Nov. 15, 1966 M. F. PARSONS 3,285,590

DOWN DRAFT VERTICAL KILN SYSTEM

Filed June 11, 1964 2 Sheets-Sheet 1

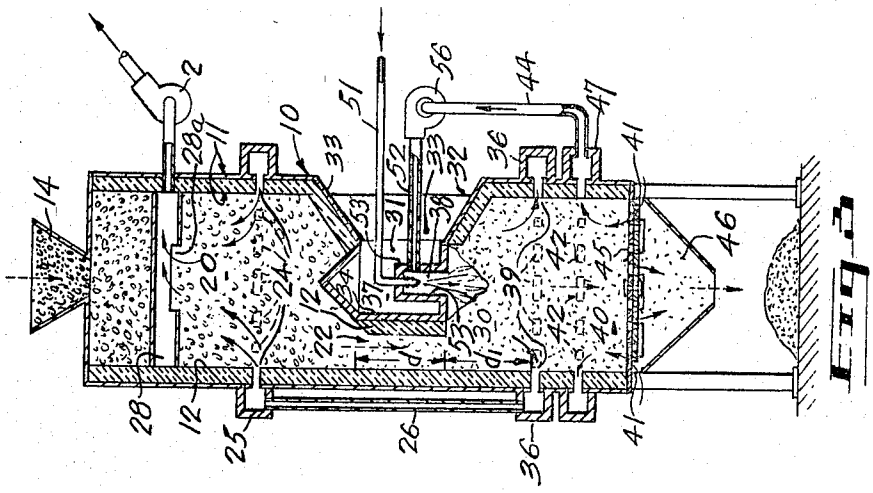


Fig. 3

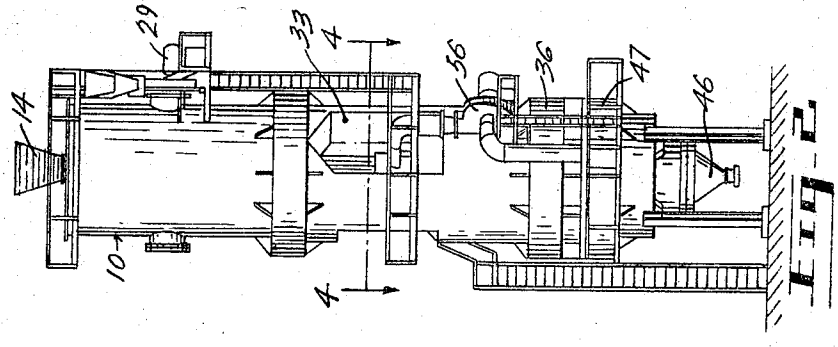


Fig. 2

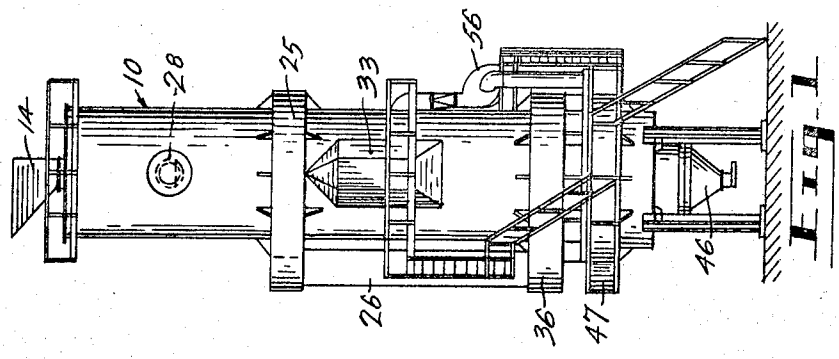


Fig. 1

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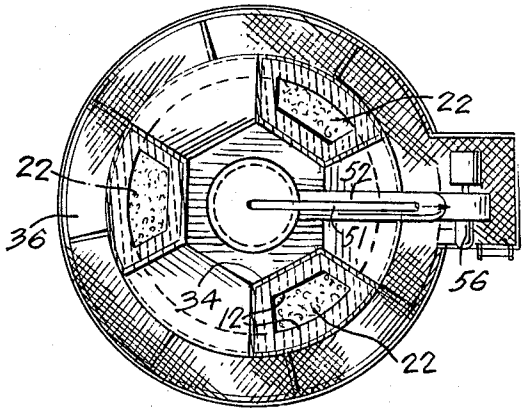


Fig. 4

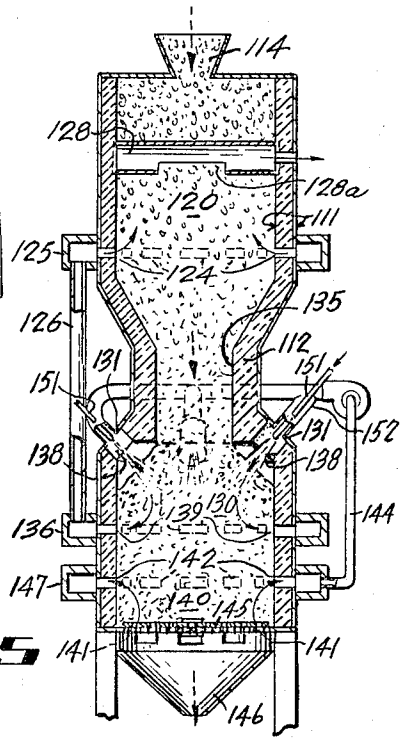
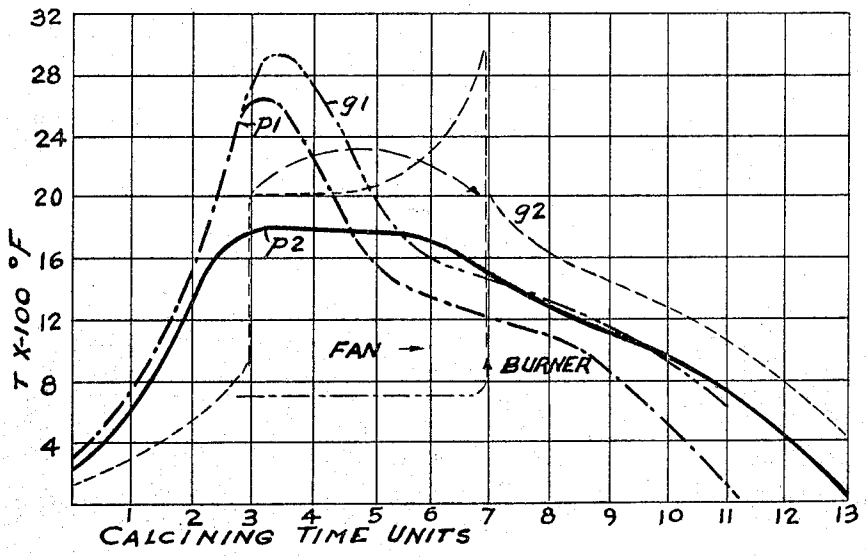


Fig. 5

Fig. 6



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DOWN DRAFT VERTICAL KILN SYSTEM

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9 Claims. (Cl. 263—29)

This invention relates to vertical kilns particularly of the type used for calcining limestone or any heat sensitive material in lump form.

Presently there are two commonly used commercial apparatuses for the manufacture of lime, the rotary kiln and the vertical shaft kiln.

The rotary kiln is probably the most widely used in North America, although it has the disadvantages of compartively high capital cost and relatively poor fuel efficiency, i.e. in the neighborhood of 30 to 35%. However, it does have a good degree of control of product.

The vertical kiln has the advantage of comparatively low capital cost, much greater mechanical simplicity and low mechanical maintenance, and comparably high fuel efficiency ranging from 50 to 75%. However, the vertical kiln has always suffered from a variety of control problems such as gas channelling, which results in nonuniform heat distribution and a nonuniform or unevenly burned product.

Another disadvantage of the average vertical shaft kiln design is the injection of the fuel in a gaseous form into the voids or spaces between the stone and the subsequent mixing of this fuel with air and the combustion occurring in the voids of the stone. It can be shown that the difficulty in mixing of the air and fuel is largely responsible for the channelling, i.e. the differential heating of parts of the charge with further irregular or nonuniform results.

Most vertical shaft kilns are charged with stone at the top and with the combustion gases passing from the bottom up to the top, this is a counter current process. It has always been generally thought that in order to achieve high efficiency, such an endothermic process as the calcining of lime, must be counter current. However, it can be shown that the counter current action which puts the highest temperature gases in contact with the stone at its highest temperature is one of the features which causes channelling and nonuniformity of product. Co-current firing on the other hand, where the higher temperature gases are contacted with low temperature stone makes it almost impossible to overburn the product and will result in a very uniform temperature throughout the hot zone.

Many and varied approaches have been made to the construction of vertical kilns in an effort to correct the above mentioned difficulties, some approaches being on the mechanical basis for regulating the flow of materials through the kilns and others working on the combustion problems of gas flow and distribution in stone beds. None of these approaches has been completely successful with the result that the vertical kiln is still rather unpopular as a commercial production apparatus.

According to the present invention, burning lime is an endothermic process produced in a single vertical shaft kiln consisting of preheating the limestone counter-currently in a preheating zone and subsequently calcining the charge in a heating zone by co-current induction of the products of combustion, and finally cooling the lime counter-currently in a cooling zone.

One object of this construction, therefore, is to cause the gases in the process to flow in such a manner that the cooler and preheat zones of the kiln are operated in a normal counter current manner, but the hot zone or calcining is operated in a largely co-current manner.

More specifically a preferred embodiment of the invention consists of an insulated vertical kiln having a

feeding hopper at the top communicating directly with a preheating chamber having lower inlet ports and an upper exhaust outlet. A calcining zone is located below the preheating zone spaced from it by a restricted passage. in the upper part of the calcining zone firing chambers are located permitting complete combustion of (gaseous, solid, or liquid) fuels mixed with induced air. Immediately below a set of exhaust ports in the lower part of the calcining zone is a cooling zone having upper exhaust ports and lower inlet ports. The bottom of the kiln is provided with controlled chute and hopper.

Air is drawn in at the bottom of the cooling zone in the kiln which is the last stage in downward flow of the limestone in the calcining process. This fresh air after cooling the newly produced lime in a counter-current fashion is forced into the firing chamber and supports the complete combustion of the fuel induced at this point. The hot burned gases then contact the limestone in a downward co-current direction relative to the flow of the charge. The restricted passage between the adjacent preheating zone and the calcining area causes a pressure build-up, thus forcing the air and gases without direct mechanical means co-currently through the stone bed down to the exit ports.

The gases which are then introduced counter-currently into the preheating zone, can be transmitted at much higher temperatures than in previous variations of vertical kilns since a direct fan is not needed. Once in the preheating zone the gases are exhausted by an exterior fan.

It must be noted that the fuel is completely burned in a high heat release type combustion chamber, and only the combustion products are passed through the limestone charge. The basic laws governing flow of gases result in the equation.

$$P=Cdu^2$$

where

P is pressure drop
C is a constant
u is the velocity of the gas
d is the density of the gas

From the basic gas laws the density varies inversely as the absolute temperature. Therefore, the volume and the velocity for any given weight of gas will increase directly.

It is apparent that if the temperature is doubled the density will be halved and the velocity doubled. Because the velocity factor in the equation is squared, the pressure drop will be $\frac{1}{2}\times(2)^2$ or 2 times as high. Therefore, higher temperature gases create a higher resistance to flow than low temperature gases. By firing with combustion products, the coolest parts of the charge will have the lowest resistance to flow and will draw the highest volume of gases, tending to equalize the temperature of all parts of the charge, eliminating channelling.

It is noted that channelling in the kiln is an inherent result of the combustion of the fuel in the void spaces. It will be realized that, where the fuel contacts the air, mixes and burns, an interface is developed between gas streams and air streams and a high temperature is developed at the interface. Because the resistance to flow is higher for high temperature gases than for low temperature gases there is a natural tendency for the heaviest gases passing through the bed i.e., the air, to go to the coolest places in the charge and the bed system is dynamically unstable.

It is, therefore, another object of this invention to fire the charge with the completed products of combustion from a burner or furnace. It will be realized that the firing of a counter current kiln with completed products of combustion results in very high temperatures and difficul-

ties with refractory construction. Therefore, it is the combination of the co-current firing and the firing with completed products of combustion which allows the suggested design.

Having thus generally described the nature of the invention, it will now be referred to in more detail by reference to the accompanying drawings, which illustrate a preferred embodiment and in which:

FIGURE 1 is a front elevation view of a down draft vertical kiln.

FIGURE 2 is a side elevation view of the kiln showing the duct and fan assembly.

FIGURE 3 is a schematic view of one embodiment of the kiln showing the flow of combustion gases.

FIGURE 4 is a horizontal cross section taken along line 4—4 of FIGURE 2.

FIGURE 5 is a schematic view showing another embodiment of the kiln with a different firing arrangement.

FIGURE 6 is a graph showing intensity of the flame temperature against time.

Referring more particularly to FIGURES 1 to 3, the vertical down draft kiln is shown consisting of an elongated cylindrical shaft **10**. The shaft is separated into three main parts; the preheating zone **20**, the calcining zone **30** and the cooling zone **40**. The shell of the main shaft **10** is lined on the inside with highly heat resistant refractory brick **12**.

The limestone is dumped into the kiln by means of a hopper **14** which communicates directly with the preheating zone **20**. This zone is separated from calcining zone **30** by the restricted passage **22**. The preseat zone **20** has gas inlet ports **24** in cooperation with ducts **25** and **26** which permit hot gases to enter the zone and raise the temperature of the limestone in preparation for the calcining zone **30**. A fan **27** outside the kiln is used to draw off the exhaust from the zone **20** by means of an exhaust conduit **28**. The conduit **28** bisects the cross section of the kiln at a relatively short distance above the inlet ports **24**. Slot **28***a* is proivded underneath the pipe **28** to provide an unobstructed passage for the exhaust.

Included in the heat zone is a burner **38**, supported by radial wall members **32**. At this point, as seen in FIGURES 1 and 2, the walls are cut out leaving access-ways **33** permitting relatively easy access for maintenance of the burner.

Between the access-ways **33** limestone chutes constituted by the passageways **22** provided connecting the preheating zone **20** to the calcining zone **30**. As better illustrated in FIGURE 4, the passageways **22** are determined by access-way walls **32**, partial kiln walls **11**, and on the inside by walls **34**. Of course, all these walls are lined on the inside by refractory bricks **12**. The reason for the limited limestone passages is to create a restriction for the upward movement of the hot gases emitting from the firing chamber and thus forcing the gases to follow their predetermined course.

The annular chamber **38** is set back as shown in FIGURE 3, to provide enough area for the total combustion of the fuel and the air, emitting from fuel nozzle **51** and the air duct **52** respectively set in the rearward section of the burner **38**. Complete combustion is expected in this chamber which is limited radially by walls **53**.

Hot gas exit bustle or ports **39** are spaced downwardly at a distance *d***1** from burner **38** equal to the distance *d* between the burner and the top of the chutes **35**.

It will be realized that any gas pressure impressed on the combustion gases will cause an equal gas velocity in both directions from the burner. By restricting the cross sectional area of the shaft above the burner **38**, to approximately 25% or less of the cross sectional area of the main shaft **10**, the total gas mass flow of combustion products will be 20% upwards from the burner **38** to the preheating zone **20** and 80% downwards through the hot zone **30**. The actual hot zone mechanism **20** of the kiln can, therefore, be said to be 80% co-current and 20% counter-current.

Below the calcining zone **30** is the cooling zone of the kiln which includes air intake vents **41** and air outlet ports **42** cooperating with ducts **47**, **44** and burner fan **56**, to draw the air from the cooling zone and direct it to the burner assembly **38**.

The lime which has been produced in the kiln is control fed to waiting transport means below the kiln by means of a standard rotating feed apparatus **45** and hopper **46**.

Another embodiment of the kiln according to the invention is shown in FIGURE 5. In this case, an alternative version of the calcining zone is the predominate feature. Instead of having a centrally located firing chamber, a plurality of burners **131** are mounted in the kiln wall **111**. The fuel and air nozzles **151** and **152** respectively in this case are set near the exterior of the wall **111**, with the refractory bricks **112** being built up around the nozzles forming a chamber **138**.

To conform to the principal features of the invention, the passageway **135** between the preheat zone **120** and the calcining zone **130** must, therefore, be restricted a considerable amount. This is effected by narrowing the walls **111** of the kiln at a point immediately above the burners. The walls are tapered immediately above the restricted portion to minimize the buildup of dead material in the kiln.

Operation

In the production of lime using the construction according to the invention, the limestone **5** is fed into the kiln **10** by a standard hopper **14**. The limestone proceeds throughout the whole operation by gravity following the dashed arrows. Thus, it intercepts each zone of the kiln at a rate controlled by means of a control hopper mechanism **45** situated at the bottom. It is also evident that the limestone will pile up in the kiln so as to completely fill it.

The air is drawn into the kiln through openings **41** following the full arrows as seen in FIG. 3 by means of the pressure differential caused by fan **56**. Cool air is, therefore, made to pass through the heat exchange area **40**, thus cooling the pebbled product which is present. Following the draft caused by the fan **56**, the air is drawn to exit ports **42** above the inlet **41**. Thus since the stone is moving slowly downward the air moves counter-current relative to the flow of the material. The fan **56** draws the air from the duct **47** through the duct **44** and forces the air into the burner **38**.

The vented air is mixed with oil or natural gas for complete combustion in the burner **38** facing downward in the central part of calcining zone **20**. The products of combustion from the burner impinge directly on the preheated limestone which is being introduced to the calcining zone from the by-pass ducts **35** leading from the preheating zone **20**. The products of combustion flow down the calcining or hot zone **30** then through the hot gas bustle **39** where they exit at temperatures from about 1800° to as high as 2400° F.

The gases while flowing through the calcining zone, reach the ports **39** at a distance below the burner **38**, thus the gases flow in a direction co-current to the flow of the material.

It is possible in this arrangement that the products of combustion leave the burner at temperatures of about 2800° to 3200° F. Flame dilution or recirculation in the down draft kiln system is not normally required since when the high temperature gases are contacted with uncalcined stone they are immediately cooled by the calcining reaction, and overburning cannot occur. In the event that extreme degree of control is required, such as for materials exceptionally sensitive to heat, some recirculation could be used.

The effect of this arrangement on the calcining process is clearly indicated in the product to gas temperature rela-

tionship curves shown in FIG. 6. The curve for the co-current hot zone kiln shows that the calcining process takes place at a uniformly low temperature *p2* over an extended period of time. The tremendous heat potential developed between the products of combustion at a 3,000° F. and the preheated stone at 1650° F., a differential of 1350° F., which results in extremely high rates of heat transfer at a time when the high CO_2 content of the lime makes it impossible to overburn it. The product, of course, cannot be heated above the temperature of the gases and the longer the effective hot zone, the lower the final temperature of the calcining process. The lime calcining process is highly endothermic in character and as long as CO_2 is being evolved, it is difficult to overheat the lime. Curves *g1* and *p1* show the temperature of the gases or flame relative to the temperature of the stone respectively showing the critical situation incurred by a standard kiln, easily causing overburning.

Even as the stone is calcined before leaving the hot zone **20** it is in contact only with the coolest gases and cannot overburn so the charge can be left in the hot zone **20** for extended time to assure complete calcining of the entire charge. The overall effect of the co-current down draft hot zone construction is a kiln which is inherently incapable of channelling or overburning. Because of the efficiency of heat transfer and the lack of overlap in the burning and preheating zones, the fuel efficiency can be expected to be in the region of 4,000,000 per ton of high calcium lime.

It is also a result of co-current firing that the stone entering the calcining zone is contacted by the hottest gases, and as it descends the gases are proportionally cooler, thus stones which calcine prematurely are not subject to increasingly hotter gases, overburning the material.

The hot gases are led from peripheral ring **36** through ducts **26** into the preheating chamber **20** by means of ports **24**. A fan is not needed to push the extremely hot gases through vane **26**, the pressure differential is maintained by the high pressure obtained in the calcining zone and the exterior fan **29**. As is obvious, the spent gases preheat the limestone in preparation for the calcining chamber. The most favourable method of passing gases through the preheating zone would be countercurrently, and as can be observed, this is done by placing the exhaust conduit **28** above the inlet ports **22**.

It is realized that many different embodiments of the invention may be constructed, without deviating from the features expressed in the preceding description. It must be emphasized, however, that the preceding describes but a few examples of the practical employment of the invention, and that other variations may be made without departing from its spirit as defined in the following claims.

I claim:

1. A system for continuously calcining materials comprising vertically-disposed kiln means, supply means communicating with said kiln means for charging said kiln means with material to be calcined, said kiln means comprising, in series, pre-heating-chamber means, restricted-passage means, calcining-chamber means, and cooling-chamber means for progressively receiving therethrough said materials introduced by said supply means, said pre-heat-chamber means including upper, exhaust-gas, outlet port means and lower, inlet, pre-heat port means, said kiln means including downwardly-directed burner means at the upper portion of said calcining-chamber means and forming a combustion chamber portion at the upper portion of said calcining-chamber means and substantially adjacent the lower portion of said restricted-passage means, said cooling-chamber means including fluid-inlet means for permitting cooling and combustion-supporting fluid to move upwardly through said cooling-chamber means, said cooling-chamber means including combustion-fluid, outlet-port means communicating with said burner means for causing optimum and substantially complete combustion of fuel in said combustion-chamber portion prior to cocurrent passage of hot combustion gases contacting said material passing through said calcining-chamber means, said calcining-chamber means including combustion-gas, outlet-port means above said combustion-fluid, outlet-port means communicating with said inlet-port means of said pre-heat-chamber means, said restricted-passage means including a configuration above said burner means substantially inhibiting the passage of combustion gases therethrough and yet permitting gravitation of material therebelow, said restricted-passage means configuration causing hot combustion gases to flow from said combustion-chamber portion through said calcining-chamber means cocurrently with the material to said combustion-gas outlet-port means whereby no supplemental draft-creating means is required.

2. The system as claimed in claim **1** in which the cross section of said restricted-passage means is not greater than 25% of the cross sectional area of said calcining-chamber means.

3. The system as claimed in claim **1** in which the length of said restricted-passage means is approximately at least equal to or greater than the depth of said calcining chamber means.

4. The system as claimed in claim **1** in which said kiln means includes a portion making said burner means accessible for maintainence and repair at least at one side portion of said kiln means.

5. The system as claimed in claim **1** in which said restricted-passage means comprises a single passage, said burner means comprising a plurality of burners disposed in spaced relation around the top of said calcining-chamber means, said burners being disposed beneath a ledge portion formed between said restricted-passage means and said calcining chamber means.

6. The system as claimed in claim **1** in which said restricted-passage means comprises a plurality of substantially vertically-disposed, open-ended passages surrounding said burner means.

7. The process of calcining materials comprising the steps of:

(a) introducing material to be calcined into a substantially vertically disposed kiln and permitting the material to have substantially free-gravity flow therethrough;

(b) establishing a fuel-combustion zone intermediately of said substantially free-flowing material and a calcining zone beneath said fuel-combustion zone;

(c) establishing a restricted zone for said free-flowing material above said fuel-combustion zone to a degree sufficient to impede the upward travel of a substantial portion of combustion gases emanating from said fuel-combustion and calcining zones;

(d) removing combustion gases adjacent the lower portion of calcining zone and introducing at least a portion of such gases to the material above said restricted zone to preheat the material before it encounters said restricted zone; and

(e) introducing combustion-supporting fluid into said calcined material adjacent the lower portion of said calcining zone and directing at least a portion of said combustion-supporting fluid to said fuel-combustion zone and in a co-current direction with the material substantially through the entire calcining zone.

8. The method as claimed in claim **7** in which said combustion gases are introduced into the material above said restricted zone in a direction counter-current to the free-flow of material, and said combustion-supporting fluid is introduced into said calcined material in a direction counter-current to the direction of flow of the calcined material.

9. The method as claimed in claim **7** in which the volumetric flow of gases upwardly through said restricted

zone in relation to the volumetric flow of gases through said calcining zone is up to 20% of the entire volume of gases emanating from said combustion and calcining zones.

References Cited by the Examiner

UNITED STATES PATENTS

2,788,961 4/1957 Pooley et al. ---------- 263—29

3,035,823 6/1962 Harpster ---------- 263—29

3,101,935 8/1963 Zeltner ---------- 263—29

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