

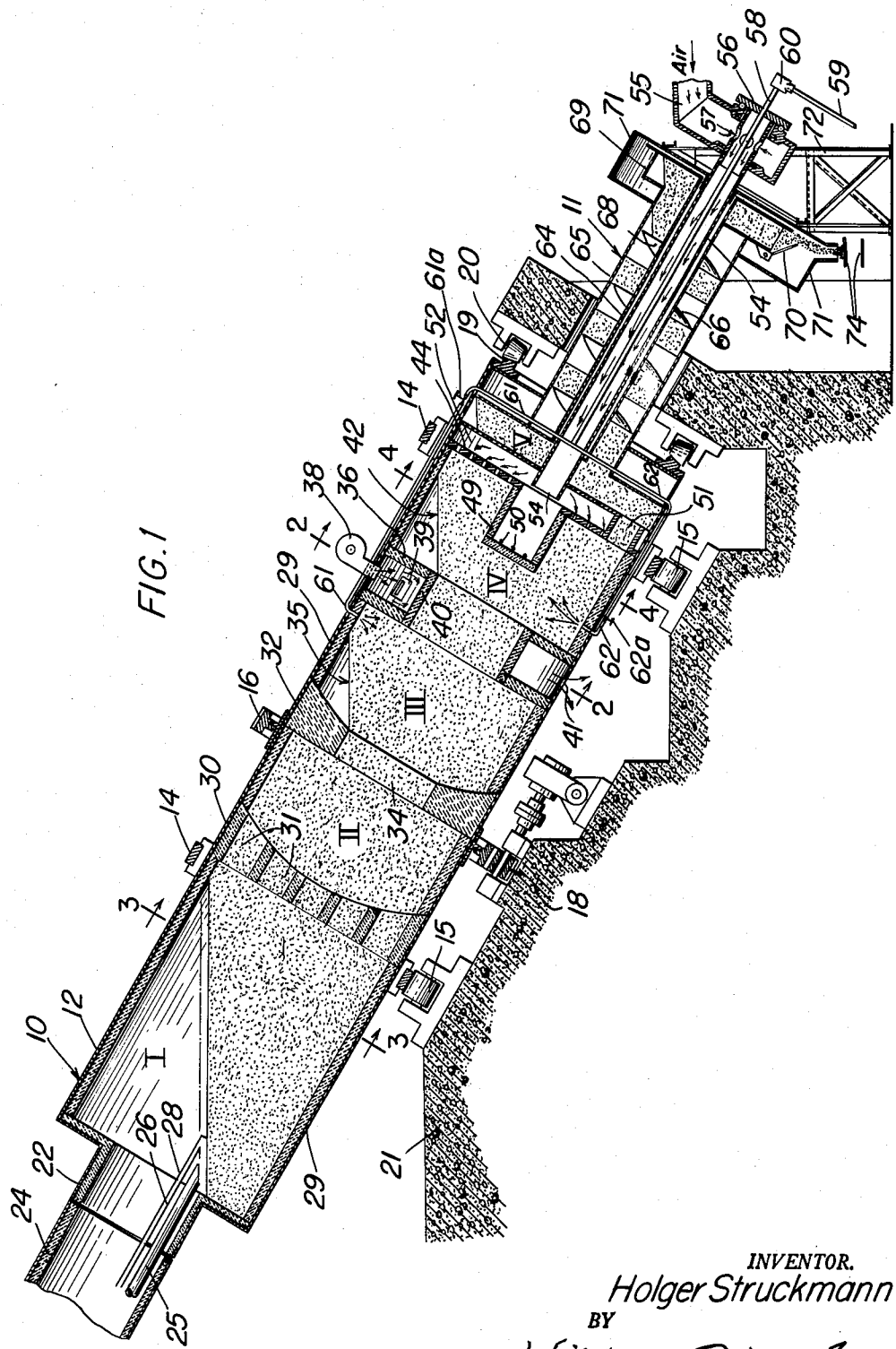
May 1, 1956

H. STRUCKMANN
HIGH ANGLE ROTARY KILNS

2,743,918

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2 Sheets-Sheet 1



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FIG. 2

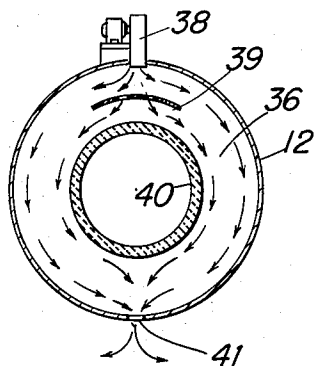


FIG. 3

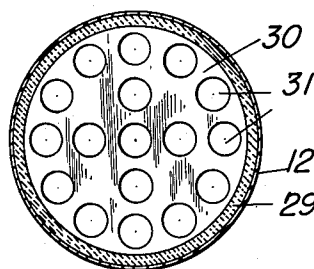


FIG. 4

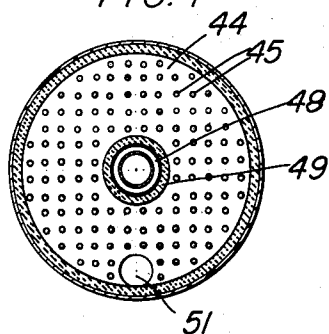


FIG. 6

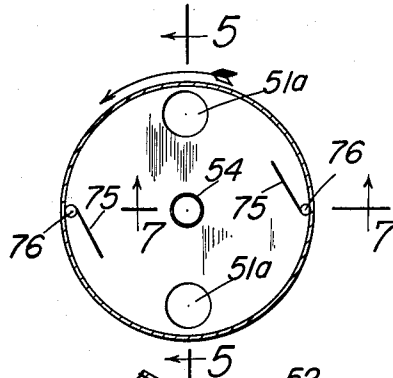


FIG. 5

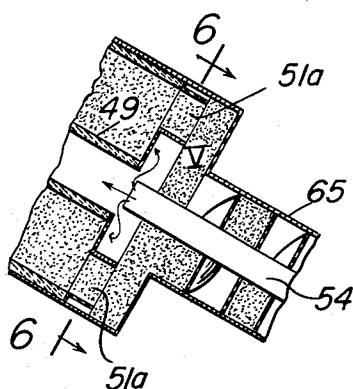
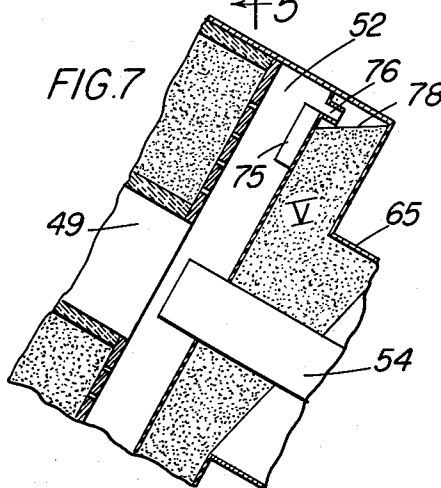


FIG. 7



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HIGH ANGLE ROTARY KILNS

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9 Claims. (Cl. 263—33)

This invention relates to kilns, more particularly rotary kilns mounted to rotate about an axis having a high angle to the horizontal.

Kilns constructed in accordance with the invention may be used to carry out processes now carried out in kilns of all types such as vertical kilns, either rotating or stationary, and low angle rotary kilns which are operated at angles of only a few degrees from horizontal.

The novel kiln hereinafter described has advantages over both of the aforesaid commonly used types, particularly in lower fuel consumption due to greater efficiency, lower initial cost, easier upkeep and better control of the process.

A particular object of the invention is to provide a compartmentized kiln in which a series of reactions may be carried out without substantial intermingling of the materials during various stages of treatment.

Another object is the provision of a kiln for the treating of solid flowable materials in a finely divided state, such as cement meal, with fluidization, the heating and fluidizing gases moving counter to the flow of materials in the kiln.

Another important object is to provide a kiln having a system of combustion in which the gas temperatures may be controlled so that temperatures which are high enough to damage the material are never reached. This is particularly important where intimate contact exists between the material and the combustion gases.

Another object is to provide a kiln in which materials undergoing treatment can be subjected to cascading and tumbling at the desired stages of the process while maintaining the kiln substantially full of material.

The term "high angle" as used herein to describe the kiln inclination is intended primarily to distinguish from the well known low angle substantially horizontal type of kiln and the vertical kiln. An angle of 30° to the horizontal is illustrative of the order of inclination intended by the use of the term. The precise degree of inclination is a matter of selection to be determined by various factors, including the nature of the material dealt with and the process to be carried out. Lower angles favor more effective reduction of channeling of the gas flow through the materials in the kiln and larger areas of cascading together with reduction of the load pressure on the materials. Increasing the angle in general has the opposite effect from reducing the angle, bringing about corresponding advantages and disadvantages. One advantage of higher angles of kiln inclination is that gases tend to travel more through the central body of the material, rather than along the uppermost portion of the kiln wall, resulting in lower wall temperatures and therefore less heat loss through the lining. It will thus be seen that the angle is not critical but is a matter of selection and that variation over a considerable range is possible, from a minimum angle which, in a comparatively short kiln, will permit the material to extend across the kiln's cross-sectional area to such a high angle that when a free surface occurs, gravity together with the material's

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angle of repose will still cause cascading and tumbling to occur along the free surface. Angles from say 25° to 60° to the horizontal exemplify but do not limit what is meant by a high angle.

The invention will best be understood from the following detailed description of the present preferred embodiment thereof taken in conjunction with the drawings in which:

Fig. 1 is a central sectional elevation through a kiln and its supporting structure;

Fig. 2 is a section through a hollow air-cooled ring dam taken on the line 2—2 of Fig. 1;

Fig. 3 is a section through the upper compartment of the kiln taken on the line 3—3 of Fig. 1;

Fig. 4 is a section through the lower combined heating and cooling compartment taken on the line 4—4 of Fig. 1;

Fig. 5 shows a modification of the discharge end of the kiln in a central sectional elevation taken on the line 5—5 of Fig. 6;

Fig. 6 is a section taken on the line 6—6 of Fig. 5; and

Fig. 7 is an enlarged sectional elevation taken on the line 7—7 of Fig. 6.

The structure shown in the drawings will first be described, followed by an explanation of how it functions.

Structure

While the entire structure shown in Fig. 1 may be referred to as the "kiln," the structure embodies two principal parts, namely the kiln proper 10 and the discharge section 11, these two main parts being assembled into an integral structure.

The kiln 10 is an elongated cylinder mounted for rotation about its longitudinal axis, this axis being inclined at a high angle to the horizontal so that material fed into the upper end of the kiln will travel downwardly there-through under the influence of gravity as the kiln rotates. The kiln is constructed in the usual way with a cylindrical steel shell 12 equipped on its outer side with supporting tires 14, which rest on rollers 15, and with a ring gear 16 engaging a drive pinion 18. The lower end of the kiln has a circular tire or thrust ring 19 which rests on rollers 20. All of the aforesaid supporting and driving mechanism is carried on the rigid concrete base 21. The upper end of the shell 12 is provided with a neck 22 which connects with a stack 24. Material is introduced into the kiln by a feed pipe 25, the level of the material in the kiln being controlled automatically by suitable means including maximum and minimum sensing elements 26 and 28.

The inner wall of kiln 10 is lined with fire-brick 29 which brick lining may be spaced from the shell 12 by a layer of insulation (not shown) if desired and where the temperatures will permit, it being necessary to keep fire-brick relatively cool. The space inside kiln 10 is divided into chambers or compartments by various partitions. At the bottom of compartment I, which is the first preheating chamber, is a partition 30 constructed of suitable refractory material such as brick, provided with a number of evenly spaced large apertures 31 arranged as shown in Fig. 3. Partition 30 serves to form a partial barrier between chamber I and chamber II, which is the second preheating compartment. The apertures 31 permit a flow of material from all parts of the bottom of chamber I into all parts of the top of chamber II, the solid surface of partition 30 serving, however, to support much of the weight of the material in chamber I, thus relieving the material in chamber II of the crushing effect of this weight. Furthermore, the large apertures 31 diffuse the heat-laden gases into the material above the partition, thereby effecting better heat transfer conditions.

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Between chamber II and chamber III, which is the first combustion chamber, is a ring dam or annular partition 32 extending inward from the lining 29 and having a single large central opening 34. Material flowing from chamber II to chamber III is thus prevented from completely filling chamber III so that there is a free surface 35 of material on the downstream side of dam 32 on which cascading and tumbling may take place as kiln 10 rotates. (The material within the kiln is indicated throughout the drawings by stippling.) Gas rising from chamber III will be forced toward the center of the kiln in passing into chamber II and must therefore pass through the material.

Between chamber III and chamber IV, which is the second combustion and cooling chamber, is a second ring dam 36, this dam differing from dam 32 in that it is of hollow construction which provides an enclosed space inside the shell 12 through which a coolant such as air may be forced by means of a blower 38 as shown in Fig. 2. The blower and its motor are attached to the shell 12 with the blower projecting through an opening therein in front of which is positioned a suitable baffle 39 (Fig. 2) to cause the air to flow around both sides of the inner wall 40 of the dam 36, the air flowing out of opening 41 in the shell 12 opposite the blower 38. This hollow dam construction may be used where the temperature to be used are such that means must be provided for cooling the fire-brick. The cooling air need not be supplied by a blower attached to the kiln, as just described, but can be supplied otherwise, for example by the blower which furnishes the combustion air to the air space 52 by a suitable piping arrangement, a valve being used to regulate the amount of cooling air tapped off. As shown in Fig. 1, the material on the downstream side of dam 36 is also held back by the dam so that it has a free cascading surface 42.

Chamber IV is provided with a perforated bottom 44 having small air holes 45 (see Fig. 4) evenly distributed over its surface so that it serves as a cooling grate. This grate has a central aperture 48 covered by the cylindrical housing 49 which extends about half way through compartment IV and is provided with peripheral air outlets 50 in its upper end and also in its side if desired. Adjacent the kiln wall, grate 44 has a single discharge opening 51. In the modified embodiment shown in Figs. 5 and 6 two openings are provided, as shown at 51a. The number is a matter of choice. These openings discharge into compartment V which serves as a reservoir to maintain a supply of material ready to enter the spiral discharge passage or passages contained in the discharge section 11.

Between the cooling grate 44 and the compartment V is an air space 52. Extending downwardly from the center of this space along the axis of rotation of the kiln is an air pipe 54 which is affixed to and rotates with the kiln. At its lower end this pipe is rotatably connected with a duct 55 which is supplied with air from a compressor or blower, air flowing from the duct into the pipe through holes 57 in the latter within the duct. The lower end of the pipe 54 is closed by a bearing plate 56 which takes the axial thrust of the duct.

Extending through the center of the air pipe 54 is a fuel pipe 58 which is connected to a fuel supply line 59 by a rotary coupling 60. Just below the bottom of the kiln the pipe 58 is divided into two branches 61 and 62 which extend along the outside of the kiln, and, respectively, into the chambers III and IV on opposite sides of the dam 36. Valves 61a and 62a are provided for adjusting the quantity of fuel to be injected into the chambers.

Concentric with the air pipe 54 are the inner and outer walls 64 and 65 of the discharge section 11, between which are helical spiral partitions 66 and 68 forming with walls 64 and 65 a spiral pipe. Air pipe 54 may be used as the inner wall if desired, as shown in Figs. 5 and

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7, thus placing the warm material in better heat exchanging relation with the incoming air. In the embodiment shown, the material passes from the chamber V between these two partitions in a single spiral path but by making an additional opening into the chamber V the material may flow in two spiral streams separated and directed by the partitions 66 and 68. In either case the material is delivered into the circular box 69 which is provided with one or more adjustable discharge gates 70, the degree of opening of which may be fixed as desired to control the rate of material flow through the kiln. Box 69, which rotates with the kiln, is enclosed in the stationary discharge hopper 71 which is supported on the frame 72. The material leaving the hopper 71 falls on the upper flight of a conveyor belt 74 or some other means for carrying the material away from the kiln.

While it is intended that all of the material leaving the kiln should pass through the opening 51, it is to be expected that there will be a certain amount of leakage of fine material through the air holes 45 in the grate 44. To remove these materials from the air space 52, scoops 75 are attached to the lower wall of this space to pick up any material falling into the space and direct it into the short pipes 76, shown in Figs. 6 and 7. As the pipes 76 reach their uppermost position during rotation of the kiln, the material which has been directed into them is discharged into the chamber V into the free space above the surface 78, as shown in Fig. 7.

Operation

The mode of operation of the kiln constructed as above described will now be explained. It should be noted at the outset that three major features are a construction and mode of operation which bring about, first, a high rate of heat transfer, second, the tumbling and cascading of material which is in a condition in which it tends to fuse, and third, a means of controlling possibly excessive temperatures of combustion. The high heat transfer rate makes possible not only the use of a kiln having a much smaller shell area but one which is so arranged and operated that most of the shell area can be insulated against heat loss. Furthermore, waste of heat is prevented by effectively extracting the heat from everything leaving the kiln, including products of combustion as well as finished material. The tumbling and cascading action permits processing those materials which must be heated to the point of incipient fusion and the action is such as to favor the formation of small nodules.

Referring to Fig. 1, the material enters the kiln at the top of chamber I while fuel enters near the bottom in chambers III and IV. The kiln is substantially full of material at all times and the rate of flow is determined by the withdrawal rate at the discharge end. Combustion takes place in the lower portions of the kiln and in intimate contact with the material by reason of the fact that the fuel and combustion air are mixed with the material in the combustion zones and the continuous movement and shifting of the material due to the rotation of the kiln assures thorough mixing of the material and fuel and combustion products.

The combustion air is forced into the lowermost chamber of the kiln, the combustion and cooling chamber IV, where it is first used to cool the material, extracting large quantities of heat therefrom, before it comes in contact with the fuel. The high preheating of the air results in large fuel savings as less fuel heat is required to heat the air. The kiln is sealed off so that the combustion air is forced to rise upward while the material being treated passes downward. This seal in effect consists of a long column of treated material which has a much greater resistance to gas flow than the column of untreated material. This long column, for economy of space, is arranged in a spiral surrounding the air tube 54. Thus the air and the products of combustion are forced upwardly,

passing counterflow through the voids of the descending material.

The compartmentizing of the kiln is highly advantageous in handling material requiring different treatments in succession since the material at each stage can be prevented from intermingling with material undergoing a different stage of treatment. Each reaction is completed, so far as may be desired, before the material is subjected to the next reaction. This is accomplished by means of the different types of partitions shown. Taking the manufacture of cement clinker as an example, compartment I is used for initially drying and to some extent heating the raw material. (If desired, this compartment can also be utilized for pelletizing by introducing the raw material in a dry pulverized state and adding a water spray to the compartment and equipping its inner walls with lifters. In the event this is done, the pellets together with the water spray will tend to act as a dust collector, trapping those dust particles which may be carried into compartment I by the air stream.) To help support the weight of the material in compartment I, its bottom is in the form of the perforated partition shown in Fig. 3. Supporting the weight of this uppermost material is of particular importance if the material is in the form of pellets, which are readily crushed if subjected to an excessive weight of overlying material.

Chamber II is maintained substantially full of material moving into it from chamber I and here the material, which has now been relieved of moisture and to some extent heated, is further heated preliminary to its introduction into the calcining compartment III, which it enters through the large central hole 34 in the dam 32. In this compartment the material is raised to a calcining temperature by products of combustion which have moved upwardly from chamber IV and which have been generated also in chamber III through the introduction of additional fuel in amounts necessary to achieve the desired heat. In this compartment there is a cascading and tumbling action due to the fact that the compartment is never completely filled. By introducing some of the fuel in this chamber instead of all of it in chamber IV, the temperature in the latter chamber can be prevented from rising too high, thus giving better control over the process and avoiding excessive gas velocities which might be produced if all of the fuel were introduced into chamber IV.

In chamber IV the calcined material is further heated to the point where, under the influence of the cascading and tumbling action, it will be formed into clinker nodules of an appropriate size without any danger of mass sintering. The clinker thus formed, by being subjected to the incoming air rushing through the cooling grate 44 and the housing 49, is cooled, giving up a substantial amount of its heat to the air before it leaves the kiln proper. Through the housing 49 covering the air supply pipe a small amount of cold air is injected into the hottest part of the mass, insuring that the surfaces of the individual particles of material are cooled below the fusion point while still high enough in the kiln for cascading and tumbling to occur, thereby aiding in the prevention of mass sintering. Cold air can also be injected further down the sides of the housing 49 so as to give a quenching treatment to the material.

Due to the kiln's slope, the amount of material in the kiln and the tendency of the gas to rise vertically, it is possible, if desired, to aerate or fluidize finely divided material in one section of one compartment to a greater extent than in other parts of the same compartment. This, taken with the constant turning, may permit the material bed, if of finely divided material, to fluctuate between a state of quiescent fluidization and particular fluidization without causing excessive turbulence. However, the kiln may be used to treat materials in the form of nodules too large to be fluidized. In the latter case

the subjection of the material to the upwardly moving gas stream is intermittent.

A kiln constructed and operating as above described provides for the control of temperature within the kiln in a very advantageous manner. One aspect of this control is the reclaiming of a high percentage of the heat by transferring it from the outgoing kiln product to the incoming combustion air with consequent cooling of the product.

In considering the matter of temperature control it should be borne in mind that while high combustion temperatures are desirable from the standpoint of obtaining a high rate of heat transfer, they are definitely limited by the necessity of not overheating the outer surfaces of the particles of material in the kiln. Particles of material such as those present in cement kilns, for example, have relatively low heat transmission rates and it is thus possible that their outer surfaces may become overheated while their cores remain relatively cool. To give the material particles time to adsorb heat without having their surfaces overheated, the kiln provides, by reason of its rotation and inclination, periodic rather than continuous heating. In each of the compartments of the kiln there is a tendency for the gaseous products of combustion to rise vertically through the material. When the particles of material come into contact with this rising stream of gaseous combustion products their outer surfaces are heated. However, the rotation of the kiln continuously moves this material out of the hot gas stream into a relatively cooler portion and thus the material is subjected to periodic rather than continuous heating which gives the material particles time to adsorb the heat imparted to their surfaces without overheating their surfaces. This intermittent heating makes possible the use of high combustion temperatures which produce high rates of heat transfer.

Furthermore, to prevent the temperatures of the products of combustion from becoming too high at any point in the kiln, fuel is added in different compartments in accordance with the heat requirements therein so that the heat generated in a given compartment is not sufficient to produce overheating.

While the foregoing description relates specifically to the construction and operation of a kiln designed particularly for the manufacture of cement clinker, it is to be understood that the invention is not limited to this specific kiln or its described mode of operation but may be adapted for use in other processes, involving different materials, requiring treatment in the nature of drying, calcining, roasting and sintering. More specifically, the invention is not limited to a kiln having any particular number of compartments since these may be increased or reduced in number as may be required by the particular process being carried out. Likewise, the addition of fuel, which is described as being injected into two of the compartments, may be made wherever additional heat is required in any given process. Fuel may be injected in one compartment only or in two or more compartments which may or may not be adjacent. Combustion takes place primarily in those compartments where fuel is introduced and for the most part above the points of fuel injection.

It should be observed that the kiln provides for a burning system in accordance with which a large excess of air is injected initially which tends to hold down the flame temperature in the lowermost compartment in which fuel is injected. The products of combustion from this compartment, in passing upwardly through the kiln, will be cooled from flame temperature to the temperature of the surrounding material by the time they reach the next higher compartment, and the inertness of these combustion products may be utilized to slow the rate of flame propagation in the vicinity of the next point of fuel injection. This provides a useful means of temperature control. Such a burning system can be carried out with

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any desired number of compartments in each of which the flame temperature may be prevented from becoming excessively high and thus damaging critical material.

It is to be understood that the invention is not limited to the specific features of the embodiment above described for purposes of illustration but is to be construed as broadly as the scope of the appended claims permits.

What is claimed is:

1. Apparatus for heat treating flowable solid material comprising a cylindrical rotatable kiln, means for supporting the kiln with its axis at a high angle to the horizontal whereby said material flows downwardly through the kiln by gravity, means for rotating the kiln, means for maintaining the kiln substantially full of material, and a ring dam extending inwardly from the kiln wall dividing the space therein occupied by said material into compartments and restricting the flow of material past the dam to the central area of the kiln, whereby a free surface of material is maintained on the downstream side of the dam and above the opening therethrough on which free surface cascading of material occurs as the kiln rotates.

2. Apparatus for burning cement and the like comprising a cylindrical rotatable kiln, means for supporting and rotating the kiln with its axis at a high angle to the horizontal, a ring dam separating the space within the kiln into compartments including a calcining compartment on the upper side of said dam and a clinkering compartment on the lower side of said dam, means for maintaining said compartment sufficiently full of material to fill the opening in said dam, means for injecting fuel into the materials on either side of said dam to provide control of the heating in each compartment, means for injecting combustion air into the lower portion of the clinkering compartment, and means for forcing the air and the products of combustion to flow up through the materials in the kiln.

3. Apparatus for heat treating flowable solid material with combustion products formed in the kiln comprising a cylindrical rotatable kiln, means for supporting and rotating the kiln with its axis at a high angle to the horizontal, means for feeding material into the top of the kiln to maintain it substantially full, means for injecting combustion air into the lower portion of the kiln, the bottom of the kiln having a material discharge opening, and a spiral discharge pipe arranged axially of and outside the kiln and open only at its ends communicating with said opening and rotatable with said kiln, the length of said pipe being such that the resistance to the flow of air therethrough when it is filled with material exceeds the resistance to such flow upward through the materials in the kiln in its substantially full operating condition, whereby the air is forced to flow upward through the materials in said kiln.

4. Apparatus for heat treating flowable solid material with combustion products formed in the kiln comprising a cylindrical rotatable kiln, means for supporting and rotating the kiln with its axis at a high angle to the horizontal, means for feeding material into the top of the kiln to maintain it substantially full, means for injecting combustion air into the lower portion of the kiln, the bottom of the kiln having a material discharge opening, a reservoir receiving material passing therethrough, and a spiral discharge pipe arranged axially of and outside the kiln and open only at its ends communicating with said reservoir and rotatable with said kiln, the length of said pipe being such that the resistance to the flow of air therethrough when it is filled with material exceeds the resistance to such flow upward through the materials in the kiln in its substantially full operating condition, whereby the air is forced to flow upward through the materials in said kiln.

5. Apparatus for heat treating flowable solid material with combustion products formed in the kiln comprising a cylindrical rotatable kiln, means for supporting and

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rotating the kiln with its axis at a high angle to the horizontal, means for feeding material into the top of the kiln to maintain it substantially full, means for injecting combustion air into the lower part of the kiln including an axially extending air pipe, the bottom of the kiln having a material discharge opening, and a spiral discharge pipe arranged axially of and outside the kiln and open only at its ends communicating with said opening and rotatable with said kiln and surrounding said air pipe in heat exchanging relation therewith, the length of said pipe being such that the resistance to the flow of air therethrough when it is filled with material exceeds the resistance to such flow upward through the materials in the kiln in its substantially full operating condition, whereby the air is forced to flow upward through the materials in said kiln.

6. Apparatus for burning cement and like materials comprising an elongated cylindrical kiln, means for supporting and rotating the kiln with its axis at a high angle to the horizontal, the interior space in the kiln being divided into a plurality of intercommunicating compartments including a preheating chamber, a combustion chamber and a combined combustion and cooling chamber, means for maintaining said chambers substantially full of material, the said three chambers being separated by annular dams extending inwardly from the kiln wall through the openings in which the said materials can flow downwardly and on the downstream side of which and above the openings therethrough free surfaces will be maintained in the two last mentioned chambers on which cascading can take place as the kiln rotates.

7. Apparatus for burning cement and like materials comprising an elongated cylindrical kiln, means for supporting and rotating the kiln with its axis at a high angle to the horizontal, the interior space in the kiln being divided into a plurality of intercommunicating compartments including a first preheating chamber, a second preheating chamber, a combustion chamber, and a combined combustion and cooling chamber, means for maintaining said chambers substantially full of material, the two preheating chambers being separated by a perforated partition, the three last mentioned chambers being separated by annular dams extending inwardly from the kiln wall through the openings in which the said materials can flow downwardly and on the downstream side of which and above the openings therethrough free surfaces will be maintained on which cascading can take place as the kiln rotates.

8. A high angle rotary kiln having its interior divided into a plurality of inter-communicating compartments through which material to be treated flows in succession by gravity, means for maintaining said kiln substantially filled with material, means for injecting combustion air in the lowermost compartment to rise through the material in said compartments, and means for injecting fuel separately into a plurality of compartments whereby the temperatures therein may be separately controlled.

9. Apparatus for treating flowable solid material with a fluid and comprising, in combination, a vessel for containing the flowable solid to be treated, means for maintaining a predetermined body of material in said vessel, said vessel having a discharge opening in its bottom, means for introducing treating fluid into said vessel in the vicinity of said opening, combined discharge and sealing means communicating with said discharge opening comprising a closed spiral passage open only at its inlet and outlet ends, and means for restricting the flow out of said passage, the length of material travel through said passage being such that the resistance to fluid flow therethrough when it is filled with said solid material exceeds the resistance to such flow upward through the material in said vessel whereby said fluid is forced to flow through the material in said vessel.

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