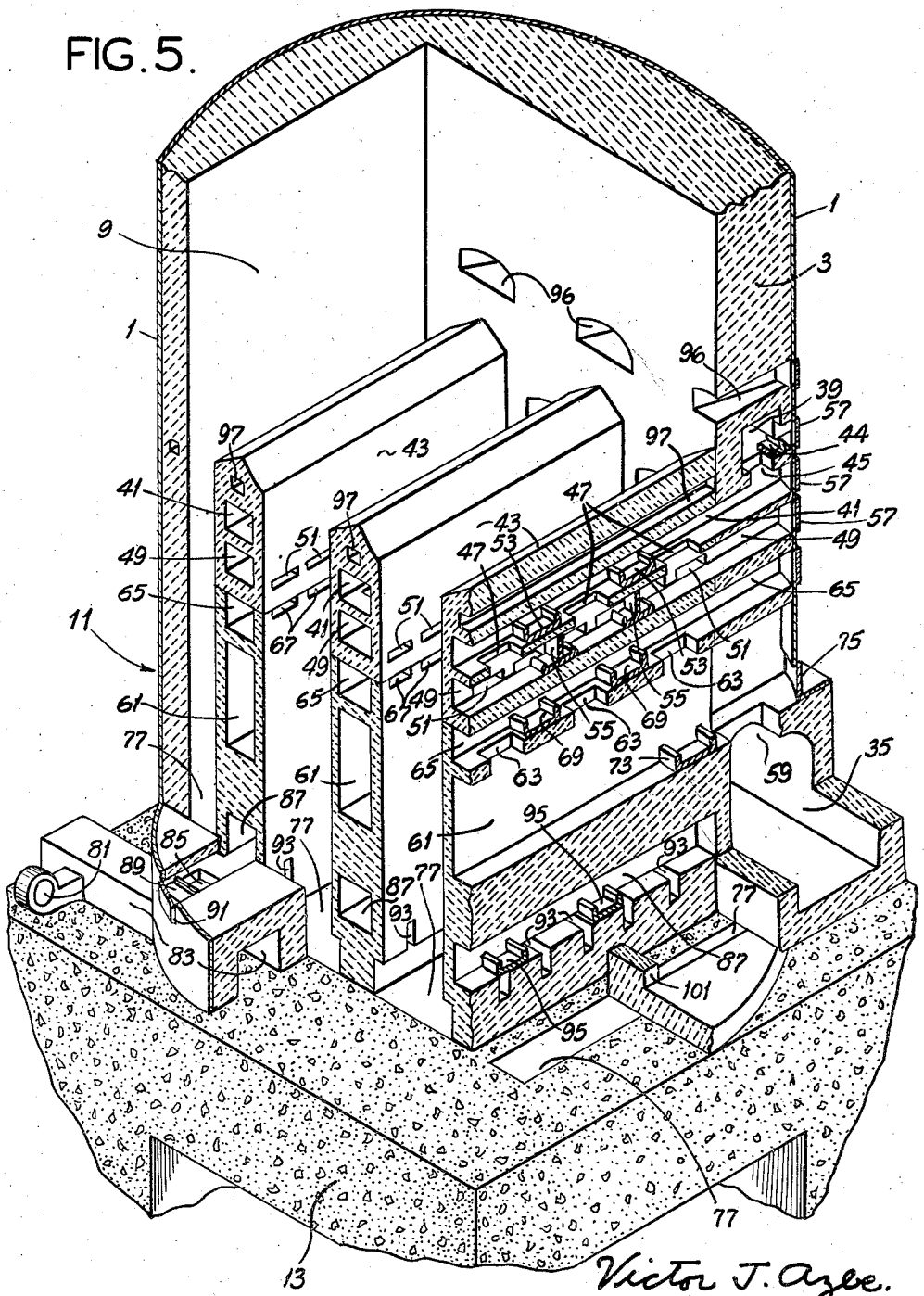
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CALCINING APPARATUS

Filed April 13, 1945 3 Sheets-Sheet 3

FIG. 5.



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UNITED STATES PATENT OFFICE

2,409,527

CALCINING APPARATUS

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Application April 13, 1945, Serial No. 588,185

19 Claims. (Cl. 263—29)

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This invention relates to calcining apparatus, and more particularly to a vertical lime kiln for calcination of smaller grades of limestone, or spalls.

Among the several objects of the invention may be noted the provision of a vertical lime kiln which will at a high rate calcine small stone or spalls and which will produce a consistently soft-burned good lime, even from relatively impure stone; the provision of a kiln of the class described which will produce controlled temperatures throughout the entire cross section of the kiln; the provision of a kiln of the class described which will consistently produce homogeneous lime of high quality; and the provision of a kiln which involves only low capital investment and upkeep cost. Other objects will be in part obvious and in part pointed out hereinafter.

In the accompanying drawings in which is illustrated one of various possible embodiments of the invention,

Fig. 1 is a diagrammatic view showing certain relationships which occur when burning large stone;

Fig. 2 is a view similar to Fig. 1 showing similar relationships when burning small stone;

Fig. 3 is a vertical section of certain parts of my new kiln;

Fig. 4 is an enlarged vertical detail section taken on line 4—4 of Fig. 3; and,

Fig. 5 is an isometric view of a broken-away section of the lower portions of the kiln.

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

In the process of quarrying limestone in preparation for the burning of lime, particularly if it involves mechanical crushing, a considerable portion of the broken mass is of small size unsuitable for use in vertical kilns as formerly constructed. These small stones are often called spalls. If there is a market for such small stones or spalls, there is no great waste, but often the market is not able to absorb it and in some cases as much as 35% passes to the dump. This represents a great economic loss, which will tend to increase, as hand-operated quarries become converted to mechanical systems.

Frequently rotary kilns are installed for the burning of these small sizes of stone, but such kilns are expensive and complicated besides being costly in respect to fuel requirements. Small lime producers usually cannot afford them and even large producers of lime would often be better off if they did not have them for various

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reasons, one of the most important being their dust nuisance.

In the rotary kiln, there is no gas flow through the mass of calcining stone, the main stream of hot gases passing along the roof. Most heat transfer is by downward radiation which to be effective must be at an undesirably high temperature. Also, since a rotary kiln acts as a mechanical classifier, the largest of the limestone will repeatedly pass over the heat absorbing slope, thus becoming flash burned, while the smallest will be shielded, coming out of the kiln possibly only partly burned. This tends to produce a nonhomogeneous product.

In the case of vertical kilns using even large stone, the objection is that often the outside of a large lump becomes overburned before the inside has been completely calcined. This is because of the temperature head that is required for heat to be conducted through to the inside. Also, the smallest of the charge which burns much faster must remain in the hot zone, sometimes four times longer than necessary, awaiting completion of the burning of the larger of the stone. Even then there is often core which never becomes calcined and itself represents a loss, in addition to the occurrence of a certain amount of recarbonation and occlusion of good lime.

Hence both rotary kilns with small stone, and vertical kilns with large stone suffer from the high temperatures, resulting in heavy repairs. Also, the lime suffers impairment of quality. For most purposes only so-called soft (low temperature) and uniformly burned lime is a good lime and neither one or the other of said kilns operating as specified is fully capable of producing it consistently.

Lime to be at its best should be burned at 2000° F. or even less, when even relatively impure stone gives a fairly good lime. But such low temperatures are not feasible in the case of the rotary kilns and would not be economical with large stone in the case of the vertical kilns.

High temperatures are not necessary if small stone can be made properly to receive its heat directly from hot gases flowing past it. Small stone calcines very quickly if it properly receives its heat. Thus if the vertical kiln can be made successfully to burn small stone, the high temperatures become unnecessary and lime can be made in quality better than that of any other kiln.

I have found that a most important factor in calcination is the amount of stone surface which transmits heat, the kiln volume being relatively

unimportant. A small kiln filled with small stone can be made of a much higher capacity at lower temperature than the large-stone kiln, provided the surface of the stone is made to function properly. This is because relative to weight, small stone has relatively more surface area than large stone. For example, 1½" stone may have six times the surface area of 8" stone. It is for this reason that, if properly manipulated, high capacity may be obtained even at low operating temperatures with small stone in a vertical kiln. This invention results in a vertical kiln which burns small stone, heretofore rejected, better than vertical kilns burned large stone heretofore.

Referring now more particularly to Fig. 1, there is diagrammatically shown at the left the calcining zone of a kiln for large 8" stone. The height of this zone is indexed H, which is about twice its diameter, for example. At the top of the zone exists all rock and at the bottom theoretically there exists all lime, assuming all core to have been burned out. As the lumps are converted from stone to lime, the phase boundary surface between stone and lime shrinks in area and the heat-transmission distance grows. Thus the kiln height must be enough to allow time for the action to complete itself as the stone descends. At the right of Fig. 1 is plotted the phase boundary surface per cent of the original surface against time, the core diameters being also indicated in inches. Above the rectangular diagram is a circular diagram indicating the relative space within the calcining zone of the kiln occupied by the stone ($CaCO_3$).

In Fig. 2 is shown how, with stone of 4" diameter, the relative height of the calcining zone may be halved and how the time of calcination is halved. This amounts to an increase in capacity. At the same time the relative space occupied by the stone (calcium carbonate) is about 50% of the calcining space. In other words, the kiln space is much more efficiently used. The present invention shows how to take advantage of these conditions.

It should be observed that the rate of calcination is according to the temperature and the amount of heat-transfer surface, the higher the temperature and the more surface the stone presents the more heat will be absorbed by a given volume of stone. The surface referred to is not the outer surface of the stone but rather the phase boundary surface between the lime and the limestone. Thus if the transfer surface can be increased, temperature may be decreased.

When 8" lime-rock lump is reduced to 4" core, there will still be the original outer heat-gathering surface but the calcining surface will be reduced to only one-fourth its original area and the weight of the stone remaining will be only one-eighth. Therefore the calcination of this one-eighth of the original weight goes on under very disadvantageous conditions.

It is to be understood in connection with Figs. 1 and 2 that they represent ideal conditions. They also show that it is stone surface that is important and not a mere large kiln volume, as formerly supposed. A smaller kiln filled with small stone can be made of much higher capacity than a larger kiln filled with large stone, due to the greatly increased surface and also due to the greatly reduced distance of heat penetration.

But the difficulty with burning small stone is to obtain a proper gas distribution through the smaller voids which produce increased frictional resistance. The present invention provides this proper distribution. The lower kiln height required is of help in that it tends to reduce the overall frictional resistance. Thus higher operating efficiencies are feasible.

My invention also minimizes "hanging" of the lime and in this connection I provide improved means for determining conditions within the kiln without requiring examination of "hung" masses.

Referring now more particularly to Figs. 3 to 5, there is shown at numeral 1 the outside metallic sheath of the kiln in which is arranged a refractory brick lining 3. This forms the vertical kiln shaft. At numeral 5 is shown the lower part of an upper stone storage compartment A which from time to time is supplied through an upper inlet with fresh stone which gravitates downward. This compartment is not shown in its full length, nor is the inlet shown, these being conventional in the parts not shown.

Below the storage zone A is a pre-heating zone B constricted at 7 and below this is a hot calcining zone C made with straight walls 9. At the lower end of zone C calcination is completed.

Below the zone C is the gas injection region 11, details of which will be described. The calcining zone C extends down to this. Below the region 11 is a cooling zone D. The entire kiln rests upon a foundation 13.

Just below the storage zone A is provided a cool gas off-take cross-pipe 15. One connection of this pipe leads to an exhaust suction fan 17 and the other leads to a pipe 19 which in turn is connected to a hot-zone recirculating cross-pipe 21. Pipe 21 connects with a recirculating suction fan 23. Both pipes 15 and 21 bridge the kiln. Openings 25 are provided in the bottom of the pipe 15 and openings 27 are provided in the bottom of pipe 21. Within the pipe 21 are sliding covers 28 which may be moved into various positions to control the flow through the openings 27 (see Fig. 4). Similar slides could be used in the pipe 15 but are not so necessary and are therefore not shown. These slides may be reached through doors 29 by means of hooked rods. They carry catch lips for the purpose. In return pipe 19 is a damper control 31.

By means of the damper 31 and the slide covers 28 the gas in and from pipe 21 which reaches the recirculating fan 23 is blended or tempered, that is, enough relatively cool gas may be drawn into pipe 21 from pipe 15 via pipe 19 so that neither pipe 21 nor the fan 23 will be overheated. Also, the slides 28 may be adjusted so that the distribution of gas flow through the sections of the kiln below pipe 21 may be controlled and evenly distributed.

The fan 23 delivers tempered hot recirculating gas to recirculating pipe 33. This leads to a main combustion duct 35 in the base of the kiln. It will be understood that this duct 35 may be made up as a plurality of ducts if desired. The gas delivered to duct 35 from pipe 33 is used as a tempering agent for the combustion medium in the duct 35. This medium may be natural gas, producer gas or oil. The gas in pipe 33 is mostly CO_2 which functions as an inert diluent for the combustible gas.

From the pipe 33 is a branch pipe 37 which leads to a main tempering duct 39. This duct 39 has individual connections 45 with branch ducts 41 in firing walls 43 located crosswise of the base of the kiln. Slides 44 provide for individual control of the openings 45 between the duct 39 and the ducts 41.

On the bottoms of the ducts 41 are openings

47 which lead to tempering ducts 49 in the walls 41. Ducts 49 are parallel to ducts 41. These ducts 49 have lateral outlets 51 in the walls 43 by means of which the hot recirculating gas is introduced into the fuel shaft proper between the walls 43. This gas acts as an inert mixing gas for more evenly distributing the combustion throughout the kiln section, and preventing local overburning. Slides 53 individually control the openings 47 and sliding vertical control walls 55 serve to sectionalize passages 49 so that flow is controlled from the outlets 51. The slides 44, 53 and 55 may be reached through suitable doors 57 in connection with the respective passages. All of the slides have hooked edges so that they may be moved by hooked reach rods.

The main combustion duct 35 is connected through openings 59 with distributing ducts 61 in the walls 43. Openings 63 in the tops of the ducts 61 connect them with parallel fuel distribution passages 65, the latter having lateral combustion outlets 67 in the walls 43. The connecting openings 63 are under control of slides 69 reached for adjustment from doors 71. Passage 59 is also controlled by a slide 73 reached from a door 75. The relative positions of the slides 44, 53, 55, 69 and 73 in Figs. 3 and 5 are in some instances different to indicate their adjustability.

Between the walls 43 are openings 77 which lead to drawgates 79, two of these gates being used between each pair of walls, making eight in all. Short vertical walls 101 separate the individual openings 77. Air is forced into the kiln by a fan 81, although some air also enters through the drawgates 79 and slots 77. The air from the fan 81 is distributed by means of a lateral duct 83 which has openings 85 connected with air distribution passages 87 in the bases of the walls 43. The connections 85 are under control of slides 89 reached from doors 91. The ducts 87 connect with the inside of the kiln through lower slots 93. These slots 93 are also under control of a number of slides 95 which may be reached from said doors 91.

It will be noted that in respect to tempering gas, combustible and air, the controls provide for adjustment of total volumes as well as local distribution. The total volume of tempering gas in each wall 43 is controlled by the slide 44 and its distribution by the slides 53 and 55. Total volume of combustible in each wall 43 is controlled by the slides 73 and local distribution by the slides 69. Total air is controlled in each wall 43 by the slides 89 and local distribution by the slides 95.

It will also be noted that the several sets of longitudinal ducts in the firing walls form cross channels for flow of tempering or diluent gas, combustible, and primary air. Thus, the upper ducts 49 form cross channels for flow of tempering or diluent gas. The intermediate ducts 65 form cross channels for flow of combustible. The lower ducts 87 form cross channels for flow of primary air.

An important feature of the invention is the use of the multiple, parallel firing bridge walls 43 providing multiple outlet slots 77 with the larger than usual number of drawgates 79.

Ordinarily vertical kilns have at most four or less draw-hoppers whereas the present one has a greater number, eight in the present example. It will be noted that the walls 101 cause two separate flows on opposite sides of each wall 43, each flow being handled by one draw-hopper.

This feature allows for a much more selective and accurate control of the flow.

The construction also permits of the more precisely controlled introduction of combustible, tempering gas and air throughout a greater area of the kiln.

From what has been said above it will be appreciated that with small stone the voids left in the kiln (Fig. 2) are much smaller than those left in a large-stone kiln (Fig. 1). This increases the friction against gas flow with the result that flame projection into the mass of stone cannot be very far, but I provide for injection at more points with better distribution over the kiln section, as described.

Also, the new manner of introduction of the tempering gas improves turbulence. This is partly due to the fact that this gas is introduced at many well-distributed points. Also the large number of well-distributed tempering gas outlets 51 are closely adjacent to a large number of well-distributed combustible outlets 67. There are also a large number of air-outlet ports 93 at the bottom of the kiln. The result is that an overall turbulent distribution of combustible, air and tempering medium is brought about throughout the entire cross section of the kiln. Also, the spaces between what may be called the burner walls 43 are relatively narrow, thus assuring adequate penetration of gases throughout the masses flowing down between the walls. The construction is feasible since the low temperatures involved will not burn out the walls 43 even under high rates of operation.

In effect, the kiln is divided into various operative sections, the off-take pipe 15 being at the bottom of the storage zone A and at the top of the pre-heating zone B. The recirculating pipe 21 is at the bottom of the pre-heating zone B and at the top of the calcining zone C. The combustible outlets 67 are at the bottom of the calcining zone C and at the top of the cooling zone D. The air outlets 93 are at the bottom of the cooling zone D. Below the cooling zone is the discharge by way of the drawgates.

It should be noted that when natural gas is used as a fuel, individual ducts may lead to the individual burner ports 67 but otherwise the principles of the invention would be the same.

In former kilns using large stone the practice has been to allow the charge to "hang" from time to time, and then to examine its condition under the hanging portions through inspection ports. With a kiln such as the present burning small stone, such hanging does not usually occur although once in a while it might. Trimming doors 96 are provided for breaking in the lime if such a remote contingency occurs. Normal operation is without hanging. Inspection of the condition of the lime can therefore not ordinarily be made through the doors 96. For this inspection dead-end observation ducts 97 are provided in the top portions of the bridge walls 43. By opening end doors 99 the heat of the various zones across the kiln cross section may be gauged according to the visible radiant conditions within the duct being examined. Both ends of these observation ducts 97 may be opened to the exterior of the kiln for examination purposes although in the present embodiment the duct 39 interferes. Thus by examining the radiant conditions within respective ducts 97, operating corrections may be made in the heating by adjustment of the various control slides mentioned so that the lime condition in various kiln sections may be controlled.

The examination ducts 97 are feasible with this kiln when using small stone because of the closely compacted nature of the small stone and lime around the walls 43 which would not be the case with large rock. In other words, the gauged temperature within the ducts is truly representative of the lime condition inside. Also with small stone a certain surface temperature is more accurately indicative of the amount of lime which has been produced, but in the case of large stone the lime surface may be hot but there may still be a great amount of core. Thus with the present invention the temperature as determined through the ducts 97 is a better gauge of whether the firing must be speeded up or slowed down in order to obtain optimum internal operating conditions.

It should be understood that while the invention is particularly directed to problems connected with kilns for burning small stone, some of its advantages accrue also to kilns for large stone.

It is to be understood that if desired the stone may be retained in the hot zone much longer without impairing its properties by use of the invention because of the fact that with small stone in this kiln the temperature may be kept at a relatively low point. It is temperature that does more harm in lime manufacture than time of exposure to temperature. Thus in this kiln lime may be carried higher if desired, in fact, so high that even occasionally the core burns out entirely and so high that there is virtually no residual CO_2 remaining, no portion of lime being recarbonated.

The number of walls 43 is such that the wall spacing will not be too great, that is, to ensure distribution of combustion throughout the entire areas between the walls and between them and the shaft wall. In this regard it will be noted from Fig. 5 that the spacing between walls is about double the space between the end walls and the shaft sides. This is because there are no burner outlets in the shaft sides.

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 kiln comprising a vertical shaft having a pre-heating zone and a calcining zone, a cross-pipe within said shaft located near the top of the calcining zone and having inlet means for hot gas from the calcining zone, means connected with said pipe for recirculating said gas to a point at the lower end of the calcining zone, a second pipe across the interior of said shaft and located near the top of the pre-heating zone and having inlets for receiving cooler gas from said pre-heating zone, and a connection between said last-named pipe and the first pipe whereby the cooler gas from the pre-heating zone flows through the first pipe and tends to cool the latter and to temper the hot gas from the calcining zone flowing therethrough.

2. A kiln comprising a vertical shaft having a pre-heating zone and a calcining zone, a cross-pipe within said shaft located near the top of the calcining zone and having a plurality of inlets for gas from the calcining zone, control means for

the inlets, means connected with said pipe for recirculating said gas to a point near the lower end of the calcining zone, a second pipe across the interior of said shaft and located near the top of the pre-heating zone and having inlets for receiving cooler gas from said pre-heating zone, and a connection between said last-named pipe and the first pipe whereby the cooler gas from the pre-heating zone flows through the first pipe and tends to cool the latter and to temper the hot gas from the calcining zone flowing therethrough.

3. A kiln comprising a vertical shaft having a pre-heating zone and a calcining zone, a cross-pipe within said shaft located approximately between the calcining and pre-heating zones and having inlet means for gas from the calcining zone, means connected with said pipe for recirculating said gas to a point near the lower end of the calcining zone, a second pipe across the interior of said shaft and located approximately at the top of the pre-heating zone and having inlet means for receiving gas from said pre-heating zone, a connection between said last-named pipe and the first pipe whereby the gas from the pre-heating zone flows through the first pipe and tends to cool the latter and the gas from the calcining zone therein, the inlet means in said first pipe consisting of a plurality of openings, and means for varying the flow through any particular opening.

4. A kiln comprising a vertical shaft having a pre-heating zone and a calcining zone, a cross-pipe within said shaft located approximately between the calcining and pre-heating zones and having a plurality of adjustable inlets for gas from the calcining zone, a suction fan for withdrawing gas from the pipe, means connected with said fan for recirculating said gas to a point near the lower end of the calcining zone, a second pipe across the interior of said shaft and located near the top of the pre-heating zone and having inlet means for receiving gas from said pre-heating zone, a suction fan for withdrawing gas from the second pipe, a connection between said second pipe and the first pipe whereby some of the gas may be withdrawn from the pre-heating zone and circulated through the first pipe tending to cool the latter and the gas from the calcining zone therein, and damper control means in the connection.

5. A kiln comprising a vertical shaft having a preheating zone and a calcining zone, a cross-pipe within said shaft located between the calcining and pre-heating zones and having inlet means for gas from the calcining zone, means connected with said pipe for recirculating said gas to a point near the lower end of the calcining zone, a second pipe across the interior of said shaft and located near the top of the pre-heating zone and having inlet means for receiving gas from said pre-heating zone, a connection between said last-named pipe and the first pipe whereby the gas from the pre-heating zone flows through the first pipe and tends to cool the latter and the gas from the calcining zone therein, the inlet means in said first pipe consisting of a plurality of openings having controllable adjusting means for varying the flow to any opening, means for introducing gas from said recirculating means to a plurality of openings below the calcining zone, and means for controlling flow through said last-named openings to control gas distribution in the calcining zone.

6. A vertical kiln comprising a pre-heating and a calcining section, a plurality of burner walls

built across the base of said calcining section and determining a plurality of flows of calcined material between the walls, cross passages within the walls for carrying combustible gas, inert diluent gas, and primary air, individual control means for the flows of gas and air to the burner walls, a plurality of inlets from said cross passages for admitting flow at various points to the inside of the hollow body, movable slide valve means within said cross passages and reachable from the exterior of the kiln for controlling flow into the kiln through the various inlets, a first gas off-take near the top of the calcining section, a second gas off-take near the top of the pre-heating section and connected with the first gas off-take, and branched means connecting the first off-take with the combustible gas passages and with the diluent gas channels respectively.

7. A kiln comprising a hollow shaft having a calcining zone, a firing wall across the base of said shaft, said wall having a dead passage near its upper end the interior of which is adapted to be observed from the outside of the kiln to determine by observation the temperature of material flowing past the upper edge of the wall.

8. A kiln comprising a hollow shaft having a calcining zone, a firing wall across the base of said shaft, passages in said wall connected by inlets with the interior of the shaft, said passages being for combustible gas, inert gas, primary air and the like, said wall having a dead passage near the upper end the interior of which is adapted to be observed from the outside of the kiln to determine by observation the temperature of material flowing past the upper edge of the wall.

9. A kiln comprising a vertical shaft comprising a pre-heating zone, a calcining zone and a cooling zone, a plurality of firing walls across the base of the shaft at the lower end of the calcining zone and within the cooling zone, upper channels in said walls for inert diluent gas, cross channels in said walls below the diluent gas channels for combustible gas, each of said channels having a plurality of outlets into the shaft, cross channels at the lower ends of said walls for primary air, each air channel having a plurality of outlets into the shaft, means for variably controlling the amount of gas flowing into each cross channel, individual control means within the channel for controlling entry of gases into the shaft through said outlets, all of said control means being reachable from the exterior of the shaft.

10. A kiln comprising a vertical shaft comprising a pre-heating zone, a calcining zone and a cooling zone, a plurality of firing walls across the base of the shaft at the lower end of the calcining zone and within the cooling zone, upper channels in said walls for inert diluent gas, cross channels in said walls below the diluent gas channels for combustible gas, each of said channels having a plurality of inlets into the shaft, cross channels at the lower ends of said walls for primary air, each air channel having a plurality of inlets into the shaft, means for variably controlling the total amount of gas flowing into each cross channel, individual control means within the channel for controlling entry of materials into the shaft through said inlets, all of said control means being reachable from the exterior of the shaft, an off-take pipe extending across the shaft at the upper end of the calcining zone having a plurality of inlets, control means in said cross-pipe operable from the exterior of the shaft for controlling distribution of flow from the shaft into said pipe through said inlets, and connections from said pipe to said diluent gas channels and to said combustible gas channel.

11. A kiln comprising a vertical shaft comprising a pre-heating zone, a calcining zone and a cooling zone, a plurality of substantially parallel firing walls across the base of the shaft at the lower end of the calcining zone and within the cooling zone, upper channels in said walls for inert diluent gas, cross channels in said walls below the diluent gas channels for combustible gas, each of said channels having a plurality of inlets into the shaft, cross channels at the lower ends of said walls for primary air, each channel having a plurality of inlets into the shaft, means for variably controlling the total amount of gas flowing into each cross channel, individual control means within the channel for controlling entry of materials into the shaft through said inlets, all of said control means being reachable from the exterior of the shaft, an off-take pipe extending across the shaft at the upper end of the calcining zone having a plurality of inlets, control means in said cross-pipe operable from the exterior of the shaft for controlling distribution of flow from the shaft into said pipe, connections from said pipe to said diluent gas channels and to the said combustible gas channel, said walls being spaced apart a distance small enough to ensure distribution of combustion throughout the entire space between walls.

12. A kiln comprising a vertical shaft comprising a pre-heating zone, a calcining zone and a cooling zone, a plurality of firing walls across the base of the shaft at the lower end of the calcining zone and within the cooling zone, upper channels in said walls for inert diluent gas, cross channels in said walls below the diluent gas channels for combustible gas, each of said channels having a plurality of inlets into the shaft, cross channels at the lower ends of said walls for primary air, each channel having a plurality of inlets into the shaft, means for variably controlling the total amount of gas flowing into each cross channel, individual control means within the channel for controlling entry of materials into the shaft through said inlets, all of said control means being reachable from the exterior of the shaft, a hot-gas off-take pipe extending across the shaft at the upper end of the calcining zone having a plurality of inlets, control means in said cross-pipe operable from the exterior of the shaft for controlling distribution of flow from the shaft into said pipe, connections from said pipe to said diluent gas channels and to the said combustible gas channel, a cool-gas cross-pipe in said shaft near the upper end of the pre-heating zone, and a connection from said last-named cross-pipe to said first-named cross-pipe for cooling the first cross-pipe and tempering the gas flowing therein.

13. A kiln comprising a vertical shaft comprising a pre-heating zone, a calcining zone and a cooling zone, a plurality of firing walls across the base of the shaft at the lower end of the calcining zone and within the cooling zone, upper channels in said walls for inert diluent gas, cross channels in said walls below the diluent gas channels for combustible gas, each of said channels having a plurality of inlets into the shaft, cross channels at the lower ends of said walls for primary air, each channel having a plurality of inlets into the shaft, means for variably controlling the total amount of gas flowing into each cross channel, individual control means within the channel for

controlling entry of materials into the shaft through said inlets, all of said control means being reachable from the exterior of the shaft, an off-take pipe extending across the shaft at the upper end of the calcining zone having a plurality of inlets, control means in said cross-pipe operable from the exterior of the shaft for controlling distribution of flow from the shaft into said pipe, connections from said pipe to said diluent gas channels and to the said combustible gas channel, a cross-pipe in said shaft near the upper end of the pre-heating zone, a connection from said last-named cross-pipe to said first-named cross-pipe, and damper control means in said connection.

14. A kiln comprising a vertical shaft having a pre-heating zone and a calcining zone, a first gas intake within said shaft located near the top of the calcining zone, a second gas intake within said shaft in said pre-heating zone, a connection between said gas intakes, and means connected with said first gas intake for withdrawing the cooler gas from said second intake through said connection and said first intake, whereby said cooler gas tempers the hotter gas in said first intake, and for delivering said tempered gas to a point at the lower end of the calcining zone.

15. A kiln comprising a vertical shaft, a portion of the shaft constituting a calcining zone, a plurality of substantially parallel firing walls extending across the shaft at the base of said zone, each firing wall having vertically spaced longitudinal ducts therein and a plurality of lateral outlets from said ducts to the interior of the shaft, one of said ducts constituting a channel for flow of combustible gas, the other of said ducts constituting a channel for flow of diluent gas.

16. A kiln comprising a vertical shaft, a portion of the shaft constituting a calcining zone, a plurality of substantially parallel firing walls extending across the shaft at the base of said zone, each firing wall having an upper longitudinal duct therein for flow of a diluent gas, an intermediate longitudinal duct therein for flow of combustible gas, a lower longitudinal duct for flow of primary air, and a plurality of lateral outlets from each of said ducts to the interior of said shaft.

17. A kiln comprising a vertical shaft, a portion of the shaft constituting a calcining zone, a plurality of substantially parallel firing walls extending across the shaft at the base of said zone, each firing wall having vertically spaced longitudinal ducts therein and a plurality of lateral outlets from said ducts to the interior of the shaft, one of said ducts constituting a channel for flow of combustible gas, the other of said ducts constituting a channel for flow of diluent gas, means for controlling the total flow of combustible gas to said one duct, means for controlling the total flow of diluent gas to the other duct, and control means within each of said ducts for individually controlling the flow through said outlets so as to distribute said combustible and inert gases throughout the cross section of the kiln.

18. A kiln comprising a vertical shaft, a portion of the shaft constituting a calcining zone, a plurality of substantially parallel firing walls extending across the shaft at the base of said zone, each firing wall having vertically spaced longitudinal ducts therein and a plurality of lateral outlets from said ducts to the interior of the shaft, one of said ducts constituting a channel for the flow of combustible gas, the other of said ducts constituting a channel for flow of diluent gas, means for controlling the total flow of combustible gas to said one duct, means for controlling the total flow of diluent gas to the other duct, and control means within each of said ducts for individually controlling the flow through said outlets so as to distribute said combustible and inert gases throughout the cross section of the kiln, said control means comprising slide valves within said ducts reachable from the exterior of the kiln for controlling the flow through individual groups of said outlets.

19. A vertical kiln comprising a vertical shaft having a pre-heating zone and a calcining zone, a plurality of burner walls built across the lower end of said calcining zone and determining a plurality of flows of calcining materials between the walls, each wall having longitudinal ducts therein for carrying combustible gas, inert diluent gas and primary air, respectively, and a plurality of lateral outlets from each duct to the interior of said shaft, means for controlling the total flow of combustible gas, diluent gas, and primary air to their respective ducts, and movable slide valve means within each of said ducts and reachable from the exterior of the kiln for controlling flow through the outlets of said ducts.

VICTOR J. AZBE.