

May 12, 1942.

G. D. HILL

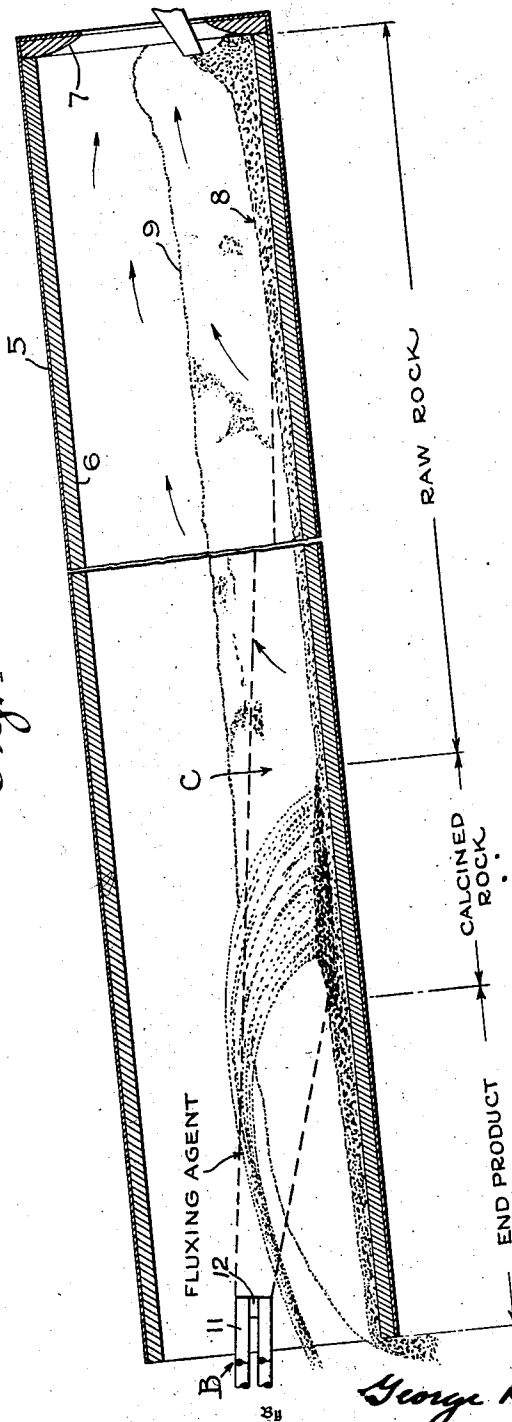
2,282,584

METHOD OF OPERATING ROTARY KILNS

Filed Aug. 2, 1940

2 Sheets-Sheet 1

Fig. 1



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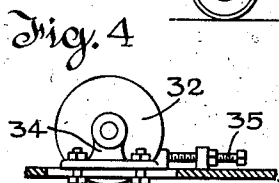
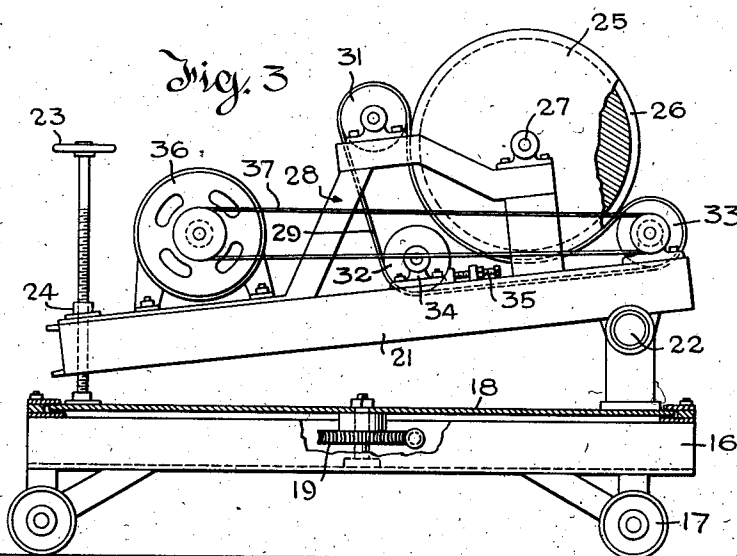
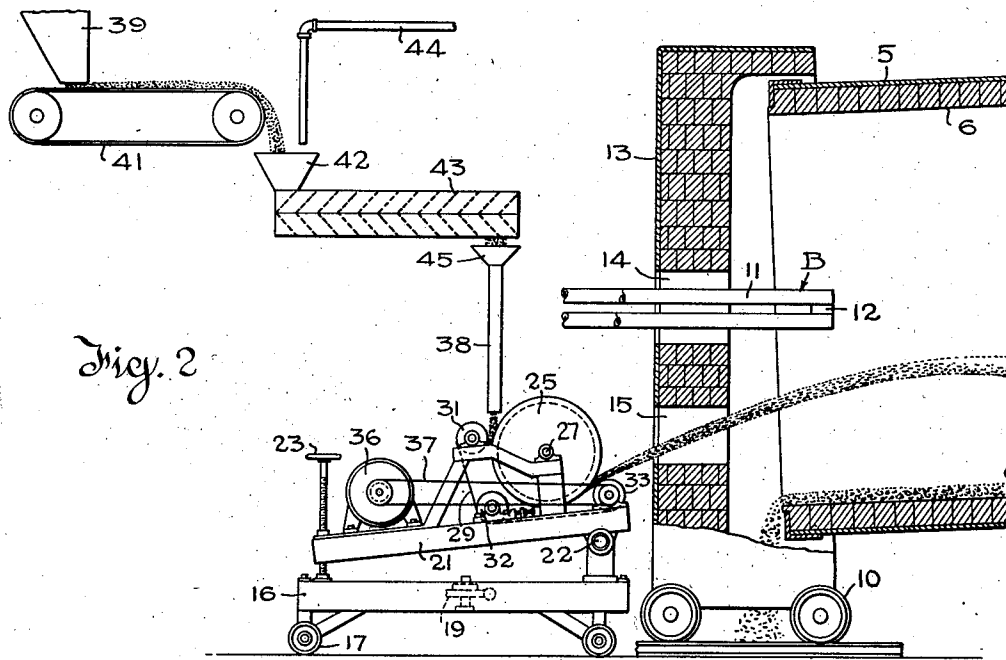
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METHOD OF OPERATING ROTARY KILNS

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2 Sheets-Sheet 2



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UNITED STATES PATENT OFFICE

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METHOD OF OPERATING ROTARY KILNS

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Application August 2, 1940, Serial No. 349,807

12 Claims. (Cl. 263—53)

This invention relates to methods of operating rotary kilns and particularly to operating them in the roasting or dead-burning of refractories and fluxes. More particularly it relates to operations in which dolomite and limestone are roasted or dead-burned.

In the roasting or dead-burning of dolomite and limestone it is the usual practice to add to the raw rock a certain amount of fluxing material that in the hot zone of the kiln reacts with some of the lime in the calcined dolomite or limestone to form reaction compounds of lime. Some of these compounds have lower fusion temperatures than the temperatures reached in the kiln and consequently are in a soft and sticky condition and readily pick up pieces of stone and adhere to the furnace lining to form thick coatings and high rings within the kiln so as to interfere with its operation and require frequent shut-downs for removal of the rings. Not only does this entail loss of production, but it also causes damage to the refractory lining of the kiln. The higher the percentage of fluxing materials admixed with the stone, the more serious does this problem become and the more frequently is it necessary to shut down the kiln to remedy the condition. The cause of this condition lies in the prior art methods of firing rotary kilns and of admixing the fluxing materials. It has been discovered that this condition can be greatly ameliorated by an improved method of firing the kiln, and by an improved method of admixing the fluxing materials. By combining these two improvements and suitably adjusting the flame and the placement of the fluxing materials, it is possible to reduce or prevent the formation of rings or other accretions, and even to remove rings that have formed without interrupting the operation of the kiln. It is also possible to manufacture roasted dolomite and limestone with a flux content much higher than has hitherto been possible or commercially practicable.

In the firing of rotary kilns the usual practice is to employ a single burner, usually at or near the discharge end of the kiln. This practice produces an expanding circular flame which results in a zone of maximum temperature that extends around the entire interior circumference of the kiln. The heat from the burning fuel is transferred to a large extent to the refractory lining of the kiln, except for that small segment of the circumference of the kiln that is covered by the material being burned. The material covering that segment of the interior of the

kiln within the hot zone receives a portion of its heat from the flame itself. As the kiln revolves and the material is rolled around the inner circumference of the kiln, it comes in contact with the heated refractory lining and heat is transferred from the lining to the material. The burning of the material is accomplished, therefore, only in part by direct heat transfer from the flame, and in a larger part indirectly by transfer of heat from the refractory lining to the material. This indirect transfer of the heat of the flame to the material being burned places a severe burden on the refractory lining and subjects it to wear and deterioration.

An important object of the present invention is, therefore, to concentrate the flame upon the material that is being burned to transfer the heat directly to the material and to avoid subjecting the refractory lining to the full intensity of the heat of the flame. This is accomplished preferably by dividing the stream of fuel, such as pulverized coal, into a plurality of smaller streams with their flames directed in successive spaced relation on the incoming rock along a line more or less parallel to the axis of the kiln within the hot zone. In this way, instead of a flame with a more or less circular periphery that extends around the inner circumference of the kiln, a linear flame is produced that extends along the sector of the kiln that is covered by the incoming rock. Obviously a given amount of heat is used more effectively and more efficiently when applied directly to the material being burned, than when applied indirectly through transfer from the refractory lining. This application of the heat has other important advantages in the manufacture of dead-burned or roasted dolomite and limestone that will be hereinafter described.

The advantages of firing the kiln in this way are a more intense heat of combustion, concentration of the heat of combustion on the material being burned instead of on the refractory lining of the kiln, and control of the length of the hot zone and the position of the hot zone with respect to the discharge end of the kiln, so that the heat may be directed at will where it will best accomplish its purpose.

Another important object of this invention is an improvement in the method of introducing the fluxing materials that are admixed with the dolomite and limestone in manufacturing dead-burned or roasted dolomite and limestone and materials of that class. The fluxing materials that are usually mixed with the dolomite and

limestone consist of silica, alumina, and iron oxide, or contain one or more of these oxides. The preferred fluxing material used in the art is iron oxide in the form of mill scale or iron ore, or other materials consisting dominantly of iron oxide. In the process of burning the admixture of dolomite or limestone and the fluxing oxide-containing materials, the fluxing oxides combine with lime in the dolomite or limestone to form reaction products of lime. In their simplest forms these reaction products are silicates, aluminates, and ferrites of lime, although more complex compounds of lime, such as aluminoferrites, are also formed. The lime that is in excess of that required to form the reaction products, and the magnesia of the dolomite crystallize as refractory oxides. The melting points of some of these compounds are:

	°F.
Magnesium oxide	5072
Calcium oxide	4618
Dicalcium silicate	3866
Tricalcium aluminate	2795
Dicalcium ferrite	2617

It will be clear that the melting points of the oxides are much higher than those of the other compounds, hence the tendency to formation of sticky masses of silicates and the like as above indicated.

The product of the roasting or dead-burning is a material comprising a matrix of the reaction products of lime and the fluxing oxides, in which are embedded the crystals of free lime and magnesia. The relative percentages of the refractory oxides of lime and magnesia and of the more fusible lime bonding reaction compounds, are determined by the average chemical composition of the admixture of dolomite or limestone and fluxing materials. Inasmuch as the temperature of the hot zone of the kiln is as high as, and usually higher than the melting temperatures of the calcium aluminates and ferrites, these compounds will be in a soft, sticky condition in that zone. Where these are present in appreciable amount they will readily adhere to the refractory lining of the kiln, tending to build up a thick coating or ring which retards the flow of material through the kiln and also affects its uniformity, a condition that is conducive to a more rapid accumulation of these objectionable accretions.

It is customary to admix the limestone or dolomite and the fluxing materials either before feeding them to the kiln or as they are fed to the kiln. The fluxing oxides are also at times blown into the kiln, wholly or in part, in dry pulverized form at the firing or discharge end. Ordinarily the dolomite or limestone is in relatively large particles and the fluxing materials are in relatively small particles. Also there is usually a difference in specific gravity between the stone and the fluxing materials. As an admixture of materials so heterogeneous in size and specific gravity rolls down the kiln as it rotates, some degree of segregation of the materials inevitably occurs so that the resulting product is heterogeneous in chemical composition irrespective of how uniform the feed may be. Where the fluxing oxides are most segregated, the maximum amount of sticky aluminates and ferrites is formed, increasing the tendency to the formation of thick coatings and rings on the kiln lining, and also destroying the kiln linings through reaction between the refractories of the lining and the fluxing materials.

It has been discovered that the fluxing materials become soft and sticky and tend to pick up particles and adhere to the kiln lining before calcination of the rock is complete, that is before all of the carbon dioxide has been expelled from the rock. When the rock is completely calcined, the fluxing oxides react with the lime and are absorbed more rapidly than they are before calcination is completed. These discoveries led to the further discovery that if the fluxing oxides are admixed uniformly at the point in the kiln where calcination has been completed or substantially so, segregation of the fluxing oxides is prevented and that reaction with the lime takes place quickly to form a product of uniform composition. In this way the formation of soft sticky masses that adhere to the kiln lining and pick up particles of the calcined stone to form rings is avoided.

The required uniformity in feed and required accuracy in placement of the fluxing materials can not be achieved by blowing them into the kiln in dry pulverized form, as has hitherto been the practice when the fluxing materials are introduced into the burning zone separately from the dolomite or limestone. Moreover, when the fluxing material is blown into the kiln in dry pulverized form there are appreciable stack losses of the dust, and the dust of the fluxing materials adheres to the exposed refractory lining of the kilns and leads further to the building up of coatings and rings.

Another important object of this invention is to introduce the fluxing materials directly into the firing zone where they will react immediately with the calcined lime without stack loss of dust. The fluxing materials do not come in contact with the refractory lining of the kiln before they have reacted with lime, and hence the amount of fluxing oxides delivered to the burning zone is rigidly controlled and uniformly added. These advantages are preferably achieved by projecting the fluxing material directly onto the hot completely calcined stone, a short distance above the middle of the bed of stone on the high side of the kiln. As the kiln revolves, the stone on the high side rolls over on the top of the fluxing material, folds over it, and prevents it from coming in contact with the kiln lining until after the reaction products have been formed. This insures a uniform distribution of the fluxing oxides through a calcined material to give a uniform product, and also prevents the formation of the objectionable coatings and rings. Control of the trajectory of the fluxing oxides permits placing them in the exact spot on the calcined stone where reaction takes place most rapidly, and permits changing their placement readily as conditions in the kiln change. By this method not only may the chemical composition in the reaction zone be kept more uniform than has hitherto been possible, but the chemical composition of the product manufactured may be changed in minutes by appropriately changing the rate of addition of the fluxing oxides, whereas hitherto it has required hours to complete such a change.

The proper placement of the fluxing oxides is accomplished by utilizing centrifugal apparatus which can be operated to give to the particles of fluxing oxides the trajectory necessary to project them to the exact spot on the calcined zone where the reaction is desired. The apparatus is so constructed that the trajectory of the fluxing oxide particles can be regulated to change the

locus of their placement to accommodate it to changing conditions in the kiln. This is accomplished by control of the direction of the trajectory, and by control of the impelling centrifugal force. If the fluxing particles are heavy, and not too fine-grained, they can be projected in dry condition. If they are in a light, powdery condition, they can be projected in the form of small moisture-bonded pellets. With proper control of to moisture, the pellets can be caused to impinge upon the calcined limestone and to be folded within it as the kiln revolves, without dust losses.

In roasting or dead-burning dolomite and limestone the higher the percentage of fluxing material added, the more rapidly and the more extensively do coatings and rings build up in the kiln. This is particularly the case when the fluxing material comprises dominantly iron oxide. Also, the tendency to form coatings and rings is greater in roasting limestone than it is in roasting dolomite. This tendency is so pronounced that it has not been possible hitherto, to roast limestone with an iron oxide content in excess of approximately 10% without serious interference with a uniform flow of the materials through the kiln, and without frequent and serious delays in the operation of the kiln for the removal of the coatings and rings. By the method of this invention it is possible not only to operate the kiln without the formation of rings and with the formation of a minimum amount of coating, but also by suitable adjustment of the flame and placement of the fluxing materials, to remove rings and large accumulations of coating at will while the kiln is in operation without damage or injury to the lining.

In order to disclose the details of one method embodying this invention and a practical apparatus for carrying it out, the invention will be described in connection with the drawings in which:

Fig. 1 is a longitudinal sectional diagrammatic view of a portion of a rotary kiln showing the various steps involved in carrying out processes embodying the present invention;

Fig. 2 is a detailed sectional view of the discharge or firing end of the kiln, together with certain projecting apparatus for feeding fluxing material into the kiln;

Fig. 3 is a detailed view of the projecting apparatus; and

Fig. 4 is a detail of the projecting belt adjustment of the apparatus shown in Fig. 3.

Although as indicated above, the present invention is of application in the roasting or dead-burning of refractories, fluxes, and the like, and in numerous relations where materials are to be admixed in a furnace, it is of particular importance in the manufacture, in a rotary kiln, of roasted or dead-burned rock from starting materials such as limestone, dolomitic limestone, dolomite, magnesite, and the like, where fluxing materials such as fluxing oxides of the type illustrated by iron oxide, manganese oxide, and the like are to be added.

The invention has the general application indicated, but for purposes of illustration it will be described as applied to a process of flux manufacture where the materials to be combined are a lime base comprising limestone and a fluxing agent in the form of iron oxide. These materials when combined result in a product consisting essentially of calcium oxide embedded in a matrix of calcium ferrite. The product is charac-

terized by the properties of being dense and heavy, readily soluble in a molten metal bath, capable of dissolving more readily in the slag of the bath than ordinary fluxing lime or limestone and being substantially free of periclase. It is, consequently, substantially dust-free, resistant to water and atmospheric deterioration, and combines more rapidly with the impurities of a furnace charge than ordinary lime or limestone. Such a flux and its method of manufacture and use is disclosed and claimed in the patent to Nicholas No. 2,159,977, dated May 30, 1939, to which reference may be had for details which are not essential to the present disclosure. Fig. 1 of the drawings indicates roughly the steps involved in the process. In this figure reference character 5 indicates the kiln wall having the usual refractory lining 6. In practice, of course, this kiln will be subjected to continuous rotating movement, but to simplify the drawings the mounting for the kiln and the driving mechanism are both omitted. The inlet end of the kiln has the usual retaining ring 7 through which the raw rock to be burned is fed by a feeding mechanism as indicated. Since the feeding apparatus constitutes no part of the present invention, and various types of apparatus may be employed, specific description of the feeding mechanism is omitted. The raw rock falls from the feeding mechanism into the rotating kiln and is gradually fed downwardly by the combined action of gravity and the force of the incoming material behind. As illustrated, it is assumed that the kiln rotates in a counterclockwise direction looking from left to right in Fig. 1. 8 designates the body of raw rock as it rests on the floor of the kiln, and dotted line 9 indicates roughly the position of the material as it collects on the high side of the kiln during its rotation.

While the heating apparatus may take various forms, it is preferably of a type made up of several burners capable of producing an elongated flame substantially parallel to the axis of the kiln and extending over a considerable longitudinal area thereof so as to impinge directly upon the body of rock as it enters the firing zone of the kiln, thereby imparting its heat directly to the material being treated.

While the fuel employed may be oil, the burner has been illustrated as a type employing powdered coal. The burner designated generally by the reference character B is made up of four tubes 11 inclined with respect to the axis of the kiln, but so directed as to cause the flame from the four tubes to impinge upon the material under treatment over a considerable longitudinal area, the various tubes 11 being differently directed so as to cause their spheres of action to overlap longitudinally of the kiln and produce a uniform flame. The approximate locus of the flame is indicated by the dotted lines in Fig. 1. The ends of the tubes 11 are jointed by plates 12 which form an inlet tube for secondary air. The type of burner illustrated is preferred, but since it constitutes the invention of another, and various equivalents may be utilized, the details will not be set forth in this application. This burner is described and claimed in the copending application of Thomas A. Cherry, filed August 2, 1940, Serial No. 349,821.

As the raw rock flows downwardly through the kiln to approximately point C, the carbon dioxide will be driven off leaving the material consisting essentially of lime, assuming that limestone is the rock under treatment. At this point, the

fluxing agent, as indicated, is caused to impinge upon the body of calcined rock or lime and the two ingredients become mixed by the tendency of the material on the high side of the kiln to fall over and embrace the incoming fluxing agent so that under the heat of the burner B the two materials are sintered together as they approach the discharge end of the kiln.

It is desirable to introduce the fluxing agent by means entirely outside of the kiln to avoid openings in the wall and to permit adjustment of the point of delivery. For purposes of illustration Fig. 2 shows the details of one suitable arrangement. Reference character 13 designates a portable end closure lined with suitable refractory and embracing the discharge end of the kiln. This closure is preferably mounted on wheels 10, so as to permit its adjustment with respect to the kiln and to permit its removal when access to the interior of the kiln is desired. This closure contains an opening at 14 for secondary air and through which the tubes of the burner B project into the kiln, the source of fuel being omitted. The closure contains a second opening 15 through which the fluxing material is projected. The projecting means permits both vertical and lateral adjustment of the trajectory of the fluxing agent.

As shown in detail in Fig. 3, this apparatus comprises a frame 16 mounted on wheels 17 and carrying a turntable 18 which may be rotated about a vertical axis by worm and pinion 19. Mounted on this turntable is a frame 21 capable of vertical adjustment about a horizontal axis 22 by hand wheel 23 operating a feed screw and nut connection 24 between the frame 21 and the hand wheel shaft. Mounted on the frame 21 is a pulley 25 having a grooved periphery 26. The pulley is rotatably mounted on a shaft 27 carried by a supporting structure 28 on the frame 21, and the periphery of the pulley engages an endless belt 29 carried by three pulleys 31, 32 and 33. The pulley 32 is capable of adjustment horizontally to tighten or loosen the belt 29 and to vary the degree of frictional contact between the periphery of the pulley 25 and the belt. As indicated in Fig. 4, the pulley 32 is journaled in adjustable bearing blocks 34 having bolts slidable in slots in the frame 21 and adapted to be held in adjusted position by adjustable locking screw 35 (see Fig. 4). The pulley 25 is driven by a motor 36 attached to front pulley 33 by belt 37.

It will be seen that the engagement between the periphery of pulley 25 and the traveling belt 29 forms a pocket into which material, such as iron oxide, may be fed through a pipe 38 whence it is projected through the opening 15 into the kiln. The fluxing material is preferably in finely divided or granular form. As shown, the material, such as iron oxide, is discharged from a bin 39 onto a traveling belt 41 whence it is delivered into a hopper 42 of a pugmill 43. Water may be added to the hopper 42 through a pipe 44. After suitable admixture, the finely divided material is discharged from the pugmill into the funnel 45 at the top of pipe 38. Thus the material is placed in pellet form and freed from dust so that it may be thrown into the kiln by centrifugal force and deposited at the precise desired point. By adjustment of hand wheel 23, the stream may be raised or lowered to change its locus of impingement. Lateral adjustment is performed by worm wheel 19. By suitably tensioning the belt 29 and controlling the speed at which it is driven, the trajectory of the pro-

jected material may be adjusted to suit any desired conditions and thus to direct the material to the precise point in the kiln where it will be most effective in preventing ring formation.

Although as pointed out above practice of the present invention reduces or eliminates the tendency to formation of coatings or rings in a rotary kiln when dolomite is being roasted, it has been a fact that when sintering calcined limestone with iron oxide, the iron oxide could not be added in excess of approximately 10% of the material under treatment without such serious interference by accretions as to substantially prevent effective operation of the kiln. Practice of the present invention not only reduces or eliminates ring formation and other accretions during addition of small percentages of fluxing material, but it makes it possible to operate a rotary kiln continuously and effectively by the addition of fluxing materials in far greater quantities than have heretofore been possible and to even remove coatings already formed.

What is claimed is:

1. The method of producing a reaction product of calcinable rock fluxing materials in a rotary kiln to reduce ring formation in the kiln, which method comprises calcining the rock during its initial travel through the kiln, adding the fluxing material to the calcined rock at the point where calcination of the rock is substantially complete, and sintering the mixture as it flows to the discharge end of the kiln.

2. The method of operating a rotary kiln to prevent ring formation therein when producing reaction products of carbonates and fluxing materials, which comprises feeding carbonate rock into the entrance end of the kiln, subjecting it to calcining temperatures to remove the carbon dioxide therefrom, and then adding fluxing material to the calcined rock substantially at the point where calcination is complete.

3. The method of operating a rotary kiln to prevent the formation of ring-like accretions therein, which comprises feeding calcinable rock into the entrance end of the kiln, subjecting the rock to calcining temperatures by direct flame impingement on the rock mass, and intermixing fluxing material with the calcined rock by forcibly projecting it through the discharge end of the kiln and onto the calcined rock substantially at the point where calcination of the rock is complete, to produce a reaction product of the calcined rock and the fluxing material.

4. The method of manufacturing reaction products of calcined rock and fluxing materials in a rotary kiln, which comprises feeding raw calcinable rock into the entrance end of the kiln, subjecting it to calcining temperatures by direct impingement of a heating flame thereon, forcibly projecting fluxing material in granular form onto the rock mass through the discharge end of the kiln substantially at the point where calcination of the rock is complete, and sintering the mixture of calcined rock and fluxing material.

5. The method of operating a rotary kiln to reduce kiln accretion during dead-burning of rock having a volatile constituent, which comprises feeding the raw rock into the entrance end of the kiln, subjecting the raw rock to calcination temperatures as it travels through the kiln, and adding fluxing material to the calcined rock at the point in the kiln where the removal of the volatile constituents of the rock is substantially complete.

6. The method of operating a rotary kiln to

reduce kiln accretion during dead-burning of rock having a volatile constituent, which comprises feeding the raw rock into the entrance end of the kiln, subjecting the raw rock to calcination temperatures as it travels through the kiln, and projecting fluxing material through the discharge end of the kiln into the mass of calcined rock at a point in the kiln where the removal of volatile constituents from the rock is substantially complete.

7. The method of operating a rotary kiln to reduce kiln accretion during dead-burning of rock having a volatile constituent, which comprises feeding the raw rock into the entrance end of the kiln, subjecting the raw rock to calcination temperatures by direct impingement of flame on the rock mass as it travels through the kiln, and projecting fluxing material onto the calcined rock at the point in the kiln where calcination of the rock is substantially complete.

8. The method of operating a rotary kiln to produce reaction products of materials of the class comprising limestone, dolomite and magnesite with fluxing oxides of the class comprising iron oxide and manganese oxide, which method comprises feeding the material into the entrance end of the kiln, calcining the material by direct flame impingement thereon, projecting fluxing oxide through the discharge end of the kiln onto the calcined material substantially at the point in its travel where calcination is complete, and sintering the resulting mixture as it flows to the discharge end of the kiln.

9. The method of operating a rotary kiln in the production of reaction products of rock materials of the class comprising limestone, dolomite and magnesite with fluxing oxides of the class

comprising iron oxide and manganese oxide, which method comprises feeding the rock into the entrance end of the kiln, calcining the rock, projecting fluxing oxide through the discharge end of the kiln onto the calcined rock substantially at the point in its travel where calcination is complete, and sintering the mixture of calcined rock and oxide as it flows to the discharge end of the kiln.

10. A new method of dead-burning or roasting dolomite and limestone in a rotary kiln by reaction with a fluxing material which consists in causing impingement of a flame with an elongated cross section substantially parallel to the axis of the kiln onto the body of calcinable rock entering the kiln and delivering the fluxing materials by their own momentum against the calcined rock at the point where calcination is complete to provide conditions favorable for reaction between the calcined rock and fluxing materials.

11. In the manufacture of dead-burned or roasted dolomite and limestone in a rotary kiln by reaction between calcined rock and a fluxing material, the step which consists in projecting the fluxing material through the discharge end of the kiln onto the calcined rock in the hot zone of the kiln at the point where calcination of the rock mass is substantially complete.

12. In the manufacture of dead-burned or roasted dolomite and limestone in a rotary kiln by reaction between calcined rock and a fluxing material, the step which consists in adding the fluxing material to the calcined rock in the hot zone of the kiln at the point where calcination of the rock is substantially complete.

GEORGE DEWEY HILL.

CERTIFICATE OF CORRECTION.

Patent No. 2,282,584.

May 12, 1942.

GEORGE DEWEY HILL.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 4, second column, line 25, claim 1, after "rock" insert --and--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 23rd day of June, A. D. 1942.

Henry Van Arsdale,
Acting Commissioner of Patents.

(Seal)