May 7, 1940. V. J. AZBE 2,199,384

CALCINING APPARATUS

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FIG. 1.

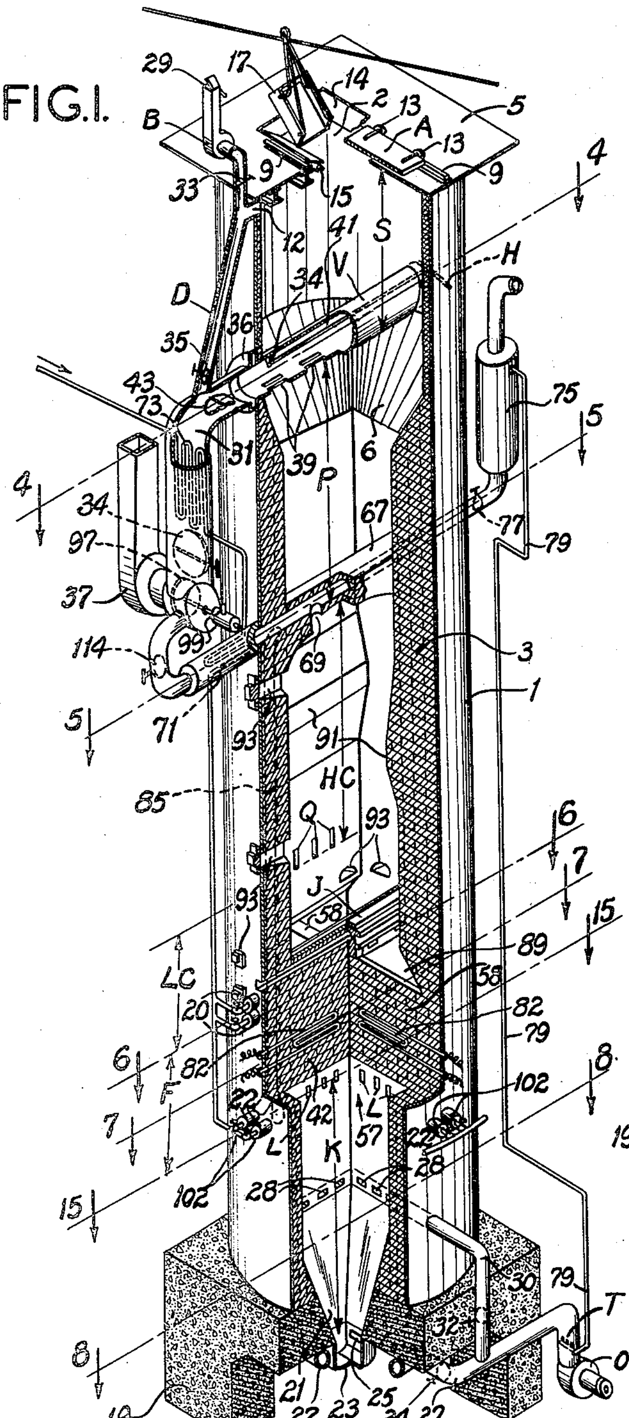

FIG. 14.

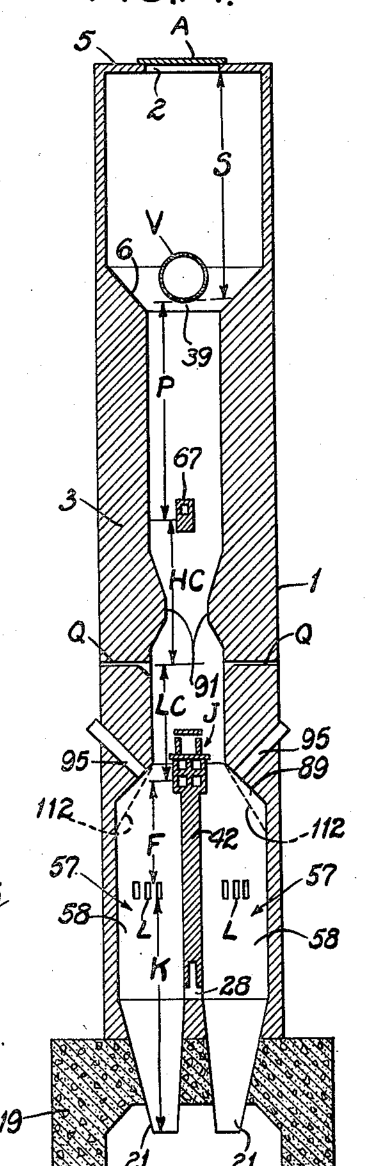

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FIG. 2.

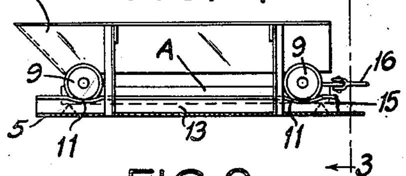


FIG. 3.

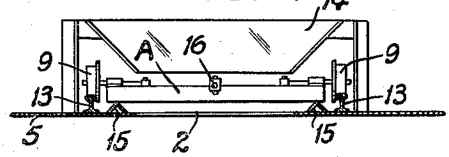


FIG. 9.

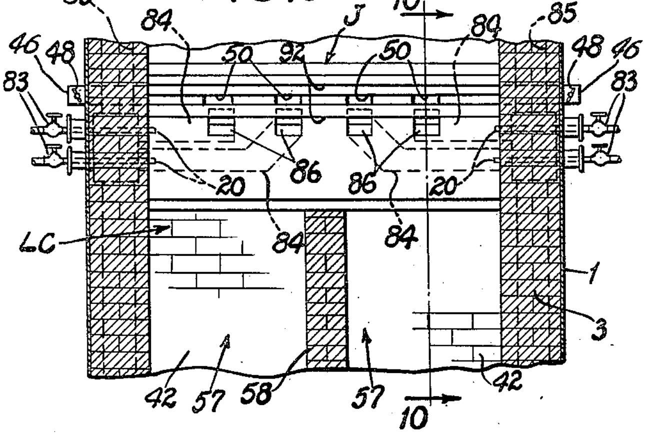


FIG. 10.

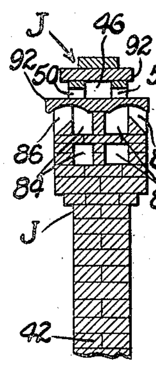


FIG. 11.

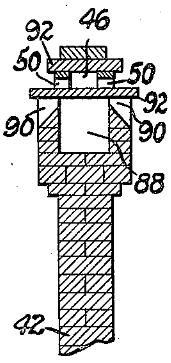


FIG. 12.

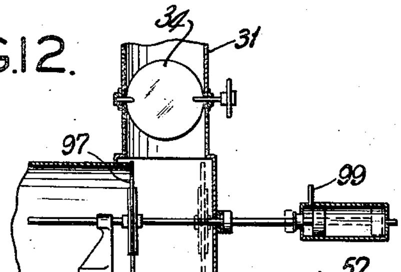


FIG. 13.

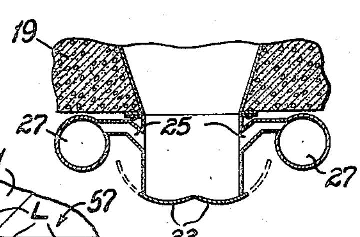
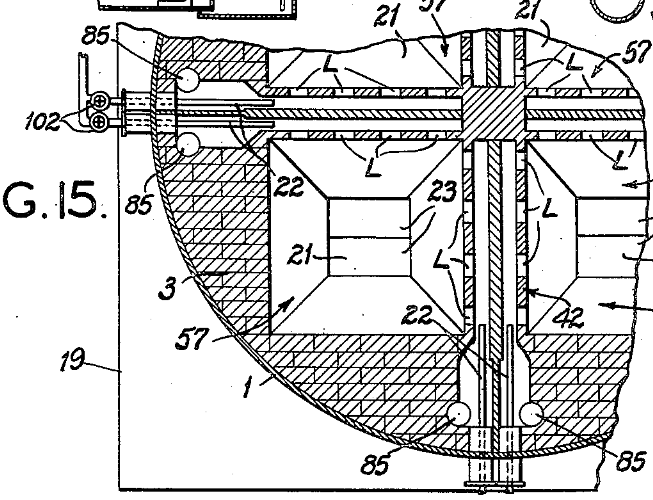


FIG. 15.



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CALCINING APPARATUS

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FIG.4.

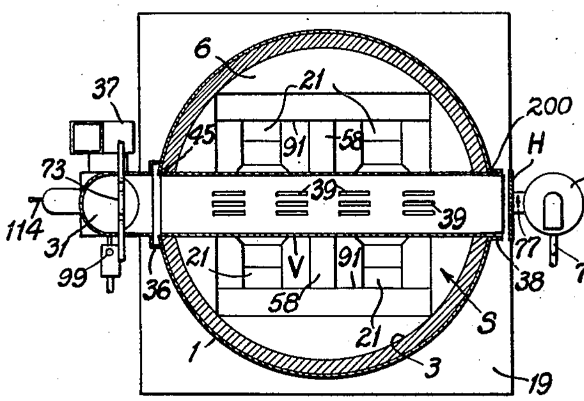


FIG.6.

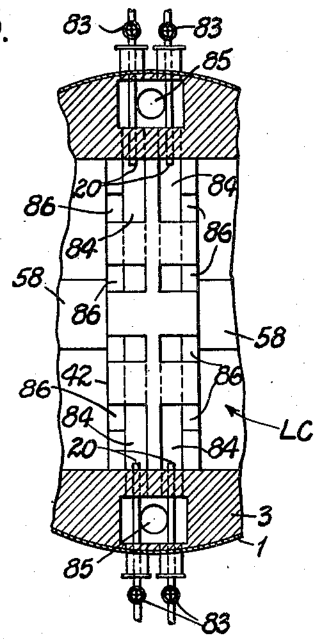


FIG.5.

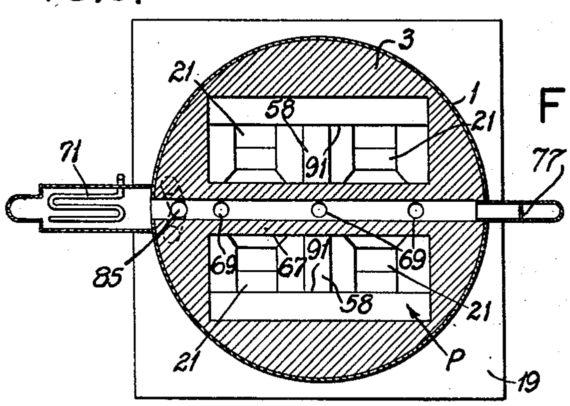


FIG.7.

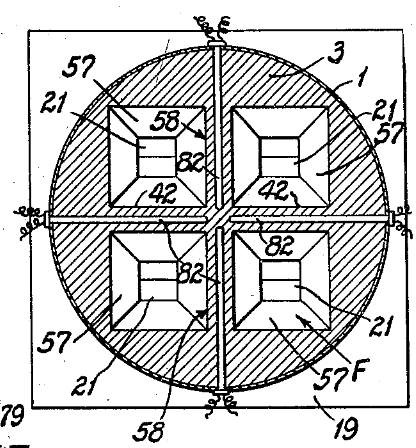
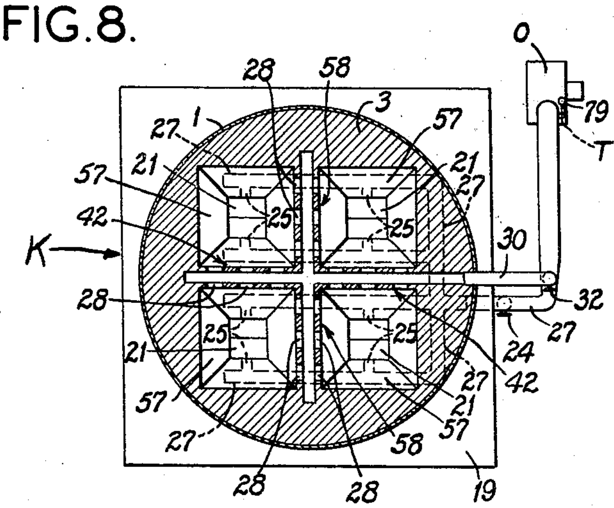


FIG.8.



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Patented May 7, 1940 2,199,384

UNITED STATES PATENT OFFICE

2,199,384

CALCINING APPARATUS

Victor J. Azbe, Webster Groves, Mo.

Application February 26, 1938, Serial No. 192,674

22 Claims. (Cl. 263—29)

This invention relates to calcining apparatus, and with regard to certain more specific features to apparatus for burning limestone to produce lime and CO_2 gas.

The present application is a continuation-in-part of my patent application Serial No. 148,190, dated June 14,1937, for Lime kiln.

Among the several objects of the invention may be noted the provision of apparatus for producing a high-grade, soft-burned, high-availability lime, with minimum of core, from low-grade or high-grade limestone, the production being at a high rate and at high efficiency; the provision of means for obtaining high capacities from small kilns without excessive deterioration of kiln linings and with long kiln life; the provision of means for burning spalls heretofore wasted or burned in rotary kilns; the provision for central injection means for gaseous fuels and control of (*a*) combustion, (*b*) hydrocarbon cracking and (*c*) temperature, in order to obtain high fuel efficiency and high quality of lime; and the provision of means for obtaining CO_2 gas of very high strength. Other objects will be in part obvious 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 is illustrated one of various possible embodiments of the invention,

Fig. 1 is an isometric view of the kiln, parts being broken away;

Fig. 2 is a side elevation of a charging apparatus;

Fig. 3 is a cross section taken on line 3—3 of Fig. 2, parts being broken away for clarity;

Fig. 4 is a horizontal section taken on line 4—4 of Fig. 1;

Fig. 5 is a horizontal section taken on line 5—5 of Fig. 1;

Fig. 6 is a horizontal section taken on line 6—6 of Fig. 1;

Fig. 7 is a horizontal section taken on line 7—7 of Fig. 1;

Fig. 8 is a horizontal section taken on line 8—8 of Fig. 1;

Fig. 9 is a vertical section of a center burner bridge wall;

Fig. 10 is a vertical section taken on line 10—10 of Fig. 9;

Fig. 11 is a view similar to Fig. 10 showing an alternative form of center burner;

Fig. 12 is a detail section of a flue control;

Fig. 13 is a detail section of certain draw gates;

Fig. 14 is a vertical section of the invention with an alternative feature; and,

Fig. 15 is a fragmentary and enlarged section taken on line 15—15 of Fig. 1.

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

The following imperfections in prior vertical, shaft-type limekilns are generally known:

1. They have a low capacity for a given investment;
2. They require considerable fuel for a given amount of lime;
3. They need to be repaired frequently;
4. They need to have large-sized limestone rock;
5. The rock needs to be of best quality to insure fair lime;
6. They are usually incapable of producing good, readily slaking lime out of poor rock;
7. They are incapable of giving uniformly burned lime;
8. They cannot be regulated so as consistently to produce lime of different characteristics when desired from the same stone; and,
9. The kiln gases have a low CO_2 content and are very hot.

Many lime plants have large piles of wasted spalls that have been accumulating through years and for which there has been no use. This is because only rock of large size could be burned in vertical kilns, since gas could not well be equally distributed when the shaft was filled with small rock or spalls. By means of this invention, the burning of spalls in vertical kilns not only becomes practical, but preferable to burning of large shapes that tend to present a relatively small surface for heat absorption.

All limestones contain a certain amount of silica, alumina and iron compounds that are ordinarily considered to be impurities. In some limestones there is a considerable amount of these undesirables. In the limekiln they combine with the calcium to form silicates, aluminates and ferrates, which reduce the amount of free lime. Furthermore, these compounds tend to destroy the sponginess of the lime and form liquid slags which upon cooling form concretions which enclose free calcium oxide, making it unavailable. Because of this, the lime becomes much less desirable for some chemical processes, and sometimes actually useless.

Even when limestone is very pure and impure compounds cannot form to any great degree, exposure to excessive temperatures for variable lengths of time impairs the quality. This is because of shrinkage and reduction of free space between unit cells of calcium oxide. Reduction need not be great for the free space to become less than the dimensions of water molecules, thus interfering with slaking. Hence settling rates, availability and plasticity, and all other important factors, become impaired.

The kiln incorporates features to be explained which effectively avoid the occurrence of this undesirable action through provision for control of zonal temperature, distribution of heat, rate of draw, and location of draw.

The invention also includes a novel method of introducing gas for combustion and a novel method of delayed combustion that tends to produce highest temperature when deleterious action on the stone is least likely to take place, and lowest temperature when such action is most likely to occur.

Prior limekilns also present difficult refractory problems. Highest temperatures are developed along the walls, and the calcium base of the lime combines with the comparatively acid silica of the refractory. This is aided by the alumina and fluxes of the refractory and by the impurities in the lime. As a result, the surface of the high-melting-point brick changes to a low-melting-point slag which, at ordinary kiln temperatures, tends to retain its shape, but which is semi-fluid. The action penetrates deeper with progress of time. This converted mass finally melts and runs when temperatures become higher. Thus some kilns needed to be repaired every few months, and all have had comparatively short lives. This invention overcomes this slagging difficulty very effectively by removing the high temperature zone away from the kiln lining, and by other means to be described.

Many conventional vertical kilns have three operating zones, namely, pre-heating, calcining and cooling. Some operate with only two zones, namely, pre-heating and calcining, these two being very indefinitely defined.

The limekiln of the present invention is divided into six zones, namely, (1) storage and drying zone, (2) pre-heating zone, (3) upper calcining zone, (4) lower calcining zone, (5) finishing zone, and (6) cooling zone. By this means, control is obtained that greatly enhances quality, quantity, and efficiency.

I have discovered that the color of lime is often impaired by reason of oxidation while it is in the cooling zone. In the present kiln there are means to avoid this, with consequent production of a much whiter product. This is accomplished by retaining of lime in a reducing atmosphere and subsequent subjection to sudden cooling.

The present kiln also includes features permitting of partial hydration of lime by admitting low pressure steam with air. This retains some of the heat of hydration in the kiln, and increases by a substantial amount the heat available for calcining. This partial hydration conditions the lime for special processes.

By means of the present invention, combustion, even with natural gas, is caused to be very luminous, and is attained by pre-heating and cracking of hydrocarbons and by special methods of introducing air for combustion. A luminous, long flame is very much desired for lime burning, as it produces better lime and greatly increases heat transfer. In this kiln, flame can be made as long or as short as desired, and either luminous or non-luminous.

In prior limekilns, there is very little or no control over the amount of lime that can be drawn from different sections of the kiln. In the present kiln, there are four outlet sections in which the amount of lime drawn from each can be increased or reduced independently of the other. At the same time, the finishing heat to each of these sections can also be controlled independently, with complete exclusion from some sections, if desired.

Another novel feature is the production of high-strength CO_2 gas that may be cooled and compressed immediately without the requirement of the usual purification and absorbing system. Ordinary limekilns give off gases containing only 20% to 40% of CO_2. This kiln is arranged for intermittent operation as a retort, self-heated from within, to provide CO_2 of substantially 100% strength.

There is also an arrangement for exact supplemental electrical heating during the retorting period in which CO_2 is driven off. This optional supplementary use of electricity lengthens the period during which CO_2 is given off. About one kilowatt-hour of energy produces 2½ pounds of lime and 2 pounds of pure CO_2 gas. By this method of CO_2 generation, gas can be obtained uncontaminated with products of combustion, and suitable for dry ice manufacture. A CO_2 plant construction can thus be simplified in operation and reduced in cost.

The kiln includes means to aid uniform gas introduction and distribution into the limestone charge; means to regulate the flow of stone in different sections; means to assure hanging of charge when drawing, to enable trimming, and of clearing of the walls; and means for aiding practical operation and avoiding possible difficulties caused by excessive temperatures or expansion and contraction due to heating of structural members.

Referring now more particularly to Fig. 1, there is shown at numeral **1** the cylindric outside metallic body of the kiln in which is arranged a refractory brick lining **3**. It is shown circular in cross section but an ovate form is sometimes preferable The kiln is divided into six zones, as above noted, these being identified as the storage and drying zone S, the pre-heating zone P, the upper, calcining zone HC, the lower, calcining zone LC, the finishing zone F, and the cooling zone K. All zones except the last two are single pass; that is, all flow through the zones S, P, HC and LC is bounded by a single cylinder.

The body is capped by an enclosure **5** having an opening **2** for which is provided a warp-proof, charging and explosion door A having wheels **13** travelling on rails **9**. The rails **9** have cam depressions **11** into which the wheels **13** of the door A sink when the door is in position over opening **2**. Thus the door, in its closed position, lowers to a seat **15** that is triangular in vertical section, upon the upper edge of which dirt cannot collect. The seat **15** surrounds the charging opening **2** and the rails **9** are outside of this seat. Thus, the closing of opening **2** is always tight. During natural draft operation, this door serves as draft regulator as well, enabling precise adjustment of pressure under the enclosure **5**. Charging apparatus is diagrammatically illustrated at 17 and a hopper at 14. As shown in Figures 2 and 3, the door A moves under the hopper 14. Suitable manual or automatic means (not shown) are adapted to draw the door by member 16.

Gases may be withdrawn at all or any of three points, each with a special purpose. The purpose of the uppermost exhaust at 12 is to dispose of leakage air which enters the charging opening 2, and to dispose of steam created while drying the stone in the storage chamber S.

The purpose of the middle and main exhaust through pipe V is to discharge the cooled gases that have served their purpose in pre-heating the stone. Due to the upper exhaust at 12, these gases are, if desired, undiluted with air or with steam from the drying of the rock in zone S or from melting of the ice and snow from this rock during winter periods.

The third withdrawal point is from the hollow offtake bridge 67 at the top of the calcining zone HC where there is a temperature of around 1500° F. Inasmuch as the gases coming through the calcining zone HC have a surplus of heat necessary for pre-heating in zone P, a portion may be withdrawn at this point through openings 69 and utilized for pre-heating of natural gas (if this be used), or for pre-heating air for a gas producer, or for the generation of steam for injection with air into the cooling zone K, or for other use.

This pre-heating not only has the effect of saving the heat for use in the pre-heating process, but permits the combustion process to be started at a temperature higher than atmospheric, with the result that the calcining temperature is more easily and economically reached than would otherwise be possible.

The kiln also has arrangements for making useful the surplus relatively cooler gas from the top of the calcining zone HC, LC. This relatively cooler gas is recirculated for the purposes of lowering temperatures in the lower calcining zone and making them more uniform; hence eliminating hot spots which ordinarily would occur in zone LC. There is also effected increased velocity of gas flow and better heat transfer. This is accomplished, without the gases leaving the kiln, through special passages 85 built in the kiln wall, and the flow is created by injector effect at burner nozzles 20 (Fig. 6) and 22 (Fig. 15) and without using a fan for propelling these gases. Due to the great heat of these gases, a fan would be impractical. A further value of recirculation of these hot gases is that, the kiln shaft is insulated with hot gases which tends to reduce heat loss, as well as to cool the walls, thus lengthening their life. The cooling is by reason of the fact that the gases, although hot enough to reduce the temperature gradient through the wall, are relatively cool enough to effect the cooling desired.

The kiln is on a foundation 19 and has four lower tapered outlets 21. Each outlet has charge-releasing doors 23 movable to shut (solid-line positions), or to open (dotted-line positions). Each outlet 21 is also provided with draft inlets 25 leading from an air line 27 (Fig. 8). In the air line 27 are a forced-draft fan O and a control damper 24.

A second set of air inlets is at 28 supplied from a branch air pipe 30 in which is a damper 32.

A fan B draws sufficient hot gas through the storage zone S to dry the rock. This gas, with its moisture and with all such air as may have entered through the charging door while charging, is discharged to waste at outlet valve damper 29. By this means, the storage zone S is utilized for useful purposes other than mere storage and the gases passing through the main exhaust 31 from pipe V are undiluted with leakage air or moisture from stone.

When fan B carries off gas from zone S, a damper 33 is open and a damper 35 in a by-pass pipe D is closed. When damper 33 is closed and damper 35 is open, the gas from zone S flows to the exhaust pipe 31 by way of both pipes V and D. An exhaust fan 37 draws gases from the exhaust 31. Thus when the presence of air or steam in the main exhaust stream at 31 is not harmful, the fan B is cut off and damper 33 is closed. The storage zone S is nevertheless utilized as a mild pre-heater and dryer by the passage of small controllable amounts of gas through the by-pass line D. A damper 43 in line 31 permits of further control. Damper 34 permits control of all flow through pipe 31. It is clear that whatever gas does not go through pipe D, goes through pipe V, and hence the flow of gas from the remainder of the kiln into pipe 31 remains substantially constant, regardless of the setting of damper 35.

All dampers are of the specially devised, thin, flexible edge type that accommodate themselves to the contour of the opening, and which seal tightly.

Pipe V constitutes a submerged gas offtake pipe preferably of heat resisting metal which is located crosswise of the kiln at a position substantially between the storage zone S and preheating zone P. It is slotted on its bottom at 39 so that gases are drawn uniformly from the entire cross section of the shaft. The slots are on the underside of the pipe F and thus cannot become clogged. Furthermore, an open pocket forms in the material under the pipe V. The gas offtake pipe V divides the storage from the preheating zones, and, in fact, creates these two zones.

Whenever the kiln is drawn, it receives fresh rock from the storage zone S, although kiln charging may take place less often than kiln drawing. This prevents wide fluctuations in gas temperatures and draft. The presence of the cross pipe V in connection with the constriction 6 between the storage zone S and main kiln shaft effectively breaks the fall of rock and reduces rock breakage and excessive packing.

Within the gas offtake pipe V there is a thermostat bar 41 having one end anchored at 34 while the other is articulated with the door H. When temperatures become excessive, the lengthening of the bar opens the door, admitting cold air, and by this automatic means, damage to the fan 37 is prevented.

The pipe V is subject to considerable expansion by heat, and hence is not directly connected to the external pipe 31. It lies independently within the kiln left-hand wall as shown at 45. The external pipe 31 is welded to the shell at flange 36, and thus a tight connection is established that cannot possibly develop a leak. The door H is hinged to the pipe V and pipe V is welded to the kiln body 1 at 200. The bar 41 expands faster than pipe V and therefore can open the door H despite the fact that with heating the anchor 34 moves to the left.

By means of tight dampers and tight charging door, it is possible to operate the kiln in a novel way. If the capacity desired is less than half normal, forced draft is not necessary, and natural draft is sufficient, as by opening the top door A. If a still smaller output is desired, it can be efficiently obtained by regulating this top door A so that a back-pressure is created, counteracting the normal draft of the hot kiln, and thus reducing the air admitted at the bottom to correspond with the fuel to be burned. If no lime is wanted at all, the door A is closed tightly and then as no gases can escape (all dampers being closed), no air can enter, and hence no heat is lost, except through normal radiation through the kiln walls. In this way, the kiln can be maintained on the line red hot for a week without any burning of fuel, and be ready at the end of that time to get under production immediately.

At J is shown a bridge arch with a wall 42 beneath. This arch serves to retard the flow of lime and aids its hanging, and thus permits proper trimming of the charge. It is hollow, thus enabling admission of combustible gases to the kiln center. It is arranged so that the rate of gas flow to either of several sections of the kiln shaft are independent of one another. This is accomplished by arranging eight valves 83 respectively on the eight nozzles 20, each of which controls the flow of gas into a separate duct 84 in the center burner bridge J. Each duct 84 has an outlet 86 (Fig. 10). A secondary center air inlet is shown at 46 under control of dampers 48 and having ports 50 in the bridge J above the fuel ports 86.

In an alternative form of center burner shown in Fig. 11, a single passage 88 is used for gas with a multiplicity of outlets 90. This type of bridge is used for producer gas. Both bridges of Figures 10 and 11 are arranged so that the ports cannot clog. This is done by providing overhanging portions 92.

By means of this bridge, there is obtained the effect of a center burner. No outside burners are necessary, although they may be used for special purposes, as in the cases where espcially small-sized limestone is to be burned, to be referred to later in connection with Fig. 14. Thus greatest heat is removed from the kiln walls, and placed closer to the center, and air coming from the cooler mixes better with the combustible gas.

The kiln from this point down in zones F and K is partitioned by walls 42 and 58 into four equal sized sections or quadrants 57, each of which can be independently drawn at its bottom doors 23, and each of which can receive independently any desirable amount of combustible gas and air. Thus, the kiln becomes, to all practical purposes, one with four independent production units, if the bridge J of Figures 9 and 10 be used. Each of the four units is, for example, readily capable of producing the equal to one or two ordinary kilns. One-unit limekilns of large size are ordinarily poor performers, but this invention increases capacity and improves performance.

In addition to the upper firing level at bridge J, there is a lower firing level shown at ports L. Here to the air coming up from the cooling zone K there is added a sufficient amount of gas to heat a limited amount, for example, not more than 1800° F. Expressing it differently, the gas is burned with such a large amount of excess air that temperatures cannot be high. By this means, a new, heretofore never used, limekiln zone is created, that is, the controllably heated finishing zone F, which extends from the level of burners L to the level of the burner outlets 86 in the bridge J. In this finishing zone F the core of the lime is calcined and the last amounts of CO_2 are driven off.

The degree of burn of lime can thus be very readily controlled, as it depends upon the temperature to which it is exposed and the time it requires to pass the finishing zone F. The temperature depends upon the simple matter of adjusting the amount of gas admitted through the valves 102 of the lower burners 22. Lime thus can be obtained hard or soft burned. As the lower divided section F of the kiln is utilized for controlled finishing, it is possible consistently to obtain one kind of lime from one section and another kind from another section; and this very simply and quite independently.

There is the further advantage that the CO_2 content of the finishing zone F is very low, thus reducing CO_2 tension, and so reducing the temperature required for calcination and eliminating the possibility of recarbonization, which together bring on the advantage that the lime drawn has a higher calcium oxide content, due to lower loss on ignition. Further, the lime, before it is fully calcined and so before it has acquired the temperature of the combustion zone HC, LC, passes into the low temperature zone F. Hence, the impurities do not tend to combine. This is another reason for the higher amount of calcium oxide obtained.

If desired, it is possible to use the finishing zone F according to the principle of the fireless cooker, calcining the core with stored heat remaining after the lime passes down below the upper burners in the bridge J. In this event, the finishing zone F is by-passed by the air which comes up through the cooling zone K. At this time, the injecting nozzles 22 are turned off, but the nozzles 20 remain on. Thus, the upper gas injecting nozzles 20 function to draw air through the ports L and through the lower portions of passages 85 of the kiln wall. This air is then forced into the center burner J, thus by-passing the finishing zone F, and acting as primary air in the center burner J. The finishing zone F would, in this case, have no flow excepting for the normal convection currents.

The ability to by-pass the air from the cooling zone K through the ports L through passage 85 to burners 20 and out through the burner arch J permits of obtaining a whiter lime, because a reducing atmosphere is maintained in the finishing zone F. This is because some gas may be drawn down from zone LC. This also permits of drawing in a large amount of air through the cooling zone K without affecting the finishing zone F, so that the lime passes suddenly from the finishing zone F into the cooling zone K. This prevents deterioration in color.

The cooling zone K receives air from passages 25, and/or 28, either through natural draft, or forced draft, from the blower O, and is conditioned with steam from jets T, if partial kiln hydration is desired. Natural draft is obtained by a slightly open condition of the gates 21, 23 to a degree that will not permit falling out of the charge, but will permit entry of the air. The fan 37 then functions to induce the draft. Both fans 37 and O may be used at the same time. The provision of the forced-draft fan O at the air inlet and the provision of the induced-draft fan 37 for drawing gases out of the kiln shafts results in the combination of induced and pressure drafts which improve gas distribution so as to improve the heat transfer and capacity.

There is no intention ordinarily to hydrate in the kiln, except for special reason, nor completely to hydrate lime therein. Only partial hydration is intended, when used at all, as limited by the difficulties due to lime expansion and disintegration. But absorption of even small quantities of steam is sometimes advantageous. The sensible heat and the latent heat of the steam, and the heat of hydration of lime, are thus liberated and in turn passed on to the air. For each pound of steam, 1600 B. t. u. is given off, which in the kiln all serves as heat of high elevation capable of making lime. One pound of steam absorbed gives 1.15 pounds of additional lime, without any more fuel. A boiler is shown at 75 which may be cut in by means of damper 77. The steam line 79 from the boiler 75 leads to the jets T. Thus, air entering the cooler K may be humidified by steam from the jets T. In the cooler, lime is cooled and water vapor absorbed, which in turn releases heat for re-heating of air.

Above the cooling zone K, the air receives a certain amount of combustible at the lower firing ports L, sufficient to create a desirable temperature in the finishing zone F. At the top of the finishing zone F, at bridge J, the full amount of combustible is admitted in excess of that required to satisfy the air coming up from the cooling zone K. This combustible is pre-heated at preheaters 71 and 73 and hydrocarbons partially cracked. Burning this gas with insufficient air gives a very luminous, long, and mild flame. At openings 50, the remaining amount of air is admitted and combustion is completed. More air may be admitted at Q, or further firing may be effected through these openings Q where the air otherwise admitted is in excess for a given limestone. Either one or both heat transfer apparatuses 71 and 75 may be used. If both are used, then not only would all heat be recovered for carbonate dissociation, but the heat of hydration would be utilized for this purpose as well.

The injection of primary gas at L and secondary gas at J is with turbulent, high-velocity flow, thus aiding mixing and preventing hot spots or heat channels, and thus greatly aiding heat transfer.

The storage zone S is flared out, as shown. The pre-heating zone P is narrower and constricted. In addition, and this is novel, the finishing zone F and cooling zone K are made of large cross-sectional area, as indicated at 89. In addition, a choke is used at 91 for the purpose of breaking the fall of rock and loosening the lime in the hot zone so that the material in it is not so densely packed, and so that the gas can circulate more readily through it. Trimming to permit the fall of the charge is effected through poke holes 93.

In Fig. 14 is shown the value of the enlarged portion 89 adjacent the center burner J. This enlarged portion permits the rock, particularly fine rock such as spalls, to assume a position, according to its angle of repose, which is peripherally spaced from the enlargement 89 (see dotted lines 112). At the enlargement 89, auxiliary external burners 95 may be used at an angle, as shown or at any other convenient position, to inject a combustible into the space thus left. It will be understood that with spalls or other fine rock the center burner J may not distribute the combustible as satisfactorily as might be desired, and that the auxiliary distribution into the nozzles 95 assures that all spall areas are exposed to heating.

The wide lower section also increases the length of stay of lime in the finishing and cooling zones and reduces the pressure necessary to deliver the air.

By the time that the calcining zone HC has been traversed by the gases, they have cooled to below the temperature of dissociation of the carbonate and may then only be used for pre-heating of stone in the pre-heating zone P. The division between zones HC and P depends upon the kind of limestone calcined, but may be around 1500° F.

Since there is a surplus of heat available for pre-heating of stone, some of the gas can be withdrawn at the junction joint between zones HC and P and utilized in a way that makes this heat of low elevation (not any more available for calcination) again very useful for this purpose. This can be accomplished in several ways. It is possible to draw off through openings in the wall, but this is unsatisfactory. A better means is by use of the hollow, refractory bridge 67 sprung across at the transition point, as shown, having openings 69 in its lower portion, through which the gases enter and pass either to the fan 37 by way of pre-heater 71 and damper 114, or to other heat-exchange gas apparatus, such as the boiler 75. Or it may in part be recirculated by means of the injector effect at gas entrances at nozzles 20 and 22.

In the case of natural-gas fuel, it is first preheated in the first stage pre-heater located at 73 in the main exhaust line 31. It is heated to almost the cracking point in the secondary high-temperature pre-heater 71. Delivered in lower bridge J, it heats and cracks upon entering the burning zone of the kiln. Thus is recovered heat which might otherwise be wasted, and improvement of heat transfer by effecting higher luminosity.

The gases withdrawn at ports 69 can also readily serve to make steam for such purposes as steam may be desired, but from kiln efficiency standpoint, preferably for injection into the cooler as at jets T.

In respect to the re-circulation of gas through passage 85 for conditioning combustion, it should be noted that the gases never come out of the kiln shell, but pass through the channel 85 in the wall, propelled by the suction effect of the injection at 20 and 22. It is recirculation with no substantial loss of heat, altogether different from re-circulation practiced heretofore, when gases were brought out of the kiln to be inevitably cooled, and then reinjected by fans, and often causing more harm than good.

If all air inlets and all poke-hole doors are closed, a pressure is created in the kiln which effectively prevents any air entering through the draw gates 23. If all combustible is shut off simultaneously, the kiln becomes a retort in which the heat stored dissociates the carbonates and generates pure CO_2 gas. This gas in substantially pure undiluted form is discharged at a rate adapted to retain gas pressure within the kiln, and thus avoid any chance leaks and possible dilution.

The flow is controlled by means of a damper 97 shown in Fig. 12, which is regulated automatically by the pressure of the gas at the base of the kiln. The pressure pipe 99 in this event is connected to the usual pneumatic relay apparatus (not shown) which is responsive to kiln pressures. When the pressure builds up, the damper valve 97 opens so that the CO_2 under pressure may be relieved and vice-versa. This control apparatus has been shown merely diagrammatically, because it is known.

Exclusive heating of limekilns by means of electric current is uneconomical. In this case, it is made practical by partial use at opportune times. In the wing walls **42** and **58** of the finishing zone F, readily removable and replaceable electrical heating elements **82** are inserted. When the kiln is sealed for operation as a retort, the electric current may also be turned on and through its heating of the structure and dissemination of this heat by convection to the lime and limestone, the period of exclusive CO_2 generation is greatly prolonged.

Kiln design is in conformity with definite controlling factors, as surface presented for heat absorption, capacity desired, temperature permitted, resistance to gas flow created, time element required, kind of lime wanted, kind and cost of fuel, labor obtainable, etc.

The lime from each of the four units of zone K may be drawn intermittently. During the draw, the gas is shut off from the respective unit, with other units remaining under normal operation. In this way, interruption is reduced to a minimum, and is only sufficient properly to trim the particular kiln section. If desirable, the drawing may be continuous.

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 carrying out 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. In a kiln having a charging inlet, means providing a storage zone within said charging inlet, conduit means for drawing off gases at the bottom of said storage zone, a second conduit means adjacent said inlet for drawing off gases at the top of the storage zone, both of said conduit means being joined, suction means for drawing gases through both of the conduits, and auxiliary suction means adapted to draw gas from the conduit connecting with the upper portion of said storage zone.

2. In a kiln, a storage zone, a pre-heating zone therebelow, a gas offtake member extending across the kiln between said storage and pre-heating zones, a calcining zone below said pre-heating zone, gas offtake means extending across the kiln between the pre-heating and calcining zones, an inlet member for combustibles extending across the kiln at the base of the calcining zone, a finishing zone below said calcining zone, said finishing zone being divided into a plurality of compartments, each having a separate outlet, and a cooling zone including a part of each compartment below each respective finishing zone compartment.

3. In a kiln, a storage zone, a pre-heating zone therebelow, a gas offtake member extending across the kiln between said storage and pre-heating zones, a calcining zone below said pre-heating zone, gas offtake means extending across the kiln between the pre-heating and calcining zones, an inlet member for combustibles extending across the kiln at the base of the calcining zone, and a finishing zone below said calcining zone.

4. In a kiln, a storage zone, a pre-heating zone therebelow, a gas offtake member extending across the kiln between said storage and pre-heating zones, a calcining zone below said pre-heating zone, gas offtake means extending across the kiln between the pre-heating and calcining zones, an inlet member for combustibles extending across the kiln at the base of the calcining zone, a finishing zone below said calcining zone, a cooling zone below the finishing zone, and means for admitting air to the cooling zone for cooling, whereby the air becomes pre-heated and provides a supply of air for primary combustion.

5. In a limekiln, a shaft having a calcining zone, means for introducing a substantial quantity of combustible gas into said calcining zone, said shaft having a finishing zone below said calcining zone and below the point of entry of said combustible gases, and means for introducing combustible gas with an excess of air for combustion below the level of said finishing zone.

6. In a limekiln, a shaft having a calcining zone, means for introducing a substantial quantity of combustible gas into said calcining zone, said shaft having a finishing zone below said calcining zone and below the point of entry of said combustible gases, means for introducing combustible gas with an excess of air for combustion below the level of said finishing zone, said excess of air combining with the gas in the calcining zone, and means for introducing additional air at the calcining zone.

7. In a kiln, a shaft having a calcining zone and a finishing zone therebelow, an injection burner at one level between the calcining and the finishing zones, a second injection burner below the finishing zone, air inlet means below the finishing zone, flue means between said burners, and means for turning off the burner below the finishing zone whereby under continuous action of the burner above the finishing zone air is drawn in from the air inlet through the lower injection burner connections and into the upper burner connections, thereby by-passing said finishing zone to permit the latter to drive off CO_2 without auxiliary heating of the lime core that remains in the finishing zone.

8. A limekiln comprising a shaft having therein a single calcining zone in which limestone is heated by combustion, said shaft being downwardly divided into a plurality of finishing compartments in communication with said calcining zone into which finishing compartments products from the calcining zone flow respectively, means in the finishing compartments for heating the products therein, the heating in each compartment being independent of the heating in others, and means for independently drawing the respective finishing compartments, whereby a different type of lime may be produced in each compartment.

9. A limekiln comprising a hollow shaft having openings therein, means for introducing limestone into said shaft, means for introducing burning gases and passing them therethrough to heat the limestone, means adapted to stop introduction and passage of burning gases from time to time and at the same time to close the openings in the shaft, whereby self-contained heat produces CO_2 from the limestone without substantial dilution, outlet means for the CO_2 and electric heating means adapted to supply heat to the shaft during the time that the kiln is closed.

10. In a lime kiln, a shaft forming a calcining zone, a hollow burner bridge extending across the shaft at the lower region of said calcining

zone and having at least one burner outlet, a hollow offtake bridge at the upper portion of the calcining zone having at least one opening to receive gases from the calcining zone, means providing a connection between said hollow offtake bridge and the burner bridge to provide for recirculation of gases through the calcining zone, and at least one burner arranged to fire into the burner bridge and to inject gases received from said offtake bridge and to force them from the burner bridge during the process of combustion.

11. In a lime kiln, a shaft forming a calcining zone, a hollow burner bridge extending across the shaft at the lower region of said zone and having at least one burner outlet, a hollow offtake bridge at the upper portion of the upper section of the calcining zone having at least one opening to receive gases from the calcining zone, said shaft having hollow wall means providing a connection between said hollow offtake bridge and the burner bridge to provide for recirculation of gases through the calcining zone, said gases serving also as heat insulators within the shaft wall adjacent the calcining zone.

12. In a lime kiln, a shaft forming a calcining zone, a hollow burner bridge extending across the shaft at the lower region of said calcining zone and having at least one burner outlet, walls below and supporting the burner bridge and separating the shaft into a plurality of compartments, a hollow offtake bridge at the upper portion of the upper section of the calcining zone having at least one opening to receive gases from the calcining zone, hollow means providing a connection between said hollow offtake bridge and the burner bridge to provide for recirculation of gases through the calcining zone, and at least one gas nozzle arranged to fire into the burner bridge and to inject gases received from said offtake bridge and to force them from the burner bridge.

13. In a lime kiln, a shaft forming a calcining zone, a hollow burner bridge extending across the shaft at the lower region of said zone and having burner outlets, gas burners arranged to fire into the burner bridge, and means built into the burner bridge for introducing secondary air into the calcining zone comprising outlets above and separate from the burner outlets but forming part of the bridge.

14. A lime kiln comprising a hollow shaft for containing limestone and determining draft, comprising a section providing a calcining zone, means for forcing combustible into the shaft at a point below the calcining zone, and means for drawing off gases at a point above the calcining zone at a rate to produce a draft-balancing effect to improve distribution of gaseous products and heat transfer within the limestone.

15. A lime kiln comprising a hollow shaft for containing limestone and determining draft, comprising a section providing a calcining zone, a pre-heating zone thereabove and a finishing zone therebelow, means for introducing air into the shaft at a point below the finishing zone, means for drawing off gases at a point above the preheating zone, whereby a draft-balancing effect may be obtained to improve distribution of gaseous products and heat transfer within the limestone, means comprising a firing opening for introducing combustible fuel below the calcining zone, means comprising a withdrawal opening above the calcining zone through which gases of combustion may be withdrawn, and means connecting the withdrawal opening above the calcining zone with said firing opening below the calcining zone through which recirculation of gases is effected through the calcining zone.

16. A lime kiln comprising a hollow shaft for containing limestone and determining draft, comprising a section providing a calcining zone, a finishing zone therebelow, means for introducing primary air into the shaft at a point below the finishing zone, means comprising an opening for introducing combustible gases below the calcining zone, means comprising an opening above the calcining zone through which gases may be withdrawn, means connecting the last-named opening above the calcining zone with said gas opening below the calcining zone through which recirculation of gases may be effected through the calcining zone, and means for introducing secondary air adjacent and above the point of gas introduction.

17. A kiln comprising a shaft for receiving and passing a charge, said shaft including a calcining zone, said charge moving downwardly through the kiln, a firing bridge for combustible gases located crosswise of the shaft and below the calcining zone and around which the charge passes, a gas offtake bridge member arranged across the kiln above the calcining zone and around which the charge also passes before reaching the firing bridge, said firing bridge and said gas offtake bridge each having gas openings spaced from the sides of the shaft.

18. A kiln comprising a shaft for receiving and passing a charge, said shaft including a calcining zone, said charge moving downwardly through the kiln, a firing bridge for combustible gases located crosswise of the shaft and below the calcining zone and around which the charge passes, a gas offtake bridge member arranged across the kiln above the calcining zone and around which the charge also passes before reaching the firing bridge, said firing bridge having inlet openings spaced from the sides of the shaft and laterally directed, and said gas offtake bridge member having outlet openings spaced from said shaft and directed downwardly.

19. In a kiln, a shaft providing a calcining zone, a firing bridge across said shaft near the base of the calcining kiln for introducing combustible gases, said firing bridge having a plurality of openings leading into the shaft, separate passages within the bridge connecting with the respective openings, separate firing means for said separate passages, and independent control means for the respective firing means.

20. In a kiln, a shaft providing a calcining zone, a firing bridge built across said shaft near the base of said zone, a plurality of independent passages in said bridge, each passage having a separate outlet at a point adjacent the base of said calcining zone, independently controllable gas burner members in the respective passages and separate finishing compartments joined to the calcining zone at said bridge to receive independent streams of material as differently treated by said independently controllable gas burner members.

21. In a kiln, a shaft providing a calcining zone, a plurality of finishing zones having inlets at the lower end of the calcining zone, a firing bridge built across said shaft near the base of said calcining zone, a plurality of independent passages in said bridge, each passage having at least one separate outlet at a point adjacent the base of said calcining zone and adjacent the inlet of one finishing zone, and independently controllable gas burner members in the respec-

tive passages, said burners being arranged to project combustible gas into the calcining zone at points respectively above the respective finishing zones, whereby the materials passing to the different finishing zones may be controllably and differently treated.

22. In a kiln, a shaft providing a calcining zone, a firing bridge built across said shaft near the base of said zone, a plurality of independent passages in said bridge, each passage having a separate outlet at a point adjacent the base of said calcining zone, independently controllable gas burner members in the respective passages, said burners being arranged with respect to the passages to project combustible gas and to inject therewith auxiliary gases, and at least one other independent passage in the bridge and having at least one opening into the shaft for the independent introduction of air for combustion.

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