

March 12, 1957

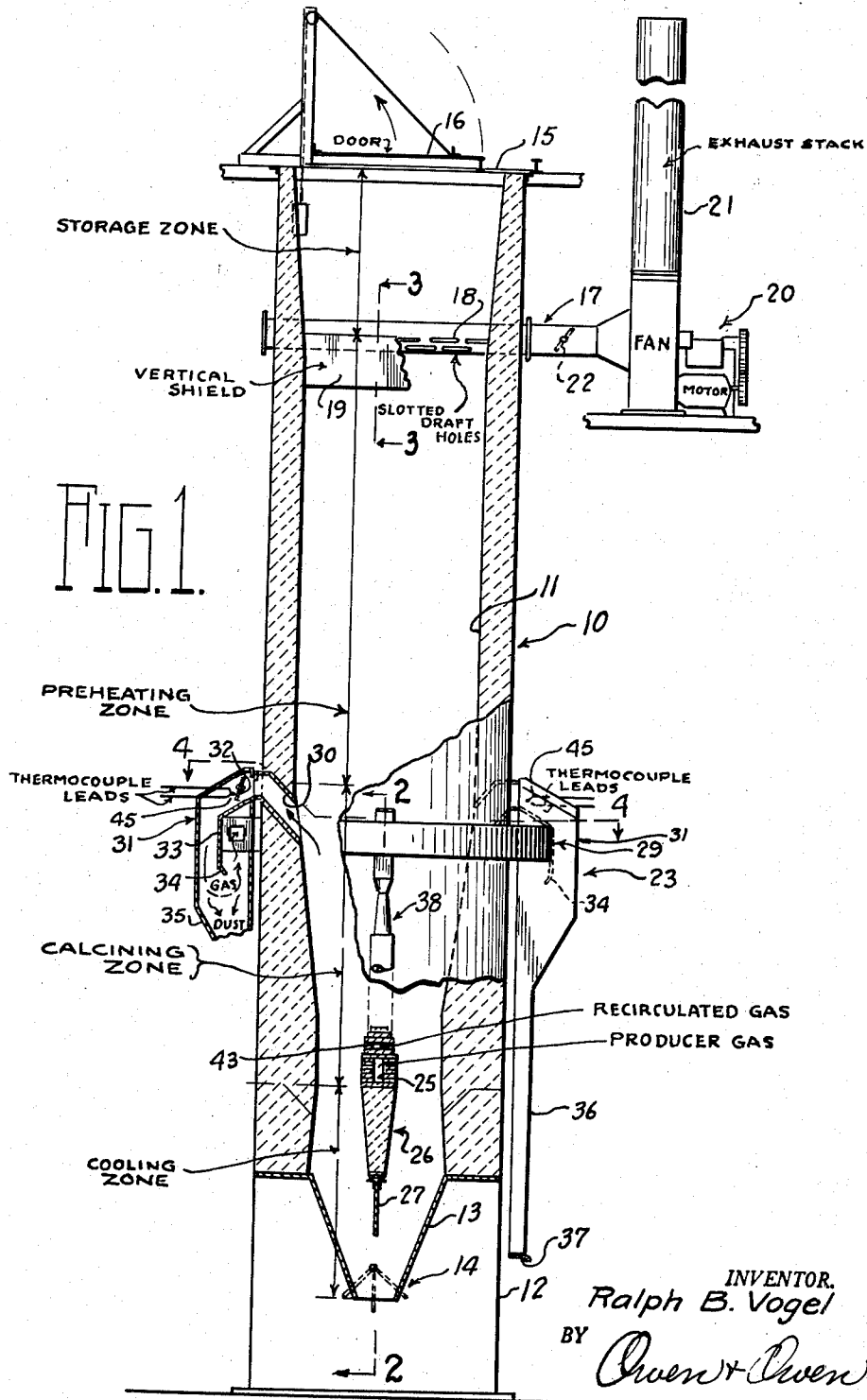
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LIME KILN

Filed Dec. 16, 1953.

2 Sheets-Sheet 1



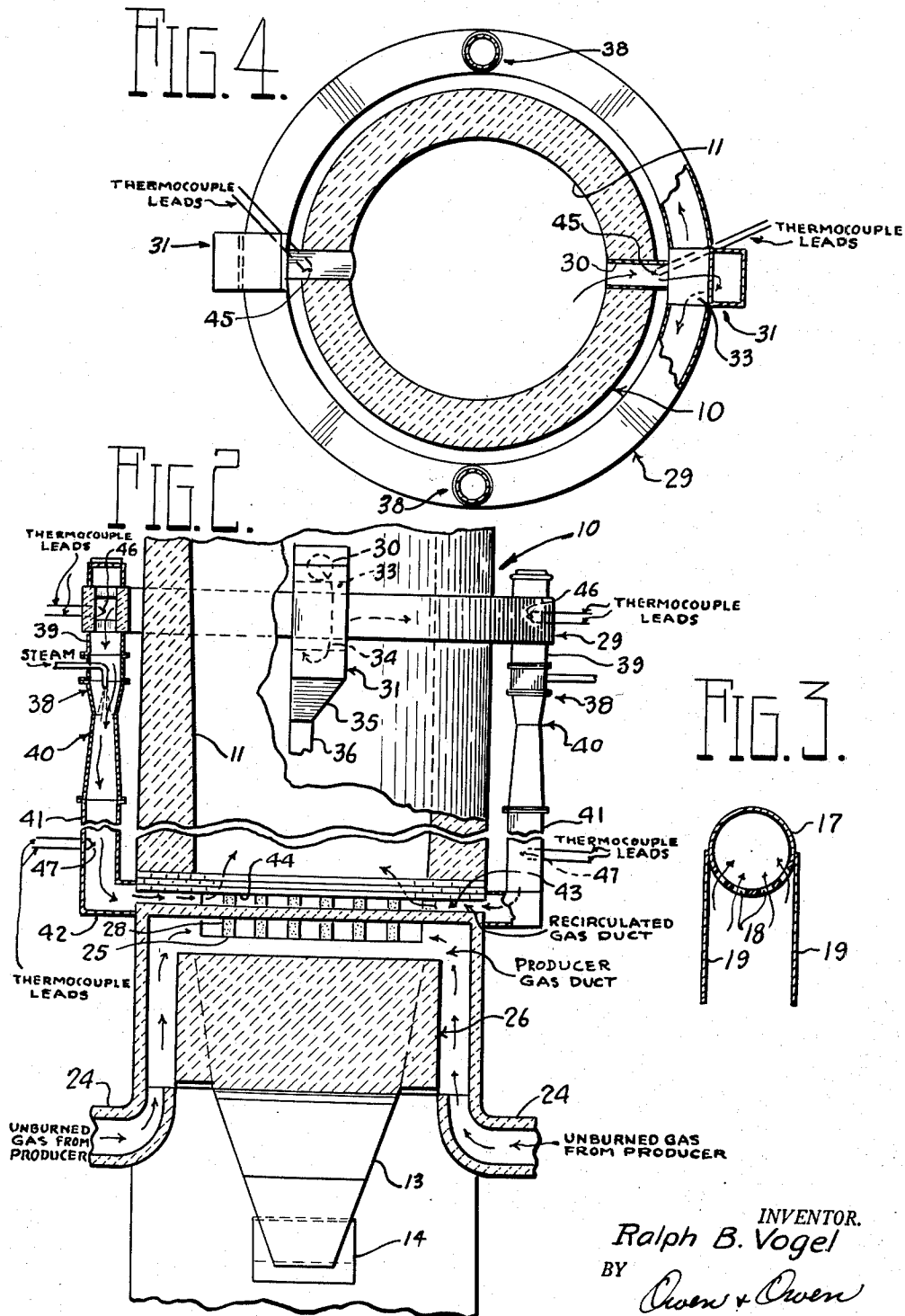
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INVENTOR.
Ralph B. Vogel
BY *Owen & Owen*

ATTORNEYS

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LIME KILN

Ralph B. Vogel, Carey, Ohio, assignor to The National Lime and Stone Company, Findlay, Ohio, a corporation of Ohio

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4 Claims. (Cl. 263—29)

This invention relates to improvements in the combustion control of vertical lime kilns.

The calcining of limestone in a vertical kiln is performed by burning substantial quantities of gas in the lower portion of the kiln with the heat thereby produced acting upon the limestone to drive off CO₂ gas and to reduce the stone to as nearly pure lime as possible. In so "burning" the lime it is desirable to avoid vitrification of the limestone and not to "dead burn" or "over burn" the stone during the disassociation process. "Overburning," or overheating of the limestone deleteriously affects the lime produced. Lime which has thus been overheated is called "hard-burned" lime, as contrasted to "soft-burned" lime—or lime having desirable qualities resulting from disassociation at a lower temperature.

One of the causes of "hard-burned" lime is the formation of local "hot spots" in the interior of the mass of limestone resulting from the formation of "chimneys" through the mass of rock and the consequent excessive flow of heat through these open pathways.

The formation of "hot spots" has a second very undesirable result in that it may burn away localized areas of the refractory kiln lining requiring that the kiln be taken out of production for the replacement of the lining.

A still further difficulty with many vertical lime kilns arises from the necessity for the use of large size rock, say, in the order of 10 to 12 inches in average diameter, in order to provide sufficient open space in the kiln to allow a draft to be maintained upwardly through the column of the kiln. When rock of smaller average diameter, say, 4 to 6 inches, is loaded into an ordinary vertical kiln it so reduces the interstices between the rock pieces as to make it almost impossible to maintain a satisfactory draft through the column of the kiln.

The objects of this invention are, therefore, to provide means for controlling the flow of hot gases through the kiln to evenly distribute the heat through the mass of stone being calcined, thus to permit the use of smaller sized stones with the resulting advantage of relatively larger surfaces per unit of mass for heat absorption and a consequent higher rate of production and to eliminate the formation of local "hot spots" with the resulting deleterious effects not only on the limestone but on the refractory lining of the kiln itself.

More specifically, the objects of the invention include the provision of a simplified control for the operation of a vertical kiln which enables the operator to determine the conditions existing within the kiln and to take steps to maintain the supply of heat to the kiln in a manner appropriate to maintain a uniform temperature throughout the calcining zone and thus to produce a "soft-burned" lime.

These and more specific objects and advantages and the mode of their accomplishment will be better understood from the specification which follows and from the drawings in which:

Fig. 1 is a vertical sectional view of a lime kiln equipped

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with apparatus embodying the invention, certain portions being shown in elevation.

Fig. 2 is a fragmentary vertical sectional view, with parts in elevation and on an enlarged scale, taken substantially on the line 2—2 of Fig. 1.

Fig. 3 is a fragmentary, enlarged vertical sectional view taken on the line 3—3 of Fig. 1.

Fig. 4 is a horizontal sectional view taken along the line 4—4 of Fig. 1.

A conventional vertical lime kiln comprises a main column generally indicated at 10 which usually consists of a steel casing lined with a thick refractory lining 11. The lining 11, for example, may vary from 2 to 3 feet in the hotter areas of the kiln to 6 or 8 inches in the cooler zones. The column 10 is erected upon a heavy frame 12 and its lower end terminates in a generally cone shaped hopper 13 below the level of the calcining zone and thus functioning both to furnish a cooling chamber and as an unloading hopper, its lower end having a conventional trap door 14 located at a height sufficient to permit cars, trucks, or conveyors to pass therebeneath.

At the upper end of the column 10 the top of the kiln is closed by a cover 15 provided with an openable door 16 through which untreated limestone is charged into the kiln. Flow of the limestone through the kiln is produced by gravity with the rate of flow being determined by the rate at which the lime is removed from the hopper 13.

The column 10 may be roughly divided vertically into four zones. The uppermost indicated as the "storage zone" in Fig. 1 extends from the top of the column 10 to a level at which there is located an exhaust pipe 17 which extends across the column 10 and has draft openings 18 in its underside (see also Fig. 3). The exhaust pipe 17 may be provided with downwardly extending shields 19 which prevent the plugging of the draft openings 18. The pipe 17 is connected to a motor driven fan generally indicated at 20 and the fan 20 has an exhaust stack 21. Operation of the fan 20 provides an induced draft through the column 10. The pipe 17 also has a damper 22 by means of which the negative pressure within the column 10 may be controlled.

The second zone of the kiln extends from the level of the induced draft exhaust pipe 17 downwardly to the level of a waste gas exhaust system generally indicated in Figs. 1 and 2 by the reference number 23. This zone is denominated the "preheating zone" in Fig. 1.

The waste gas exhaust system 23 includes means providing for a recirculation of a substantial quantity of waste gases resulting from the burning of fuel gas, usually producer gas, introduced in the lower part of the kiln from gas mains 24 (Fig. 2) which communicate with a producer gas duct 25 extending across the column 10 at the upper side of a bridge 26. The bridge 26 is constructed of refractory material and may be supported by an iron beam 27. The duct 25 has a plurality of laterally opening ports 28 through which the producer gas is fed into the interior of the column 10.

The burning of the producer gas as it is fed out of the ports 28 produces a flame of large volume which is drawn upwardly through the zone denominated "calcining zone" in Fig. 1 and, most desirably, the heat from the producer gas flame should be uniformly distributed throughout the mass of limestone in the "calcining zone". The flow of hot gases upwardly takes place through the interstices between the lumps of limestone and unless the operator experiences good fortune, it is almost impossible to prevent the formation of "chimneys" through the mass of stone which tend to draw excessive quantities of hot gases and thus to overheat or "hard burn" the limestone adjacent the "chimneys." If such a "chimney" exists along the refractory lining of the kiln the heat may rapidly rise to such a temperature as to break down the

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refractory structure and even to melt it away to an extent such that a "hot spot" appears on the steel exterior of the kiln. Of course, when this occurs it is necessary to shut down the kiln and replace the refractory material.

Operation according to the invention provides a control for more uniformly distributing the heat throughout the calcining zone and over the lumps of limestone therein. As a result the period of time for any particular stone within the calcining zone can be lessened since smaller stones can be used providing for more efficient heat absorption and since the quantity of "hard burned" stone is minimized. As a result of this time reduction, and as a result of the more efficient and uniform heating, the rate of lime production for a kiln formerly operating merely by induced draft can be increased many fold without any resulting reduction in refractory life.

The apparatus of the invention includes an annular bustle pipe 29 extending horizontally around the exterior of the column 10 and located approximately at the plane of demarcation between the "preheating zone" and the "calcining zone." The bustle pipe 29 is connected to the interior of the column 10 at at least two points, approximately 180° from each other, by waste gas exhaust ducts 30 which extend through the wall of the column 10 and the refractory 11 preferably being downwardly inclined toward the interior of the column 10. At their upper outer ends each of the waste gas ducts 30 opens into a dust separation hood 31. The hood 31 extends over the bustle pipe 29 and has a flow damper 32 and an interior baffle plate 33 which extends downwardly below the level of the bustle pipe 29. As can best be seen in Fig. 4, the bustle pipe 29 terminates at the side walls of the dust hood 31 and gas flowing out of the duct 30 must flow over the baffle 33 and around and up under its downwardly turned lip 34. The dust hood 31 has a downwardly extending hopper shaped section 35 terminating in a dust removal pipe 36 which extends down the exterior of the column 10 and is provided at its lower end with a dust removal trap 37.

Waste gases drawn out through this duct 30 at relatively high velocity are pulled around the baffle 34 and the dust carried therewith separated from the gas by its own impetus, falling downwardly into the pipe 36.

A pair of downcomers generally indicated at 38 are located at the other two quarter points of the bustle pipe 29. Each of the downcomers 38 consists of a short vertical pipe 39, a steam jet generally indicated at 40 and a lower section of vertical pipe 41 which is connected by a horizontal duct 42 to a recirculated gas duct 43 carried by the bridge 26 and located immediately above the producer gas duct 25. The recirculated gas duct 43 has a plurality of laterally extending ports 44 through which the combination of intermixed recirculated waste gases and steam is fed into the interior of the kiln along with the burning producer gas.

The gases referred to herein as "waste gases" or "recirculated gases" include not only the products of the combustion of the producer gas but also large volumes of CO₂ disassociated from the limestone in the lime producing process and large quantities of dust, consisting of silica, alumina and other impurities and of some of the disassociated lime itself which is carried away from the limestone by the blast of the burning gas and the draft through the column. Because the gases carry with them this large volume of dust, the problem of recirculating the heavily laden gas is difficult since it tends to plug or interfere with the operation of most types of recirculation means.

The use of steam jet eductors to induce the draft for the recirculation of the gas has several advantages. Among these are the elimination of moving parts, such as fans or blowers, which are exposed to the hot gases being recirculated and which thus are quickly damaged and which require frequent replacement and expensive maintenance. Furthermore, by controlling the volume of steam

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introduced into the eductors it is possible to control the volume of gas which is recirculated without requiring repeated adjustments of mechanical controllers such as dampers and flow regulators. In addition, by introducing the steam into the midst of the recirculating gases the jet effect of the steam nozzle thoroughly admixes the steam with the gases. Thus the steam jets accomplish the several purposes of causing the recirculation of the waste gases, entering into the kiln itself for "softening" the flame or blast and adding heat to the kiln.

In order to provide for controlled and accurate operation of the apparatus as described, a necessary element of the instant invention is the provision and location of a number of temperature indicating means, for example, thermocouples. As is schematically indicated in Figs. 1 and 4, a thermocouple is located within each of the waste gas exhaust ducts 30 or at upper portions of the dust separation hoods 31. These two thermocouples are generally indicated at 45. These two thermocouples give the temperature of the recirculated waste gases at the time they are removed from the kiln. A second set of thermocouples generally indicated at 46 in Fig. 2 are located at the upper ends of the downcomers 38 to indicate the temperature of the recirculated gases after having been drawn out of the kiln and carried around the exterior through the bustle pipe 29. A third set of thermocouples 47 are located one in each of the downcomer pipe sections 41 below the steam jets 40.

Knowing the temperature, volume, and specific heat of the steam fed into the steam jets 38 it is possible by the use of the apparatus of the invention to determine and control the volume of recirculated waste gases by measuring the temperature of these gases in the bustle pipe above the steam jets and in the downcomer pipes below the steam jets. By comparing the temperatures of the gases in the two dust hoods and at the upper ends of the downcomers 38 the apparatus of the invention provides means for determining whether or not the gas flow and thus the temperature within the calcining zone is uniform. Under ideal conditions, of course, the temperature in both dust hoods should be the same and the temperatures at the upper ends of the two downcomers should be the same. Similarly, if conditions are ideal, the temperatures of the combined steam and recirculated gas in the two pipe sections 41 of the downcomers 38 should also be the same. Variations between the temperatures of the gases in the two similar positions of any one of the three measurement points provide a certain and clear indication of variations in the heat within the areas of the calcining zone. Such variations can be compensated for by changes in volume and temperature of the steam, increases and decreases in the induced draft, changes in the volume of producer gas burned and by modifying the setting of the two dampers 32 in order to balance and control the quantity of waste gases drawn off and recirculated.

A typical operation according to the invention is performed with steam fed into the steam jets at 90 pounds p. s. i. The average temperature of the waste gas drawn off through the ducts 30 is approximately 900° F. and the mixture of gas and steam at the bottom of the downcomers 38 is thus approximately 700° F. Maintaining the operating conditions at this or similar ranges determined particularly for a particular kiln, enables an apparatus according to the invention to operate at a very high production rate. Under the conditions mentioned it is possible through the practice of the invention to maintain a desirable temperature, say, between 1800° and 2000° F., throughout the calcining zone and disassociation can be continuously accomplished with practically no spalling or vitrification of the exterior surfaces of the lumps of lime. By enabling the reduction of stone size through the uniformity of the heat in the calcining zone and elimination of "chimneys" and "hot spots" production on a kiln equipped with apparatus according to the

invention increased from approximately 18 tons per day before it was thus equipped to approximately 70 tons per day after it had been equipped. This four-fold increase in production was accomplished without increase in the operating temperature (it being limited by the nature of the operation being performed) and without any reduction in the life of the refractory. Operating under the temperature conditions mentioned above approximately 20,000 cubic feet of waste gases per hour were recirculated by the seam jets through the downcomers and approximately 200,000 cubic feet of waste gases per hour were exhausted from the exhaust stack 21 by action of induced draft fan 20.

The increase in production without the decrease in refractory life is accomplished without any appreciable decrease in the heat efficiency of the kiln, i. e., the quantity of producer gas and steam introduced for calcining per ton of lime from a heat standpoint remained approximately the same as the heat introduced for calcining a ton of lime entirely by producer gas in the kiln before it was equipped with apparatus according to the invention. This maintenance of heat efficiency while accomplishing the four-fold increase in production is believed to result from the better diffusion and uniform control of the hot gases, more uniform heating of the smaller size stones made possible thereby and assisted by the superior heat radiation ability of the steam and the elimination of "hot spots" and "chimneys" both within the mass of rock and alongside the refractory lining.

I claim:

1. In a kiln having a lowermost discharge outlet and an uppermost charging opening and an upper storage zone, in combination, a draft outlet from said kiln at the bottom of said storage zone, a preheating zone beneath said storage zone, a waste gas outlet at the bottom of said preheating zone at each side of said kiln, a damper for each of said outlets, a calcining zone located beneath said preheating zone, a firing bridge extending across said kiln at the bottom of said calcining zone and having a waste gas duct therein, conduit means including separate down pipes on opposite sides of said kiln and located exteriorly of said kiln for connecting said waste gas outlets to said waste gas duct, separately controllable steam jet eductors in each of said down pipes for inducing the controlled flow of waste gases therethrough and temperature responsive means in each of said waste gas outlets and in each of said down pipes below said steam jet eductors for measuring the flow of waste gases through each of said conduit means.

2. A method for controlling the operation of a vertical lime kiln, such method comprising, burning heating gas at the bottom of said kiln, feeding the limestone to be disassociated downwardly through said kiln, flowing the waste products of the combustion of said heating gas and the gas disassociated from the limestone upwardly through said kiln by maintaining a negative pressure in the upper part of said kiln, diverting a portion of such waste gases out each side of said kiln near the upper limit of the disassociation zone in volume inversely proportional to the temperature of the gases being diverted out of that side of said kiln, introducing a high pressure

jet of steam into the midst of each separated portion of the diverted gases in volume proportional to the temperature thereof for inducing the flow thereof out of said kiln and re-introducing the diverted gases and steam into said kiln at about the level of the initial burning of the heating gas.

3. A method for controlling the operation of a vertical lime kiln, such method comprising, burning heating gas at the bottom of said kiln, feeding the limestone to be disassociated downwardly through said kiln, flowing the waste products of the combustion of said heating gas and the gas disassociated from the limestone upwardly through said kiln by maintaining a negative pressure in the upper part of said kiln, diverting a portion of such waste gases out each side of said kiln near the upper limit of the disassociation zone in volume inversely proportional to the temperature of the gases being diverted out of that side of said kiln, measuring the temperature of each diverted portion of such waste gases at the point of diversion thereof out of said kiln, introducing a high pressure jet of steam into the midst of each diverted portion of such waste gases for inducing the flow thereof out of said kiln, measuring the temperature of each diverted portion of such waste gases at a point beyond the introduction of such steam therein, metering the flow of steam in relation to the change in temperature of each of such portions of such waste gases between such points of measurement and reintroducing such portions of waste gases and such steam into said kiln at about the level of the initial burning of the heating gas therein.

4. In a kiln having an uppermost charging opening, a storage zone therebeneath, a preheating zone beneath said storage zone, a calcining zone beneath said preheating zone, a cooling zone beneath said calcining zone and a lowermost discharge opening, in combination, a draft outlet from said kiln at the bottom of said storage zone, a waste gas outlet communicating with only one side of said kiln at the bottom of said preheating zone, a separate waste gas outlet communicating with only the opposite side of said kiln at the bottom of said preheating zone, a separately controllable damper in each of said waste gas outlets, a firing bridge extending across said kiln at the bottom of said calcining zone and having a waste gas duct therein, down pipes connecting said waste gas outlets to said waste gas duct and separately controllable fluid pressure means in said down pipes for inducing flow of waste gases from opposite sides of said kiln and through said waste gas outlets and down pipes to said waste gas duct in said firing bridge.

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