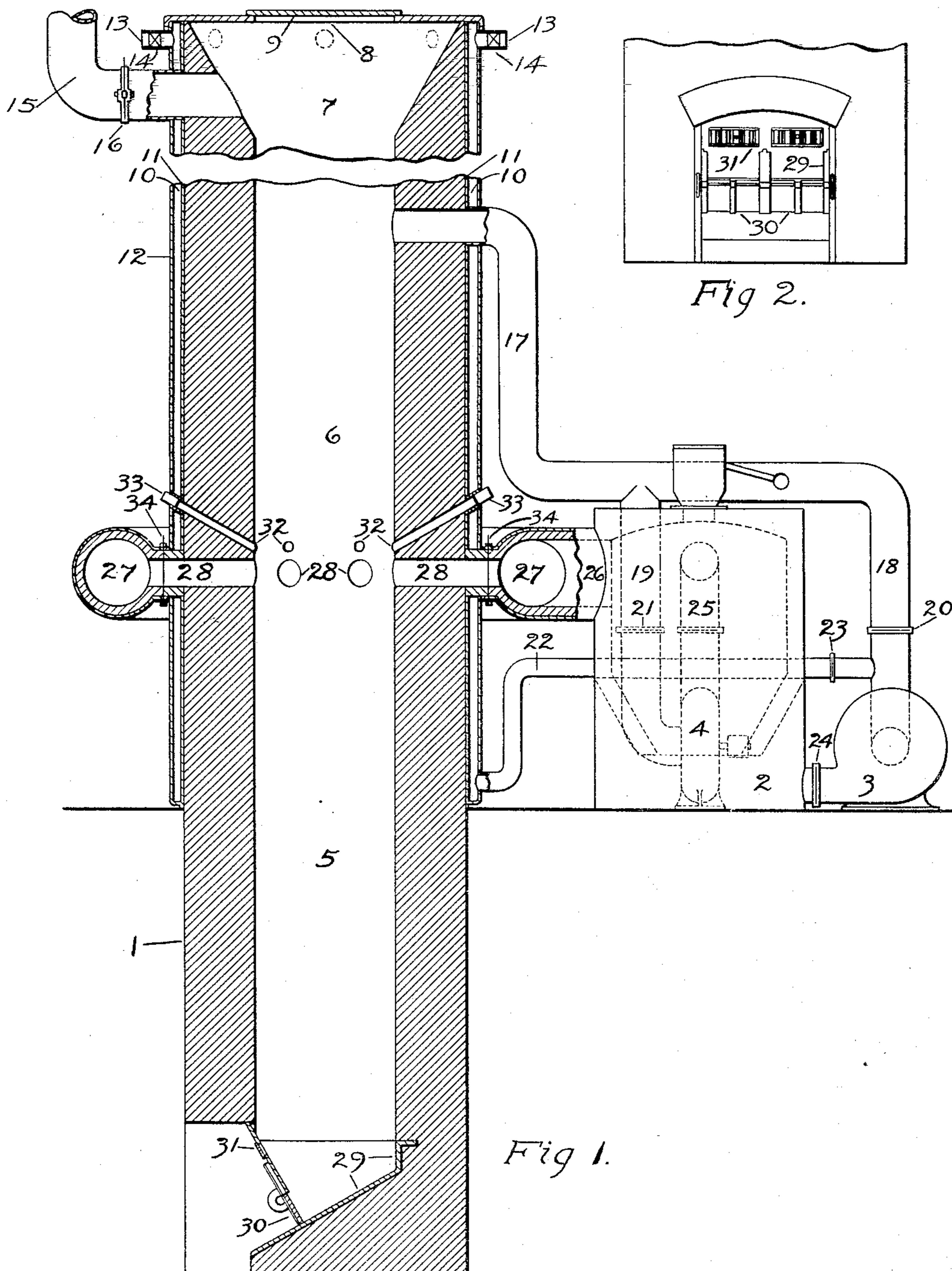


H. L. DOHERTY.
 PROCESS OF BURNING LIME AND APPARATUS THEREFOR.
 APPLICATION FILED SEPT. 14, 1908.

938,987.

Patented Nov. 2, 1909.



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PROCESS OF BURNING LIME AND APPARATUS THEREFOR.

938,987.

Specification of Letters Patent.

Patented Nov. 2, 1909.

Application filed September 14, 1908. Serial No. 452,899.

To all whom it may concern:

Be it known that I, HENRY L. DOHERTY, a citizen of the United States, and resident of New York city, in the county of New York and State of New York, have invented certain new and useful Improvements in Processes of Burning Lime and Apparatus Therefor, of which the following is a specification.

My invention relates to a process for burning lime and to apparatus therefor.

It relates, particularly, to that kind of process and apparatus wherein the heat for burning the lime is derived from the combustion of producer gas.

The objects of my invention are, the furnishing of a method and means whereby more of the heat of the kiln can be recuperated than is at present possible in apparatus of the class mentioned, the avoidance of the danger of over-burning the lime by the regulation of the temperature in the combustion zone of the kiln, and the expansion of this combustion or high temperature zone to occupy a much greater space in the kiln.

My invention consists, briefly, of a lime-kiln in which the lower part or "cooler" of the kiln is deeper than is, at present, customary, a gas producer appurtenant to the kiln, a second and outer shell surrounding the main shell of the kiln and forming with said shell an open annular air space, said annular space having air inlets around its periphery at the top and connections from the bottom through a fan with the ash pit of the producer, air inlets at the lower part of the cooler, a fan for the purpose of introducing kiln gas into the ash pit of the producer together with the air before mentioned and another fan for the purpose of introducing another portion of the kiln gas into the producer gas for the purpose of so moderating the temperature of the flame of the burning gas that the danger of over-burning is avoided, and the process of burning lime by means of a producer gas so modified, by the aforementioned apparatus.

In the drawing I have shown a cross-section of the apparatus in a more or less diagrammatic form, the two blowers being in elevation.

Figure 1 is a section through the kiln and producer on a vertical plane through their axis, the blowers being shown in elevation. Fig. 2 is a front elevation of the lower part of the cooler showing the doors for the discharge of the lime and the ports for the inlet

of the air for the combustion of the producer gas.

1, refers to the lime-kiln proper; 2 is the gas producer; 3 is the blower supplying the draft current to the producer; and 4 is the blower supplying the kiln gas to the producer gas.

5 is the lower portion of the kiln, commonly called the "cooler"; 6 designates the zone of the kiln in which the stone is dissociated or burned; and 7 designates the upper portion of the kiln whose function is simply to insure sufficient time of contact between the stone and hot gases from the dissociation zone to enable the stone to take up from the gases all the heat which it is capable of absorbing.

8 is the charging opening of the kiln, closed by a door or cover, 9.

10 is an annular air space formed between the shell proper of the kiln and the outer shell, 12. Around the upper part of this jacket are arranged ports, 13, controlled by the gates or dampers, 14.

15 is the waste gas stack of the kiln, having a gate, 16; 17 is a pipe or conduit conveying a portion of the kiln gas to the suction pipes 18 and 19 of the fans or blowers 3 and 4, respectively; 20 and 21 are gates on the respective suction pipes 18 and 19; 22 is a pipe connecting the lower part of the air jacket 10 with the suction pipe 18 of blower 3, having a gate, 23.

24 is the discharge pipe of blower 3, and 25 that of blower 4.

26 is the producer gas conduit leading off from the producer and connected with a bustle-pipe, 27, encircling the kiln. This bustle-pipe, 27, has connections, 28, into the shaft, 6, of the kiln.

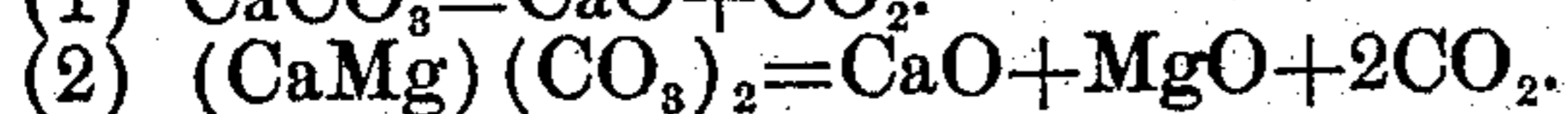
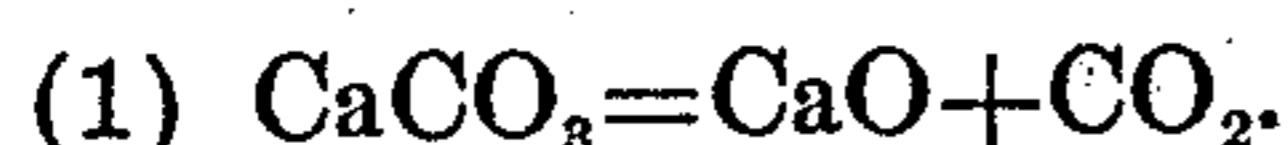
29 is the metallic hopper in which the cooler, 5, terminates. This hopper is provided with doors, 30, operated in any convenient manner, and air inlets, 31. The air inlets are so designed that their free area may be regulated at will.

32, 32, etc., are ports passing through the kiln walls, and permitting the ignition of the gas when the kiln is started in operation and the barring down of the lime. 33 are plugs closing these ports; 34 are suitable valves or dampers on the gas inlets into the kiln.

The method of operation is as follows: The gas producer having been brought into operation in the manner well known to those

skilled in the art of producer operation, the producer gas which, at first, is allowed to escape into the atmosphere until the producer is in normal operating condition, is
 5 allowed to pass into the pipe 26, through the bustle-pipe 27 to the gas ports 28, through 28 into the kiln. By means of torches or red hot irons introduced through the openings 32 the producer gas is ignited
 10 immediately upon its entrance into the shaft of the kiln and burns. The air for its combustion (which I will hereafter call the secondary air) is admitted through the damper 31 at the bottom of the cooler. When the
 15 gas flame has been maintained for a sufficient length of time to thoroughly heat the interior of the kiln for, say, ten or fifteen feet above the ports 28 to full redness, limestone is gradually charged into the kiln.
 20 After the level of the stone has been brought up to within a short distance of the gas ports it should be charged in small portions so as to avoid reducing the temperature of the gas flame below the point of ignition.
 25 When a body of highly heated stone (it should be, at least, at a full red heat) has been built up for a distance of six to ten feet above the gas ports, the remainder of the shaft can be filled as rapidly as may be
 30 desired. As the calcination of the stone in the vicinity of the gas ports proceeds, its temperature becomes higher and higher since the heat developed by the gas flame goes more and more to raising the temperature of the calcined stone (lime) and less
 35 and less is rendered latent in the dissociation of the stone. If this action proceeds unchecked the temperature of the lime finally reaches a point at which the impurities,
 40 silica, alumina, etc., which are present in greater or less amount in all limestones, will unite chemically with part of the lime (CaO) present. This causes a partial fluxing of the lime with the production of a
 45 product which will slake with difficulty, and, in large part, not at all.

In practical lime burning it is the aim to draw the lime from the bottom of the kiln at such a rate that the lime is removed from
 50 the influence of the high temperature flame just before the calcination is complete. As mentioned above, during the operation of calcination the temperature of the material is maintained considerably below the temperature of the flame with which it is bathed, on
 55 account of the fact that a large portion of the heat taken up by the stone is transformed into latent heat through the dissociating reaction incident to lime burning.
 60 This reaction takes place according to either one or both of the following equations:



65 Reaction 1 is the one which takes place

when calcite, marble or any carbonate rock in which the base is calcium is subjected to heating at or above redness. Reaction 2 is the one which occurs when dolomite is heated. Usually the so-called limestone is
 70 neither a pure calcium carbonate rock nor a pure dolomite but of a composition between the two.

By reaction 1, reducing the data to standard conditions of temperature and pressure,
 75 about 778 B. T. U. are absorbed per pound of stone calcined. If we take the specific heat of limestone as .22, this heat rendered latent would have been sufficient without dissociation to have raised the stone to a
 80 temperature of $\frac{778}{.22} = 3536^\circ \text{F}$. It is apparent, therefore, that if the lime could be withdrawn from the influence of the flame immediately on the completion of the above re-
 85 action there would be no danger of overburning. In practice, however, with the customary methods of burning, it is, for various reasons, very difficult to so regulate the operation of the kiln so as to even ap-
 90 proximately secure the desired end. The lime produced is therefore, usually, of an irregular quality. Besides, great skill is required of the men operating the kiln. Now, by the method of operation which I herein
 95 describe and claim all danger of overburning is done away with, and, at the same time, a great saving effected in fuel consumption owing to the recuperation of the heat ordinarily carried out in the lime and the saving
 100 in radiation losses which I effect.

I secure my temperature control in the kiln by mixing with the producer gas generated in the producer 2, more or less gas
 105 withdrawn from the upper portion of the kiln. The heat liberated in the combustion of the gas must therefore go to raising the temperature of this portion of kiln gas so introduced as well as to the calcination of
 110 the stone and the raising of the temperature of the stone, air and calcination products. By regulating the proportion of kiln gases to producer gas it is manifest that I can reduce the initial temperature of the pro-
 115 ducer gas to any point within the ignition limit. It is my object, however, to add simply a sufficient quantity of kiln gases to reduce the temperature of the flame to a point at which there is no danger of overburning the lime. The actual proportion of
 120 kiln gas added to the producer gas depends upon the conditions in the kiln at any given time and should be regulated from time to time according to the indications given by the actual conditions prevailing in the kiln.
 125 For example, where it is the practice to draw the lime at comparatively long intervals, (say 6 hours) during the drawing and for some time afterward the kiln gas should be cut to a minimum or omitted altogether.
 130

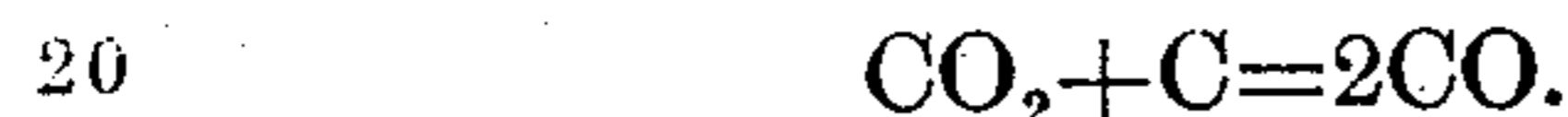
This is on account of the fact, that, the withdrawal of the lime and the consequent settling of the column of material in the kiln carries into the combustion or high temperature zone a large mass of material which is at a temperature very much below the normal temperature in that zone. The heat absorbed from the flame by the stone is therefore much more rapid than that which normally takes place at this zone. As the temperature of the stone increases to the normal temperature of the calcining stone in this zone of the kiln, I gradually increase the proportion of kiln gas until normal conditions have been reestablished. With gas of normal composition I find that the volume of kiln gas added to the producer gas as diluent should be about equal to double that of the producer gas. As I have previously stated, however, the proportion must be varied to meet the local conditions, which are seldom exactly identical at any two plants. For example, one plant may be calcining a stone which is a comparatively pure calcium carbonate, where another may be working on a dolomite rock. In such case a high flame temperature would be demanded in the first plant while only a moderate one would be necessary in the second. I would therefore use less kiln gas with the producer gas in the first case than in the second.

The kiln gas withdrawn from the upper part of the kiln and added again at the combustion zone acts simply as a carrier of heat. It takes up in the combustion zone the heat which would otherwise go to raising the temperature of the calcining and calcined stone to a dangerous degree and yields it up again to the cooler material above the calcining zone. Its action is therefore to keep a large column of the material at a safe calcining temperature while preventing a dangerously high temperature developing in the combustion zone. In other words, while limiting the maximum temperature in the kiln, I greatly increase the mean effective temperature in the calcining portion. Owing to this expansion of the high temperature (*i. e.* calcining) zone, I find it advisable to considerably increase the height of my kiln above the dimensions that usually obtain. For example, if a height of 40 feet above the gas inlet ports gives the best results in a kiln working with the ordinary method, to give the best results by my method of burning the height should be increased to say 55 feet above the gas inlets. The secondary air enters through the dampers 31 in the bottom of the "cooler" 5, and rises through the interstices of the column of lime occupying the cooler. This lime passes out of the combustion zone at very nearly the temperature therein. Part of the heat which it carries is absorbed in the

elimination of the last portions of carbon dioxide, which is usually not completely eliminated in the calcining zone proper. A large portion of the heat which the lime carries out of the calcining zone is, however, carried down into the cooler 5 as sensible heat, and yielded up by the lime to the secondary air passing up through the cooler.

In the application to lime burning of producer gas firing by methods heretofore used it has been found impossible to secure an output per unit weight of fuel consumed of more than about 55% of that secured by the earlier methods of burning the fuel in direct contact with the stone. This is due to the fact that the early lime burners, more as a matter of convenience than for any intelligent appreciation of the benefits to be secured thereby, entered air which was to burn the fuel mixed with the stone, at the bottom of the kiln. The entering cold air took up the heat of the hot lime and thus restored it to the calcining or combustion space. Now, when producer gas firing was applied to lime burning the importance of this heat recuperation in the old style kilns was apparently overlooked. At any rate, it has been the universal custom, where producer firing has been used, to introduce the air for the combustion of the gas at the same section of the kiln as that at which the gas was introduced. Indeed, by ordinary methods of producer operation, it is not possible to fully utilize the heat of the lime. In this case it is necessary to pass about one-half of the theoretical air required for the combustion of the fuel through the gas producer itself. Now the weight specific heat of air and lime is very nearly the same (about .22 in each case). The best results heretofore obtained in lime burning have been about 8 lb. of lime to 1 lb. fuel. One pound of carbon requires, theoretically, eleven and one-half pounds of air for its combustion. The full theoretical heat capacity of the air, therefore, in the old style of lime burning was only about one and one-third times that of the lime. If now we would try to take up the heat of the quantity of lime mentioned above in a producer-gas-fired-kiln of the type at present used by the air for the combustion of the gas we would immediately perceive that the heat capacity of the portion of the air which we could enter at the bottom of the kiln would be only about two-thirds of that of the lime. By the present methods, therefore, it would not be possible to return to the kiln all of the heat of the lime and even the improvement on present methods of entering the air for the combustion of the gas at the bottom of the kiln would not permit of as high an output per unit of fuel as in the old style of kilns. By entering an excess of air at the bottom the heat of the lime could, it is true, be returned

to combustion, but this would result in no saving since the excess of air would cause to be carried out at the top rather more than the heat it would take up in the lower part. Now, one of the principal objects of my present invention is to make possible such a distribution of the total air required for combustion in the gas producer and in the kiln itself that without using any but the absolutely essential quantity sufficient air is entered at the bottom of the kiln to take up, practically, all of the heat of the lime. I accomplish this by burning as much as possible of the carbon of the fuel by oxygen derived from the dissociation in the producer of part of the carbon dioxid produced in the kiln by combustion and by evolution from the stone. The reaction by which this takes place is,



Now, this reaction is a highly endothermic or heat absorbing reaction, the net heat absorption being about 6700 B. T. U. per lb. of carbon consumed. I have utilized this reaction in the process revealed in my Letters Patent 829,105, dated Aug. 21, 1906, for the purpose of regulating the temperature of my producer. In this present invention this object is only corollary to my main object, which is to burn as large a proportion of the fuel in the producer as possible by the available oxygen of carbon dioxid. For this reason, I introduce the air and the kiln gas bearing the carbon dioxid into the producer at the highest practicable temperature. In other words, I aim to maintain the temperature of my fuel bed, so far as possible, by the sensible heat of the gaseous current introduced, rather than by combustion of the fuel by air.

It is evident that for every 3.67 lb. of carbon dioxid which I can dissociate in my producer I can dispense with a weight of air carrying 1.33 lb. of oxygen or 5.77 lb. of air. At the same time I have increased the demand for air in the secondary combustion by an equal amount due to the extra volume of carbon monoxid produced from the carbon of the carbon dioxid dissociated. As a result of my improved method of operation, therefore, I transfer a portion of the volume of primary air ordinarily passed into the producer to the secondary air which I enter at the bottom of the kiln. Since I am continuously drawing off from the kiln a volume of gas corresponding to that which I introduce into the producer, I do not in any way increase the loss of heat in the gases passing out of the kiln.

In order to introduce the greatest possible quantity of heat in the draft current supplied to the producer, I heat the primary air as shown in the drawing by drawing it from an annular air jacket enveloping the

shell of the kiln. The air is admitted through dampers at the top of the jacket so as to insure a proper circulation of the air through the annular space. The circulation of the air through the jacket being comparatively slow, owing to the relatively small quantity of primary air used in my method of operating, the non-conducting property of the air comes into play. That is, the air space acts in a measure as it would if it were a strictly closed air jacket. The heat not being withdrawn as rapidly from the shell of the kiln as when the latter is freely exposed to the atmosphere accumulates, so to speak, in the metal shell, raising the latter and the air in contact with it to a much higher temperature than the normal temperature of the shell when the latter is exposed to the atmosphere. In the ordinary type of steel-shell-kiln the heat transmitted to the atmosphere through the shell amounts to at least twelve to fifteen per cent. of the total calorific value of the fuel burned in the kiln. While my device does not save all of this heat, it does take up and return to the kiln via the producer the larger part of it.

The kiln gas which I introduce into the producer, I withdraw from the kiln at quite a high temperature. By mixing the air, which is at a much lower temperature than the gas, with the latter, before it reaches the fan or blower, I am able to introduce the draft current into the producer at the highest temperature at which it is practicable to handle it with blowers of the ordinary type.

With this invention I can do, what has never, heretofore, been accomplished, secure with a producer fired kiln about as high an output of lime per unit of combustible fuel as is secured by the older methods of burning lime in which the fuel is charged with the limestone. The advantage of my method is that where, in the type of kiln referred to, the use of the most expensive fuels, coke of anthracite, is an absolute necessity, in the process herein revealed I can use the cheaper grades of fuel, such as slack, lignites, etc. Aside from the saving in fuel effected thereby, the recuperation of the heat of the lime, and the consequent withdrawal of it in a comparatively cool condition, has a considerable practical value, in that it permits of its immediate loading for transport as well as lessens the labor and annoyance of handling it.

In modifying my producer gas in the way already described two different methods are open to me. In the first, as already described, I introduce the portion of kiln gas used for modifying the producer gas by means of a separate blower 4 into the producer above the fuel bed or into the conduit between the producer and kiln. In the second method, I introduce into the fuel bed of the producer, in admixture with the pri-

mary air, the entire quantity of kiln gas which is required in both the producer and kiln.

The extent to which the carbon dioxid introduced into the fuel bed is dissociated depends upon the temperature of the latter, the thickness of the incandescent fuel, and the completeness and duration of contact between the gas and fuel. The latter condition may be said to vary inversely with the velocity of the gaseous current through the fuel bed. From the above it follows that by regulating the thickness of the fuel, and the velocity of the gaseous current it will be possible to secure the dissociation of any proportion of the carbon dioxid that may be desired; or, to put it another way, it will be possible to pass through the producer any quantity of carbon dioxid that we may desire and at the same time secure the dissociation of the proportion of the dioxid which I desire. By taking advantage of this fact, I am enabled to greatly simplify the apparatus required by my process and the operation of the same. By properly proportioning my producer and regulating the thickness of the fuel bed, I am enabled to effect the temperature control of the producer and, at the same time, secure the proper dilution of the producer gas, by means of the single blower, 3. In normal running, I find it feasible, by maintaining the proper thickness of fuel bed to operate in the manner just described. To meet abnormal fluctuations in the operating conditions I have found it desirable to retain the auxiliary blower, 4. I can thus more quickly vary the quality of the producer gas to meet any abnormal fluctuations without, at the same time, disturbing the normal working of the producer, than is possible when depending solely upon the one blower, 3.

I am aware of the process, patented to Eldred, (Letters Patent 795,257, dated July 18, 1905) in which he uses the gases from the calcination of limestone for the endothermic control of the temperature of the fuel bed in a gas producer, and I do not claim that particular invention.

As hereinbefore pointed out, the primary object of my invention is, in a producer-gas-fired-limekiln, the recuperation of the heat of the hot lime. By my present invention I accomplish this by so arranging my apparatus and the circulation of the air and gas currents that the maximum possible proportion of the total air required by the kiln and gas-producer is passed in contact with the hot lime.

Having described my invention, what I claim is:—

1. The process of calcining limestone which consists in contacting with ignited carbon, a portion of the gases produced in the calcination of the limestone, mixing with the com-

bustible gas so produced, another portion of the gases from the calcination of the stone, heating air by contacting the same with the hot lime, and burning said gas mixture with said heated air in contact with said limestone, the portion of calcination gases added to said combustible gas, being such that the temperature developed in the burning of said gas is below that at which the impurities in the stone will combine chemically with the lime.

2. In the calcination of limestone the process which consists in mixing a portion of the gaseous products of the calcination with air, in contacting such gaseous mixture with incandescent carbon forming producer gas, in mixing such producer gas with another portion of the gaseous products of the calcination of said limestone, whereby a modified producer gas is formed, in contacting the calcined limestone with a current of air whereby said air is heated, in mixing such heated air and said modified producer gas in contact with the incandescent lime, whereby a calcining flame of regulated intensity is secured, and in subjecting the limestone to calcination by said flame, all substantially as described.

3. In the calcination of limestone the process which consists in mixing a portion of the gaseous products of such calcination with air preheated by a portion of the sensible heat of said gaseous products, in contacting such gaseous mixture with ignited carbonaceous fuel, thereby forming producer gas, in mixing such producer gas with another portion of the gaseous products of the calcination of said limestone, whereby a modified producer gas is formed, in contacting the calcined limestone with a current of air whereby said air is heated, and in mixing such heated air and said modified producer gas in contact with the highly-heated lime, whereby a calcining flame of regulated intensity is secured, all substantially, as described.

4. In the calcination of limestone, the process which consists in mixing a portion of the gaseous products resulting from such calcination with air preheated by a portion of the sensible heat of said gaseous products, in contacting such gaseous mixture with incandescent carbonaceous fuel, thereby, forming producer gas, in contacting the hot calcined limestone with a current of air whereby the said air-current is heated and the said lime cooled, in modifying the said producer gas by mixing therewith sufficient of the gaseous products of the calcination to reduce the temperature of the flame formed on the subsequent combustion of said producer gas, below the temperature at which the impurities in the stone will combine chemically with the lime, in mixing the said modified producer gas and said heated air-current in contact with incandescent material, whereby said

gas is burned, and in subjecting the limestone to the flame of such burning gas, substantially as described.

5. In the calcination of limestone the process which consists, in withdrawing at a high temperature a portion of the gaseous products resulting from such calcination, in contacting such portion of the gaseous products of the calcination with incandescent carbonaceous fuel, sufficient air preheated by a part of the sensible heat of the gaseous products being admixed with said portion of the said products to maintain said fuel in an ignited condition, whereby a producer gas of regulated calorific value is formed, in contacting the lime from the calcination of the limestone with a current of air, whereby said lime is cooled and said air current heated, in mixing said heated air-current and said producer gas in contact with incandescent material, thereby burning said gas, and in subjecting the said limestone to calcination by the flame of said burning gas, all, substantially, as described.

6. In the operation of a producer-gas-fired-limekiln, the process, which consists in generating the major portion of the producer gas by withdrawing a portion of the kiln gas, while the same is at a high temperature, and contacting it with ignited carbonaceous fuel, in contacting the hot lime with a current of air, whereby said lime is cooled and said air-current heated, and in mixing the said heated air-current, and the producer gas in contact with the hot lime, whereby said gas is burned and the limestone subjected to a calcining flame of moderate intensity, all substantially as described.

7. In an apparatus for the calcination of limestone, the combination of a limekiln, a gas producer, means for introducing air and kiln gas into the fuel bed of said gas producer, means for introducing another portion of kiln gas into the gas generated in said producer, means for conducting said gas mixture from said gas producer to said limekiln, and means for burning said gas in contact with the material in said limekiln.

8. In an apparatus for the calcination of limestone, the combination of a furnace for burning said stone, a gas producer, means

for heating air by contact with the shell of said furnace, means for introducing the so-heated air and kiln gas into the fuel bed of said producer, means for introducing another portion of kiln gas into the gas generated in said producer, means for conducting said gas mixture to said furnace, and means for burning said gas in contact with the material in said furnace.

9. In an apparatus for the calcination of limestone, the combination of a furnace for burning said stone, comprising a vertical shaft, having means for charging the limestone and discharging the kiln gas at the top thereof, means for withdrawing the finished lime from the bottom thereof, means for introducing a combustible gas thereinto and burning the same in contact with the charge in said furnace, and means for heating air by contacting the same with the shell of said furnace; a gas producer; means for passing into said producer a draft current comprised of the said heated air and kiln gas, and means for conducting the gas from said gas producer to said kiln.

10. In an apparatus for the calcination of limestone, the combination of a kiln for burning said stone, comprising a vertical shaft having means for charging the stone thereinto and discharging the kiln gases therefrom, means for withdrawing the finished lime from the bottom thereof, means for heating a portion of air by contacting the same with the shell of said kiln, means for introducing into the bottom of said shaft another portion of air and heating the same by contact with the finished lime in the lower part of said kiln, and means for introducing a combustible gas into said kiln, means for igniting said gas and means for burning the same; a gas producer; means for introducing the first portion of heated air and kiln gas into said gas producer; and means for conducting the combustible gas generated in said gas producer to said kiln.

Signed at New York city in the county of New York and State of New York.

HENRY L. DOHERTY.

Witnesses:

F. D. TAYLOR,
JOHN MCGUIRE.