Feb. 17, 1953 J. J. RUIZ 2,628,829

CALCINING APPARATUS

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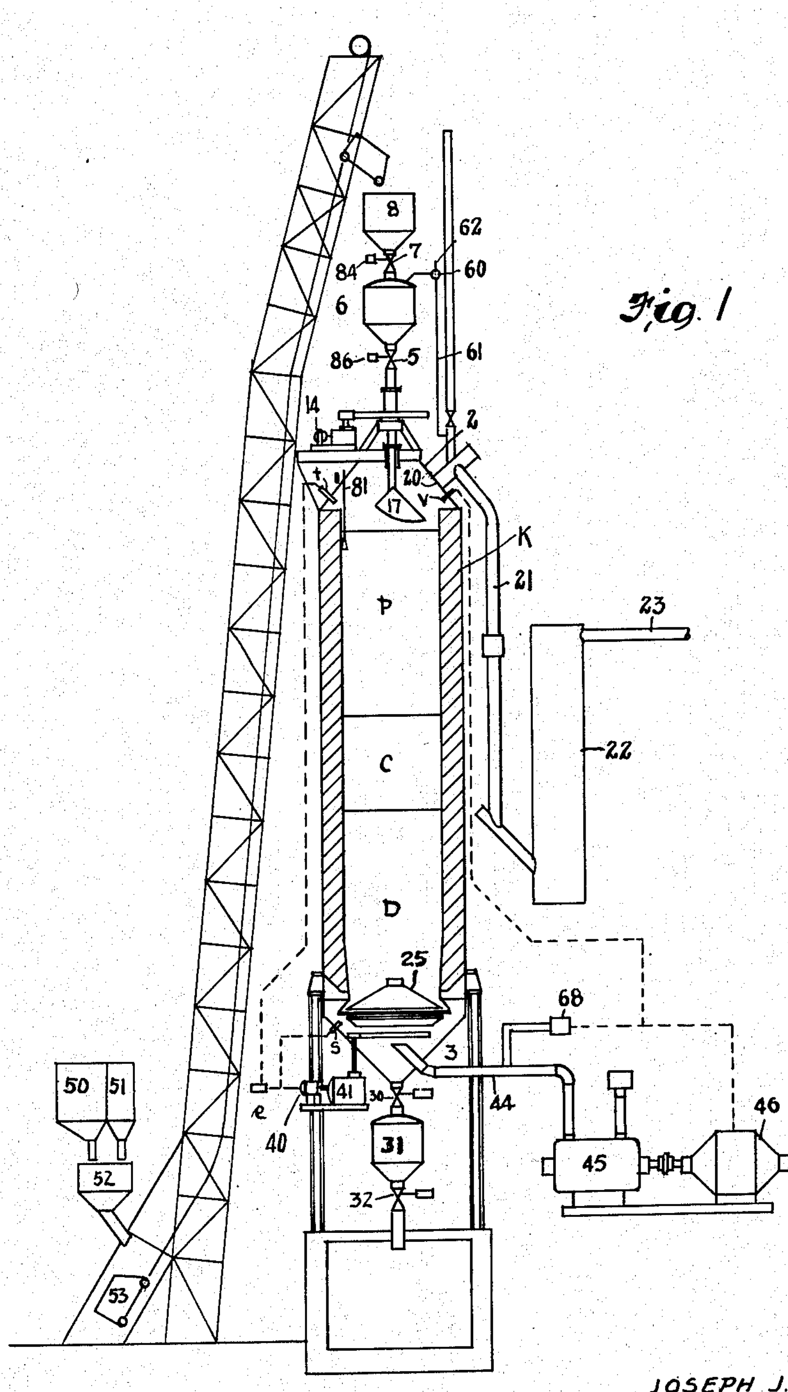

Fig. 1

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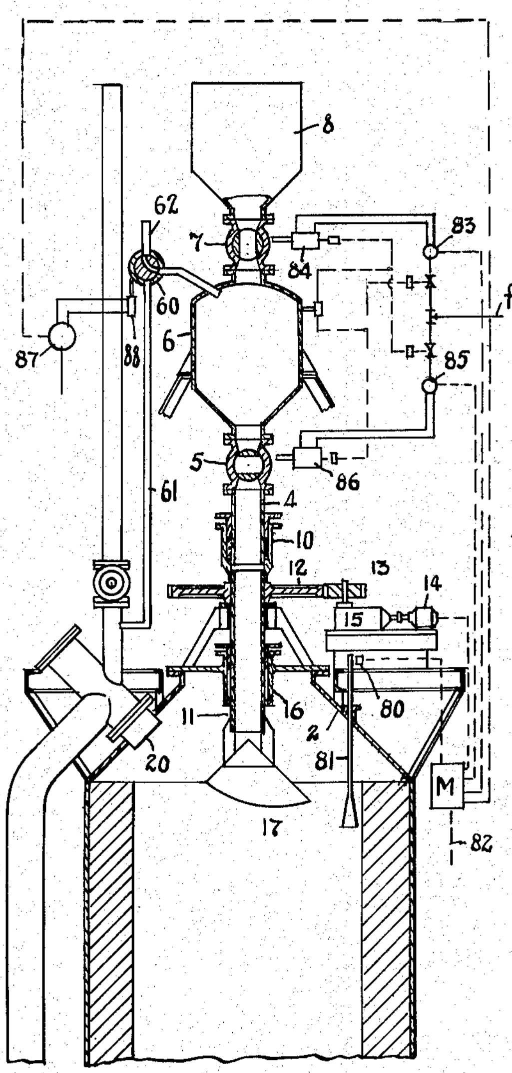

Fig. 2

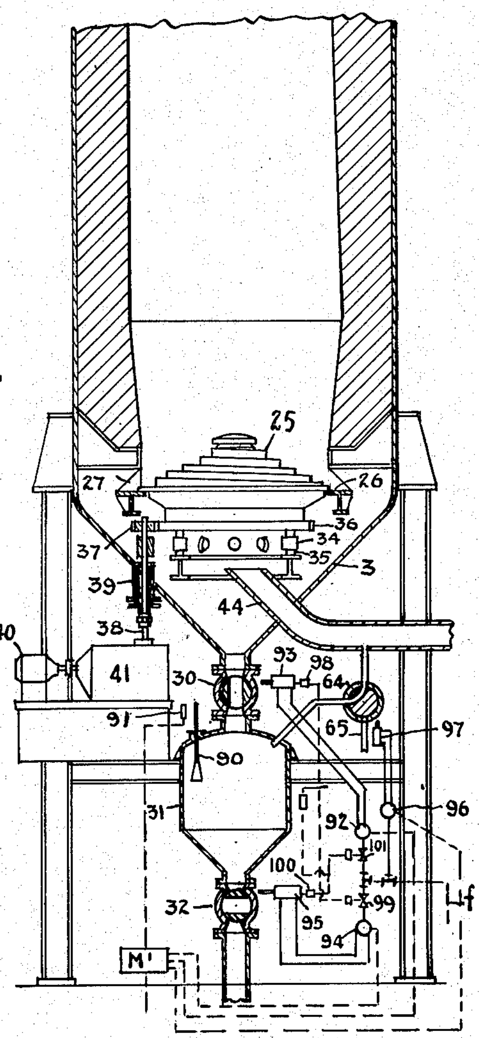

Fig. 3

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CALCINING APPARATUS

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5 Claims. (Cl. 263—29)

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This invention relates to calcining apparatus, and in its more specific applications to kilns for burning limestone, dolomite, and the like.

Commonly, lime kiln apparatus takes the form of a vertical shaft construction operating at substantially atmospheric pressure, the exit gas from the top passing off to compressors which are ordinarily required to assure draw-off and raise the pressure sufficiently to be applied in various usages. Where the fuel is charged in admixture with the limestone, it is customary to provide combustion air by a blower connection at the bottom of the kiln. With such equipment, the burden of compressing the outlet gas is considerable, and there are difficulties with compressors which have to operate on gas containing sulphur dioxide and on gas which even after going through a scrubber deposits substances on cylinder heads and valves and gives rise to unduly heavy maintenance and repair costs. In accordance with the present invention, a construction is had in which the calcining operation can be conducted under pressure, and allow the outlet gas to accordingly proceed at desired pressure without compressor requirement, and such as to be thus directly available for desired uses. All of the compressor action required is positioned at the air-supply inlet, and by this the operating pressure for the kiln and the outlet pressure of the gas may be controlled. Other objects and advantages of the invention will appear from the following description.

To the accomplishment of the foregoing and related ends, the invention, then, comprises the features hereinafter fully described and particularly pointed out in the claims, the following description and the annexed drawings setting forth in detail certain illustrative embodiments of the invention, these being indicative, however, of but a few of the various ways in which the principle of the invention may be employed.

In said annexed drawings:

Fig. 1 is a side elevational view partly in section, showing one embodiment of the invention;

Fig. 2 is an enlarged sectional view of the charging and gas-lock end of the structure; and

Fig. 3 is an enlarged sectional view of the discharge and air-lock end of the construction.

In general, the construction involves an elongated container K capable of withstanding the desired high gas pressures as well as the load of stone, and it may comprise a steel shell lined with refractory brickwork and having a conical top 2 and conical bottom 3.

Mounted in the top 2 is a conduit for inlet of material, and which, as shown in Fig. 2, may involve a stationary pipe 4 with a valve leading from the charging hopper 6, which in turn through a valve 7 communicates with a collecting hopper 8. The lower end of the pipe 4 sets in a stuffing box 10, and in relation with a sleeve 11 which is rotatable and connected with the gear 12 driven from pinion 13 by the drive motor 14 and gear reducer 15. The sleeve 11 is mounted with suitable thrust and journal bearings, and where passing through the top of the cone 2 has a stuffing box 16. Carried by the lower end of the rotatable sleeve is a material distributor 17, which may be in the form of a cone with an extension laterally whereby in revolution the material falling upon the apex of the cone from the sleeve 11 is distributed around across the entire top surface of the bed in the kiln. In small kilns such distributor is not required.

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The exit gas, carbon dioxide, is taken off through the outlet 20 and thence proceeds through conduit 21 to desired cleaning means, as for instance a scrubber 22, and thence by conduit 23 to a desired point of storage or usage.

From such construction, it is seen that the top of the calcining chamber, while permitting free outflow of the gas, may receive feed of material. And, to further prevent interference with the gas pressure, the charging hopper 6 is provided with gas-lock means, involving the outlet valve 5 and the inlet valve 7, and by operation of these valves in alternation, the valve 5 being closed when the valve 7 is opened, and vice versa, the desired high operating pressure may be maintained in the kiln.

At the bottom a rotatable discharge cone 25 having a spiral step surface, within a fixed annular platform 26, regulates the retention; and in the rotation of the cone the burned lime or other product is passed out through the annular opening 27 and falling down along the cone bottom 3, may be passed through the valve 30 to the discharge hopper 31, whose outlet is guarded by a valve 32. Here again, the inlet and outlet valves for this hopper are operated in alternation. When the valve 30 is opened, the valve 32 is in closed position, and vice versa. The cone 25 is desirably mounted on a set of rollers 34 on a raceway 35, and is driven by an attached ring gear 36 from a pinion 37 on a drive shaft 38 which passes through a stuffing box 39 in the cone bottom 3. The shaft 38 is driven, for instance, by a motor 40 and gear reducer 41.

Entering through the cone bottom 3 is a conduit 44 from a source of air under pressure, for instance a compressor 45 driven by a motor 46.

As apparent from this construction, high pressure air is supplied at the outlet end of the calcining chamber, and discharge of the calcined product may be carried on without interruption and without interfering with the maintenance of the operating pressure of the apparatus.

The material supplied to the calcining chamber may be provided by any suitable means. For instance, conveniently there may be a proportioning charge-former involving a crushed stone supply 50 and a fuel supply 51 feeding to a conventional weighing and mixing charger 52, and thence to a skip-hoist bucket 53 which is controlledly drawn to the top of its frame and dumped into the collector hopper 8. As seen, the material calcined may be of various character, and most commonly, for instance, may be considered as limestone, dolomite, and the like. The fuel may be any suitable solid carbonaceous fuel, for instance, coke. In the customary operation of lime burning by admixed fuel and combustion at substantially atmospheric pressure, the stone which is fed, and the fuel, must be in large size, not less than two inches, to permit adequate draft. With the present construction, however, on the contrary, the dimension of the material fed may be very much smaller, and with very material advantages. Thus, stone and coke sized to less than one inch is readily operated. With the supply or collecting hopper 8 provided with the desired stone and fuel, the valve 7 is opened (the valve 5 of course being in closed position as normal) and the charge is run into the hopper 6, whereupon the valve 7 is closed and the valve 5 is opened, and the motor 14 being in operation turning the cone or distributor 17, the material is fed down into the calcining chamber. When the chamber is filled and in stable operation, with high pressure air being forced in from the compressor 45, and combustion proceeding in controlled condition, the calcining chamber as a whole presents three zones of action. In the bottom zone D, Fig. 1, the material coming to the discharge cone is the calcined lime or other product, the fuel having been all burned out, and this highly heated product is passing down countercurrently to the flow of incoming air under pressure, the calcined product being thereby progressively cooled down such that it comes to final discharge at a relatively cool temperature, the heat having been transferred from the product to the air such as to heat it up to the combustion point for the middle or combustion zone C of the chamber. Here, the fuel is actively burned, directly in contact with the stone, and the carbon dioxide which is disengaged passes on up through the advancing charge, thereby imparting its heat such that when the charge comes to the combustion zone, it is at combustion temperature, while the gas passing out through the outlet 20 is relatively cool. It is seen from this that the heat efficiency of the construction is very high, substantially all the heat of combustion being used in the calcining, and without wastage in the discharged product and gas.

Desirably, a device responsive to the top level of the material in the kiln K, such as an indicator test rod 81 riding on the top of the mass in the calcining chamber, may actuate suitable electric switch mechanism as available commercially to operate in sequence the valves 5, 7, and 30, 32, and the drive motor 14, as referred to more in detail hereinafter. A schedule in which the drive motor 40, however, operates the discharge continuously is desirable, as such uniformity insures against unevenness of movement through the kiln; and thereby possible trouble from hanging or arching of the kiln contents may be obviated. In such operating cycle also, as a part of the refinement the pressure in the charging hopper 6 may be gas-equalized, and thus when the valve 7 is closed on a charge in the hopper, a gas-feed valve 60 supplied by pipe 61 from the gas outlet, may introduce gas to the hopper 6 in equalization with that of the kiln pressure, the valve 60 being then vented to the outlet 62 as the communication to the hopper 6 is closed. In similar manner, in the cycle, when the hopper 31 is filled from the valve 30 and the valve 30 is closed, the valve 64 is opened to introduce air from the conduit 44 into equalization of pressure, the valve 64 being then closed, with venting to outlet 65, all as referred to more in detail hereinafter. Electrically operating relay controls are known and commercially available.

The actual pressure selected for operation is determined to quite an extent upon the pressure desired for the carbon dioxide gas at its point of usage. Economic considerations also enter. Illustratively, a pressure of 60 lbs. p. s. i. abs. may be mentioned, but obviously it may be greater or less as desired. Apparatus thus operating under pressure results in many advantageous features. The cost of compressor power is reduced, inasmuch as compression of exit gas as customarily practiced involves more power than that required to operate the air compressors in the present apparatus, and, besides, there is a very substantial saving in that whereas compressors operating on kiln discharge gases are subject to rapid deterioration, the compressor here operating on clear air is subject to no such disability. Again, whereas under common practice the stone to be calcined must be of two-inch size or more, with the present apparatus much smaller size stone, and fuel, is desirable, and since the pressure drop of gases flowing through a bed of broken solids is proportional to the density of the gas and to the square of the gas velocity, with the total pressure as here raised, the over-all effect is to lessen the pressure drop, and since the pressure drop or loss is also inversely proportional to the size of the stone, it is to be seen that for a kiln operating at 60 lbs. abs. pressure, stone one-quarter the size of that for a kiln operated at atmospheric pressure can be used, and yet the power required to force the air and gases through the kiln is low. The size of stone could in fact be down to one-sixteenth that for the conventional atmospheric pressure operation. With the ability to use smaller size stone, there is also an improvement in the uniformity of lime burning, reducing the amounts of unburned cores and over-burned stone. To provide the best conditions for the radiation of heat from the burning fuel to the stone, the kiln charge should contain approximately one piece of fuel for each piece of stone, and with the small sizes of material applicable in the present apparatus, a saving in fuel cost is had, since coke costs decrease with the particle size, and here even coke breeze can be used, this being of low-cost particularly, in contrast to lump coke. The capacity or the tonnage of stone that can be calcined in a given kiln volume depends on the stone surface area and on the weight of air and gases flowing through it. With operation under pressure and small stone size, the stone area per volume is increased, thereby increasing the heat transfer rate from the gases to the stone and increasing the capacity throughput of the kiln. Independently of the stone size also, the heat transfer rate between the gases and the stone, and between the calcined product and the incoming air is increased in pressure operation. The heat transfer rate and kiln capacity increase as the weight or mass flow for a given cross-sectional area is increased, and as the gas pressure is increased there is an increase in its density or mass per volume. For a given linear gas velocity and pressure-loss through the kiln, operating under pressure gives an increase in kiln capacity. The rate of combustion of fuel also increases with the pressure, being a function of the partial pressure of oxygen.

Also, with a kiln operating at high pressures, the volume and velocity of gases are reduced to a point where the smaller sized fuel can be used without being blown out by the gas. It will be realized that the maximum limiting rate of operation of a vertical type kiln, for a given cross-sectional area, would be reached when the gas flow (linear velocity) becomes so high as to carry the small solid particles out of the charge. By increasing the operating pressure and gas density, a greater amount of air and gas measured on weight basis (mass) can be made to flow through the kiln without danger of blowing the small solid particles out, and in this way the amount of fuel burned for a given cross-sectional area can be increased; also the heat transfer rate between the gas and stone and the burned lime and incoming air can be materially increased with increase of mass (weight) flow of gases per given cross-sectional area. In other words, even with the same size of stone as conventionally employed, if the operating pressure be increased it increases the capacity of the kiln.

As seen, a pressure kiln may be smaller in size for a given production, and with such reduction in size and external surface there is a corresponding reduction in heat loss therefrom, and correspondingly a decrease in fuel requirements to such extent. As the calcination of carbonates of calcium and magnesium follows closely the thermo-dynamic properties of boiling water, the temperature remaining constant during the calcination, and being a function of the partial pressure of the carbon dioxide, as the pressure and temperature of the carbon dioxide are increased, the heat required decreases, and pressure operation results in a corresponding decrease in fuel requirement. Since less air is required per ton of stone calcined, correspondingly the amount of nitrogen input is reduced, and the per cent of carbon dioxide in the exit gas is increased.

Since a calcining apparatus on the lines of the present construction is capable of forwarding its contents at a much more rapid rate than the customary type of apparatus, centralized and automatic control becomes possible and is of particular value. Thus, a master controller M, Fig. 2, and which can be a relay set of electric switches or a "program" switch consisting of a motor-driven cam shaft with cams set to operate successive switches in sequence and timing, all as commercially available, may be applied, such that as initiated by a contact **80** in association with the stone-level indicator **81** riding on the top of the material in the kiln, will first, through electrical connection **82**, start the stone and coke proportioning feeders **50**, **51**, and the skip hoist **53** to bring material to the hopper **8**, and in proper sequence then operate the electromagnetically actuated valve **83** to open the valve **7** by the fluid-pressure cylinder **84** (using air or liquid), the valve **5** being in closed position as controlled by electromagnetically actuated valve **85** and the fluid-pressure cylinder **86**; and in relation, the electromagnetically actuated valve **87** is also controlled to vent the valve **60** by the fluid pressure cylinder **88**. By such sequence it is seen that the valve **5** is opened to the calcining chamber. In every phase of operation, the valves **5** and **7** are in such sequential control that they cannot be both opened at the same time but operate in alternation, thereby eliminating danger of accident. The master controller M also in its sequence puts the drive motor **14** into action when the valve **5** is opened, so as to operate the distributor **17** as the material flows down from the charging hopper **6** through the valve **5** to the calcining chamber. Analogously, the lime-level indicator **90**, Fig. 3, riding on top of material in the discharging hopper **31**, actuates a contact **91** to start a master controller M', which may be of similar character as the controller M, to sequentially operate the electromagnetically actuated valve **92** for the fluid pressure cylinder **93** to open the valve **30**, the valve **32** being closed through the action of electromagnetically actuated valve **94** and fluid-pressure cylinder **95**; and in relation, the electromagnetically actuated valve **96** and its dependent fluid pressure cylinder **97** opens the three-way valve **64** preliminarily to the opening of valve **30** so that air pressure from the conduit **44** may equalize the discharge hopper **31** to the calcining chamber pressure before the valve **32** is opened. After the hopper **31** is filled through the open valve **30**, the controller M' in the further phase closes the valve **30**, thereby shutting off communication to the calcining chamber, and then vents valve **64** to the atmosphere vent pipe **65**, and then finally opens the discharge valve **32** to allow the calcined product to discharge. The operation of the master controller here again is such that the valves **30** and **32** are never opened at the same time, but always in alternation, thereby preventing accident. In further detail, the fluid-pressure cylinder **93** for the valve **30** has a limit switch **98** arranged to close an electric circuit to actuate solenoid valve **99** into open position when the valve **30** reaches its closed position; and similarly the fluid pressure cylinder **95** for the valve **32** has a limit switch **100** to close the electric circuit to set solenoid valve **101** into open position when valve **32** reaches closed position. The operating fluid for the fluid pressure cylinders is supplied through pipe *f*. The fluid pressure control to the cylinders **84**, **86**, Fig. 2, is analogous, each of these cylinders having its limit switch like those of cylinders **93**, **95**, and the pressure fluid being supplied through pipes *f'*.

A thermostat *t*, Fig. 1, in the gas space at the top of the calcining chamber, actuates an electric controller *e* which regulates the speed of the motor **40** and thereby regulates the rate of discharge from the bottom of the calcining chamber. A temperature-limit switch *s* in the kiln bottom is set to stop the motor **40** in the event that the kiln bottom temperature exceeds the maximum operating safe temperature for the lime-drawing mechanism.

The air-flow controller **68** for regulating the speed of the motor **46**, thereby maintaining the required quantity of air and so regulating the rate of lime and kiln gas production, may be of diaphragm or other type commercially available.

A temperature-limit switch *v*, Fig. 1, in the gas space at the top of the calcining chamber, is set to stop the motor 46 in the event the kiln top temperature exceeds a maximum safe operating temperature at the gas outlet.

In the valve-control arrangement as noted, it is seen that the charging hopper 6 always has its pressure preliminarily equalized to that of the space with which it is to be put in communication; as the master controller M actuates the valve 87 and fluid pressure cylinder 88 to open the valve 60 to atmospheric-vent 62 and equalize the hopper pressure with that of the atmosphere and collecting hopper 8 before the inlet valve 7 is opened by control-valve 83 and fluid pressure cylinder 84, and again before the discharge valve 5 is opened to the calcining chamber the valve 60 is opened to the gas connection 61 and the calcining chamber, whereby the pressure in the latter is equalized into the hopper 6 and accidents from unequal pressures are avoided.

Similarly with discharge hopper 31 the master controller M' actuates the control-valve 96 and fluid pressure cylinder 97 to open the valve 64 between the compressed air pipe 44 and the hopper 31 before the valve 30 is opened to allow calcined product to flow in from the calcining chamber, and the valve 64 is opened between the discharge hopper 31 and the atmospheric-vent 65 to equalize the pressure to atmospheric before the outlet valve 32 is opened to discharge the product to the atmosphere.

Other modes of applying the principle of the invention may be employed, change being made as regards the detail described, provided the features stated in any of the following claims, or the equivalent of such, be employed.

I therefore particularly point out and distinctly claim as my invention:

1. In calcining apparatus having a vertical calcining chamber and a charging hopper therefor with an inlet valve and an outlet valve, a stationary outlet pipe from the outlet valve, a rotatable sleeve in communication for passing material into the top of said chamber, drive means for rotating said sleeve, a stuffing box between said sleeve and said pipe, a stuffing box between said sleeve and the calcining chamber, distributing means carried by the lower end of said sleeve for rotation therewith, said distributing means being within the upper end of the calcining chamber and continuously rotatable when the outlet valve is open for passing material to said chamber so as to evenly distribute the material within the chamber, discharge means at the bottom of the chamber, a discharge hopper below said discharge means having an inlet valve and an outlet valve, and means for supplying compressed air to the bottom of said chamber, said distributing means including a plate of cone-like form with the apex thereof pointing upwardly and with the bottom edge of the plate being spaced from the vertical axis thereof by amounts continuously varying around the bottom edge.

2. In calcining apparatus having a vertical calcining chamber and a charging hopper therefor with an inlet valve and an outlet valve, a stationary outlet pipe from the outlet valve, a rotatable sleeve in communication for passing material into the top of said chamber, drive means for rotating said sleeve, a stuffing box between said sleeve and said pipe, a stuffing box between said sleeve and the calcining chamber, distributing means carried by the lower end of said sleeve for rotation therewith, said distributing means being within the upper end of the calcining chamber and continuously rotatable when the outlet valve is open for passing material to said chamber so as to evenly distribute the material within the chamber, discharge means at the bottom of the chamber, a discharge hopper below said discharge means having an inlet valve and an outlet valve, and means for supplying compressed air to the bottom of said chamber, said distributing means including a plate of cone-like form with the apex thereof pointing upwardly and juxtaposed to the outlet end of the sleeve, the axes of the sleeve and the cone-like plate being substantially coincidental so that the material passing from the sleeve is evenly distributed over the plate, and the bottom edge of said plate being spaced from the axis of the plate by amounts continuously varying around the bottom edge.

3. In calcining apparatus having a vertical calcining chamber and a charging hopper therefor with an inlet valve and an outlet valve, a stationary outlet pipe from the outlet valve, a rotatable sleeve in communication for passing material into the top of said chamber, drive means for rotating said sleeve, distributing means carried by the lower end of said sleeve for rotation therewith, said distributing means being within the upper end of the calcining chamber and continuously rotatable when the outlet valve is open for passing material to said chamber so as to evenly distribute the material within the chamber, rotary discharge means at the bottom of said chamber, said rotary discharge means including a cone-like member having the periphery of its base spaced from the chamber wall so as to define a passageway between the periphery of the cone-like member and the chamber wall for the discharge of the product, said cone-like member having its upper surface formed of a downwardly and outwardly substantially vertical, spirally stepped surface joined by a substantially flat upwardly facing spiral surface so as to control the discharge descent of the product during cooling of the product by the incoming air, a discharge hopper below said discharge means and having an inlet valve and an outlet valve, and means for supplying compressed air to the bottom of the chamber.

4. In calcining apparatus according to claim 3, said last recited means including an air inlet pipe the inner end of which is disposed below the center of said rotary cone-like member.

5. In calcining apparatus having a vertical calcining chamber and a charging hopper therefor with an inlet valve and an outlet valve, a stationary outlet pipe from the outlet valve, a rotatable sleeve in communication for passing material into the top of said chamber, drive means for rotating said sleeve, a stuffing box between said sleeve and said pipe, a stuffing box between said sleeve and the calcining chamber, distributing means carried by the lower end of said sleeve for rotation therewith, said distributing means being within the upper end of the calcining chamber and continuously rotatable when the outlet valve is opened for passing material to said chamber so as to evenly distribute the material within the chamber, discharge means at the bottom of the chamber, a discharge hopper below said discharge means having an inlet valve and an outlet valve, and means for supplying compressed air to the bottom of said chamber, said distributing means including a plate of cone-like form with the apex thereof pointing upwardly and with the bottom edge of

the plate being spaced from the vertical axis thereof by amounts continuously varying around the bottom edge, and material-height sensitive means in said discharge hopper operable to admit equalizing air pressure from the calcining chamber, then to open said inlet valve to the discharge hopper to fill the latter with the material from said chamber, and then to close said inlet valve to the discharge hopper and vent the discharge hopper to the atmosphere and finally to open the outlet valve of said discharge hopper.

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