Sept. 29, 1953 V. J. AZBE 2,653,809

KILN

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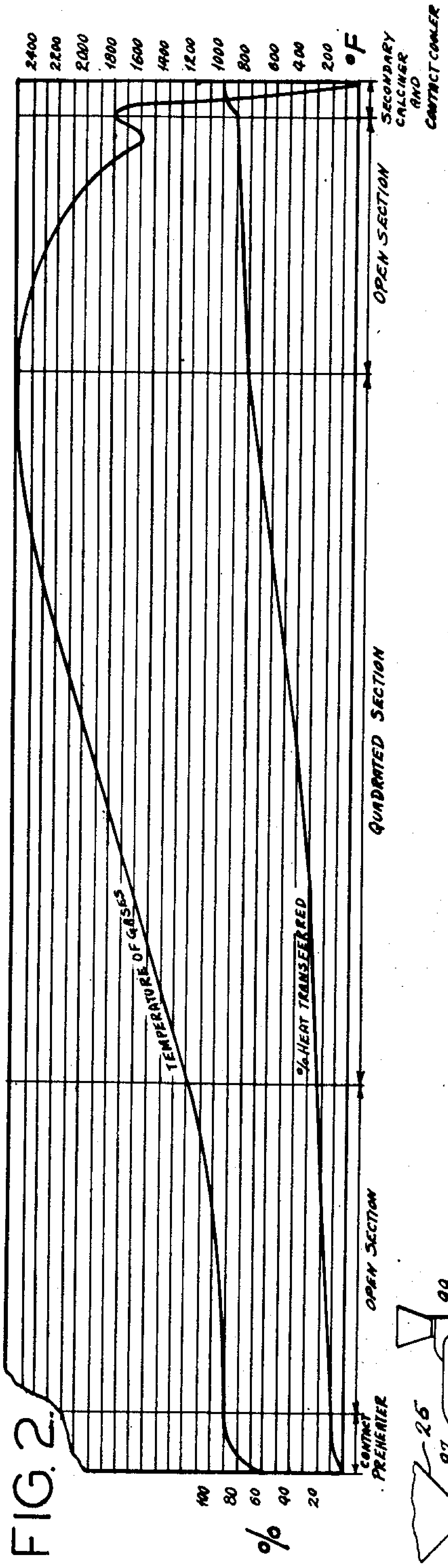

FIG. 2

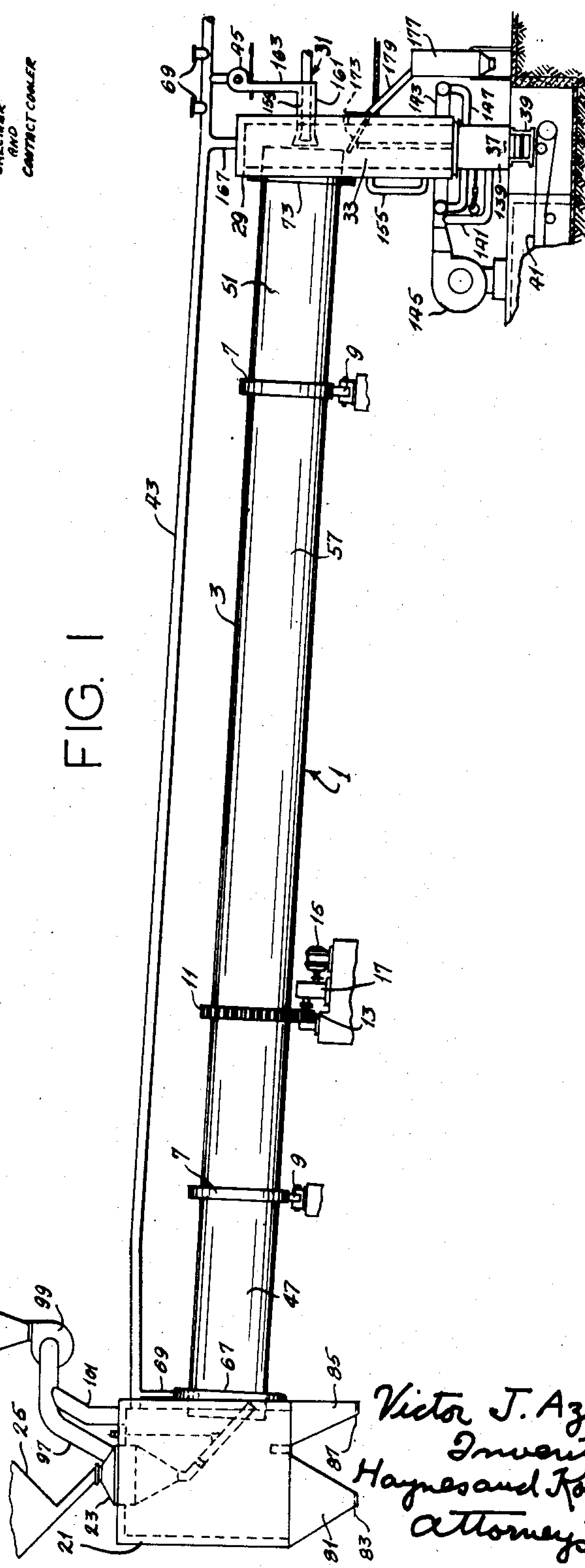

FIG. 1

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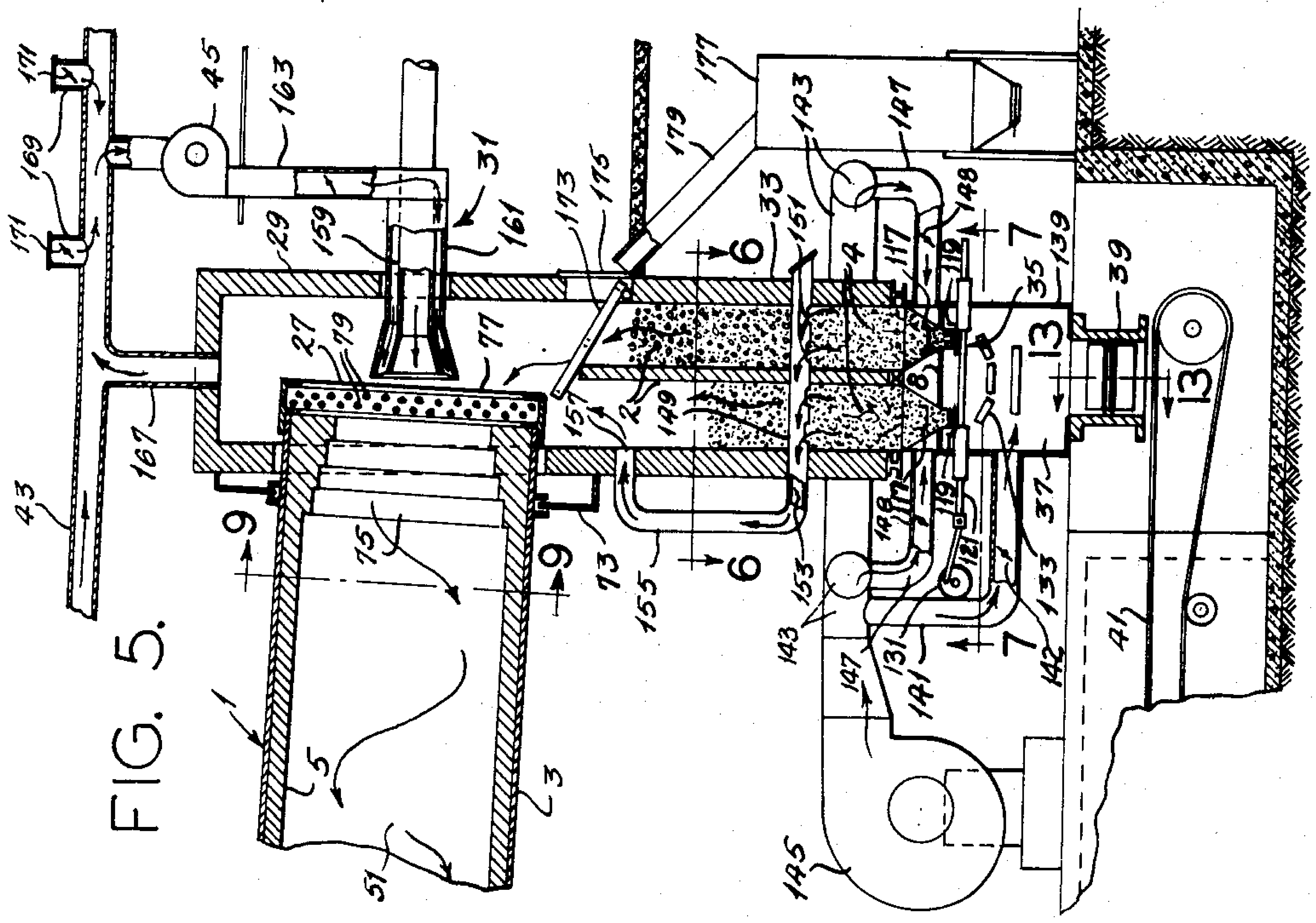

FIG. 5.

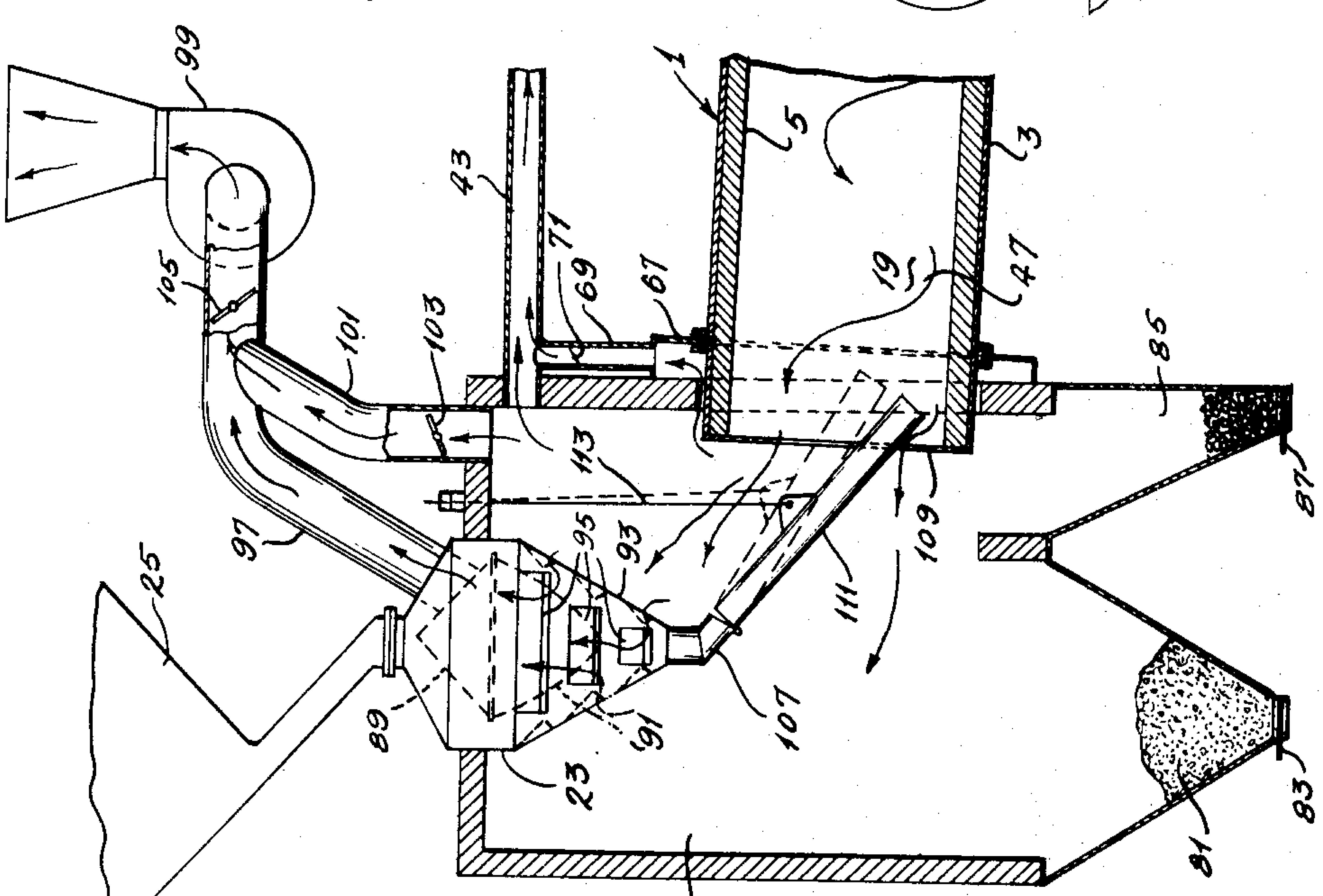

FIG. 3.

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FIG. 4.

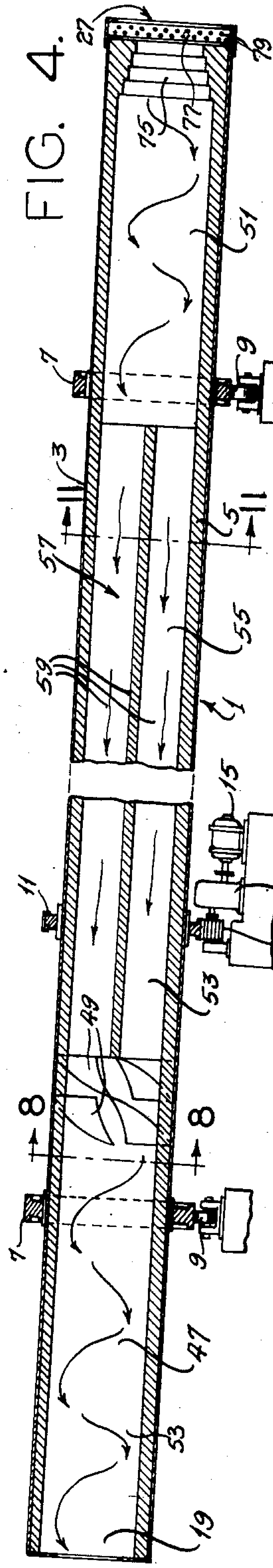

FIG. 7.

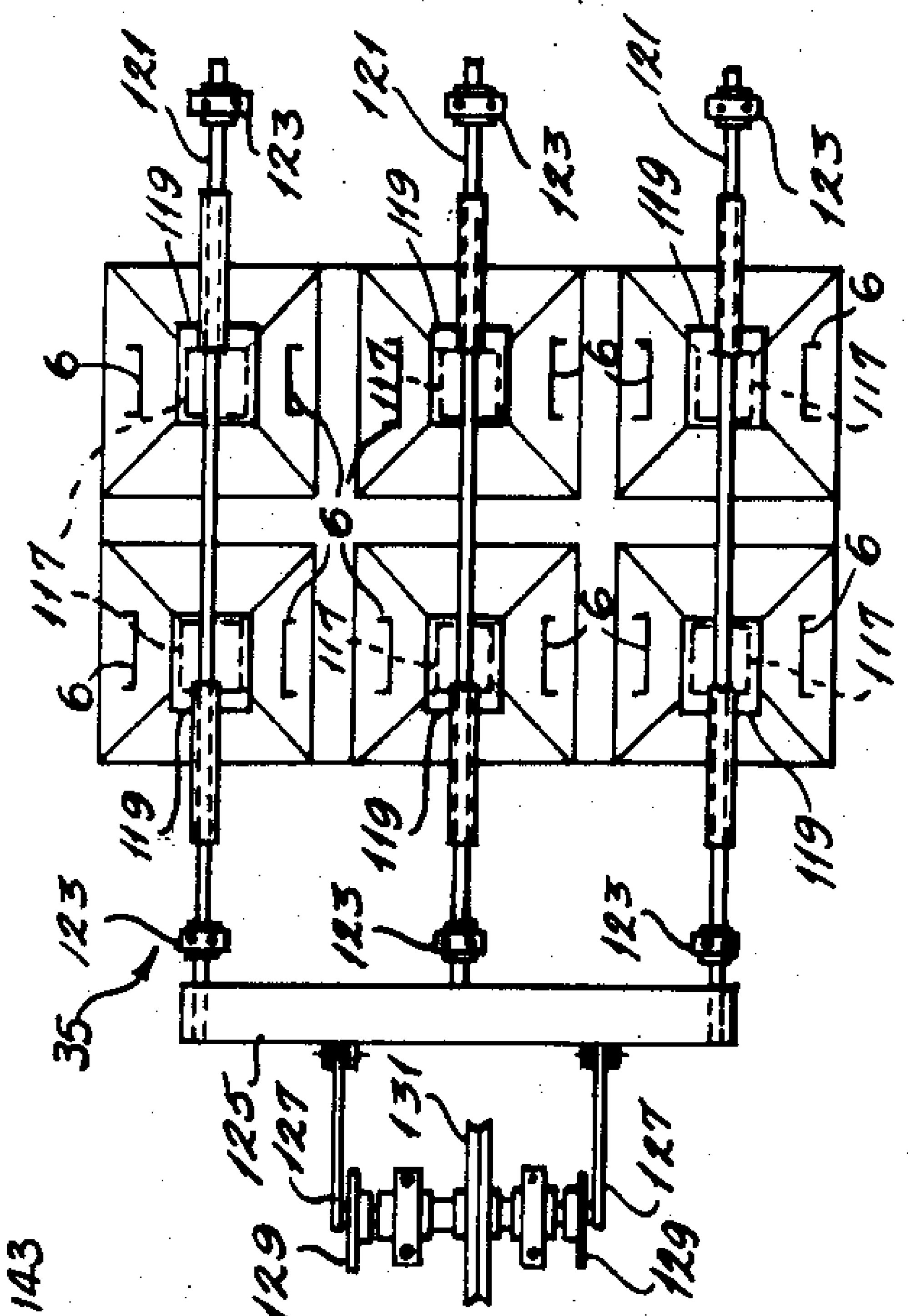

FIG. 6.

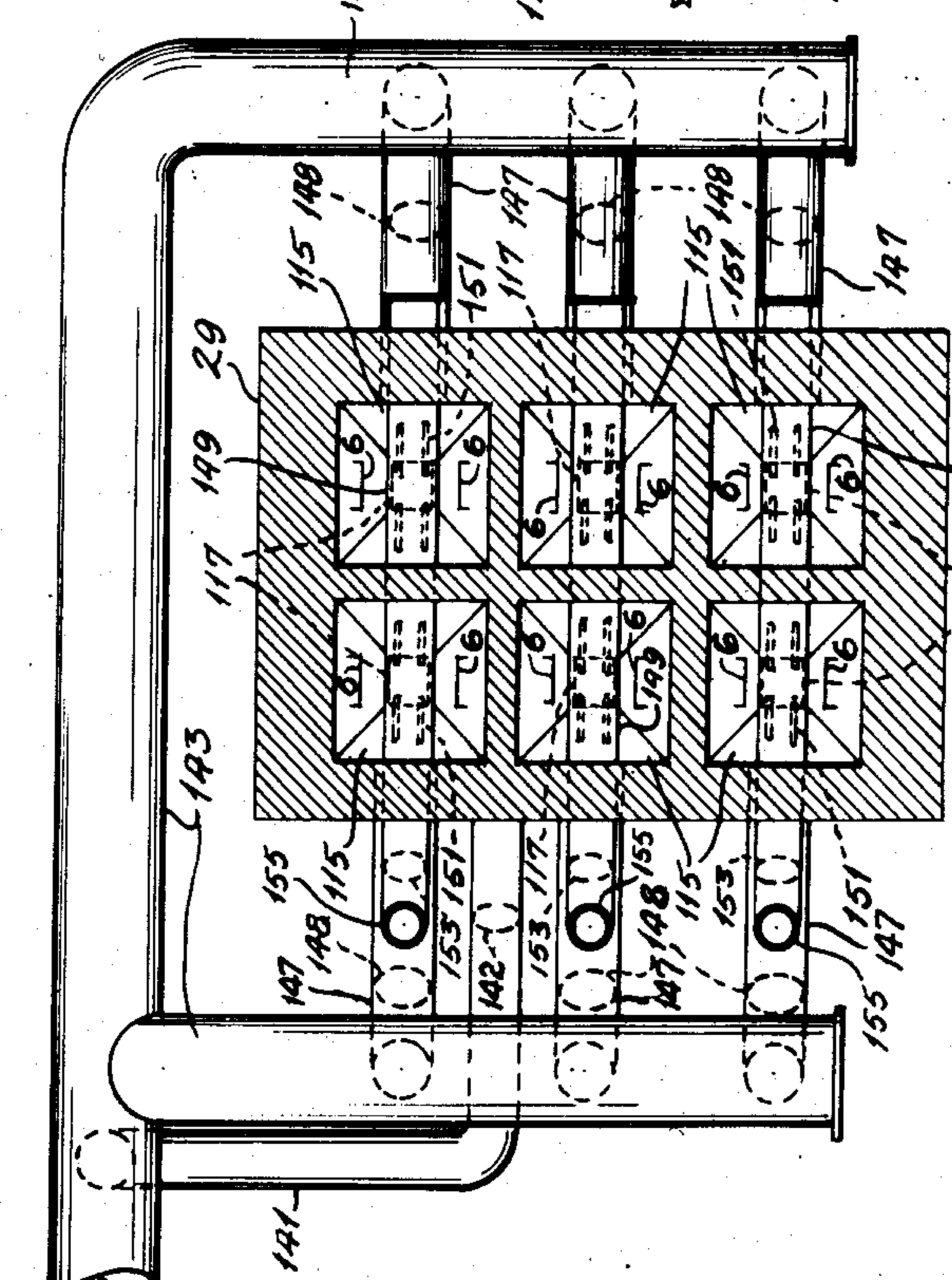

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FIG. 8.

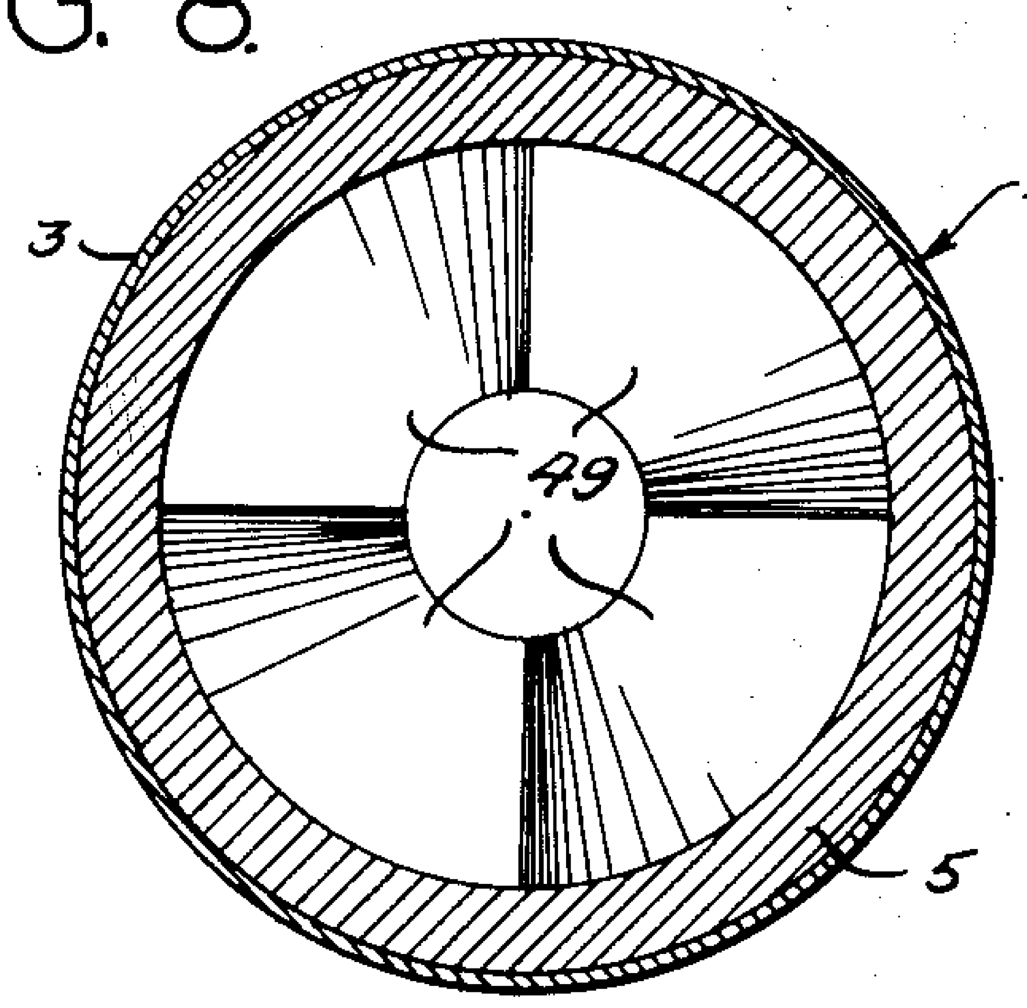


FIG. 9.

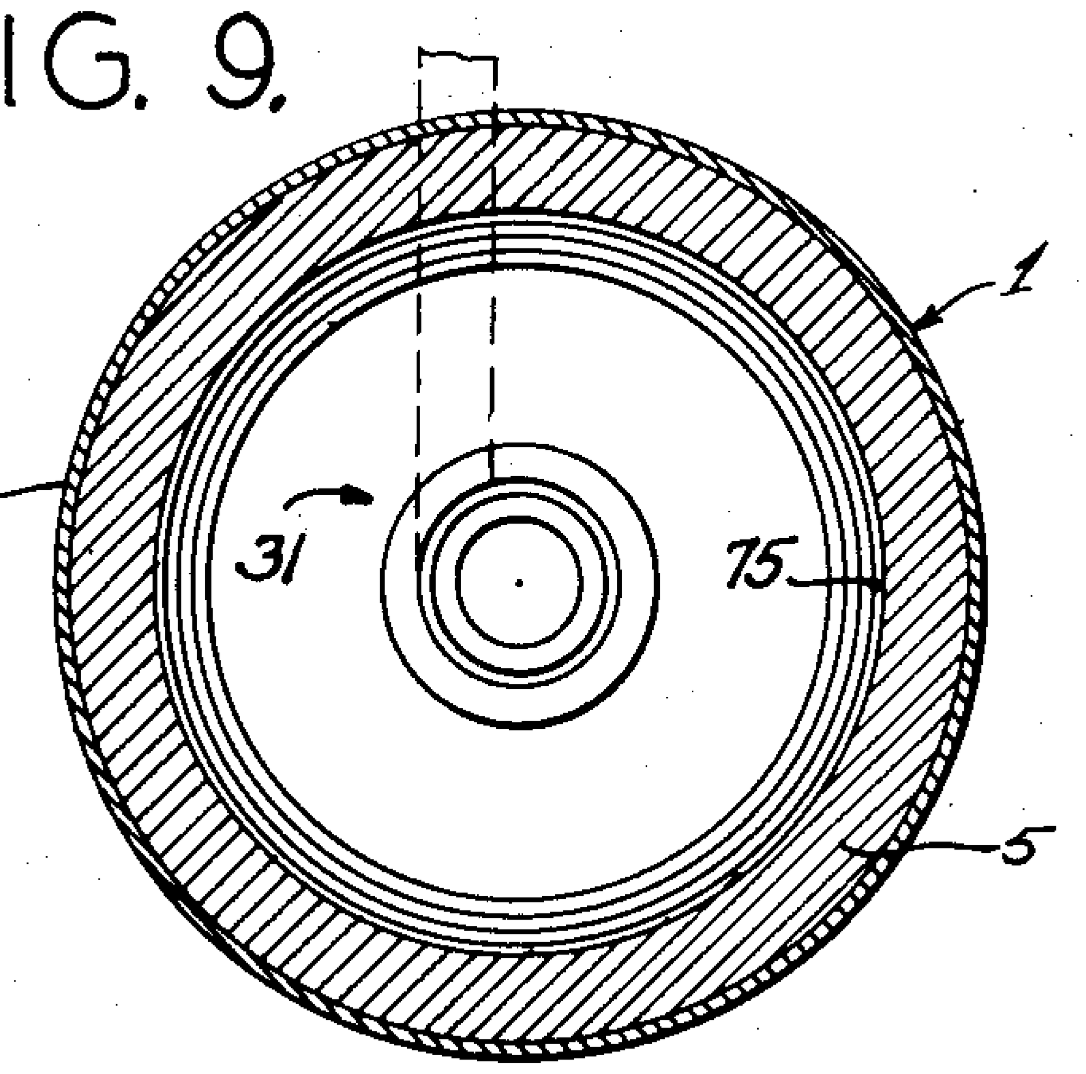


FIG. 10.

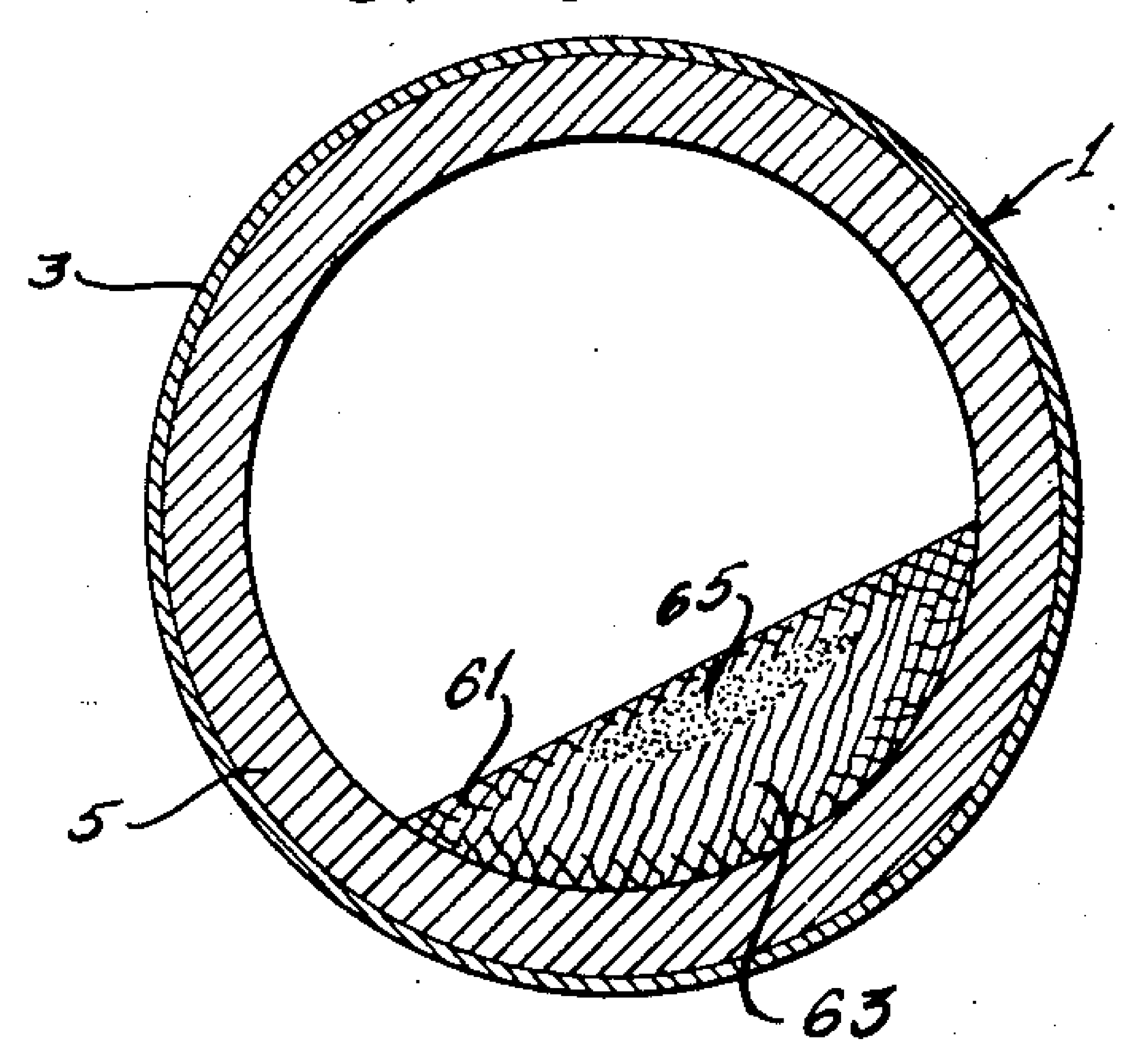


FIG. 11.

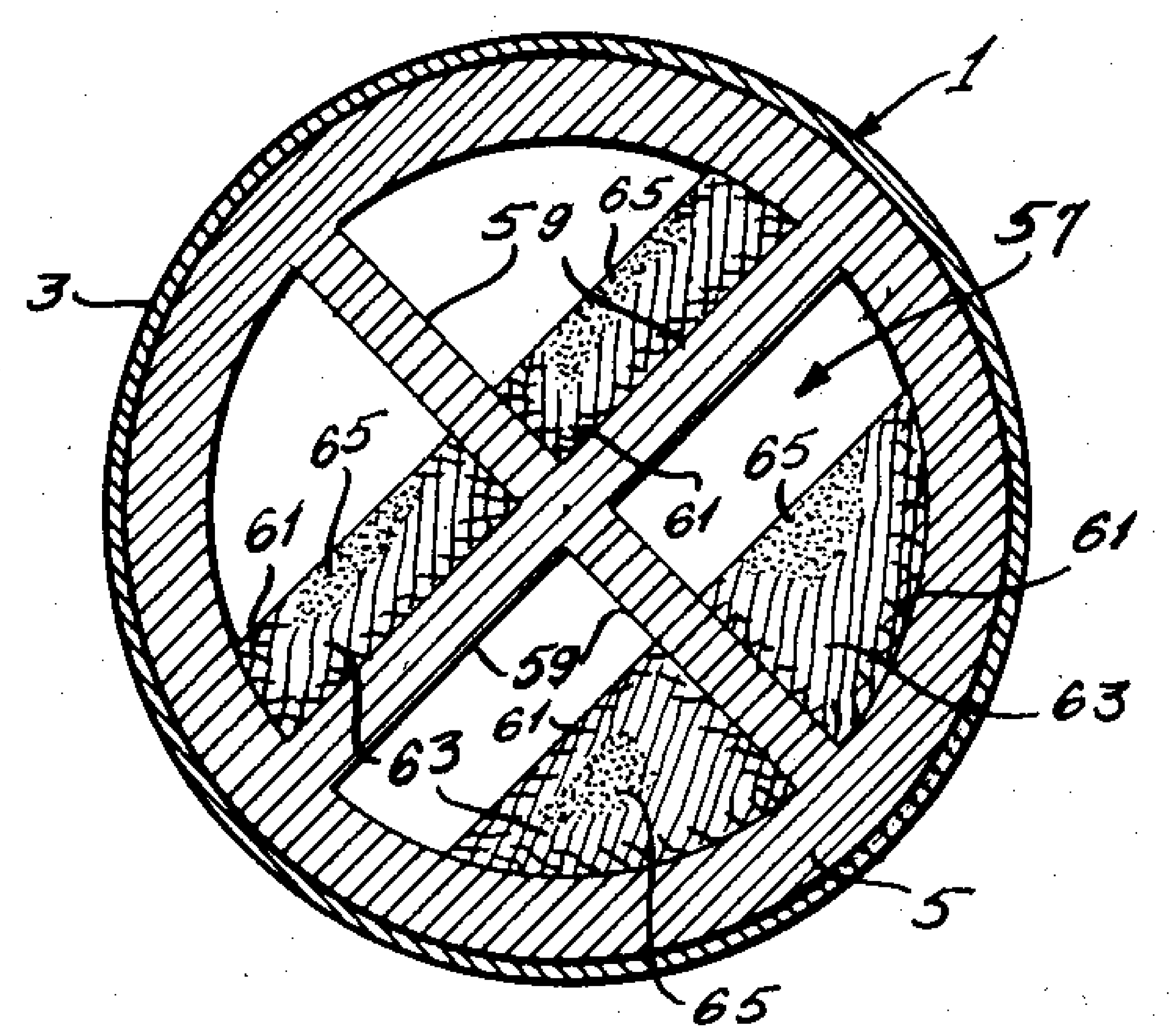


FIG. 12.

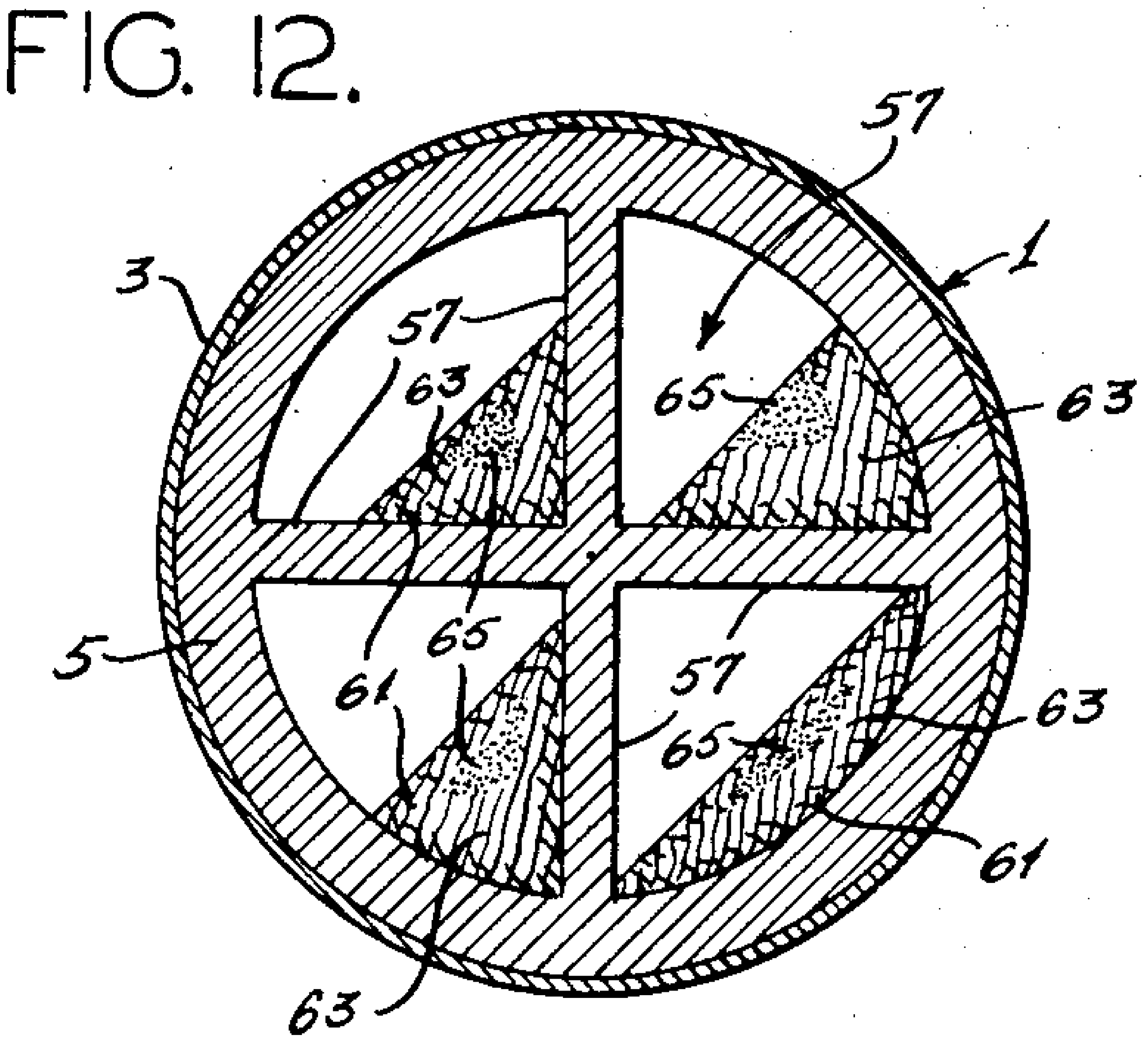
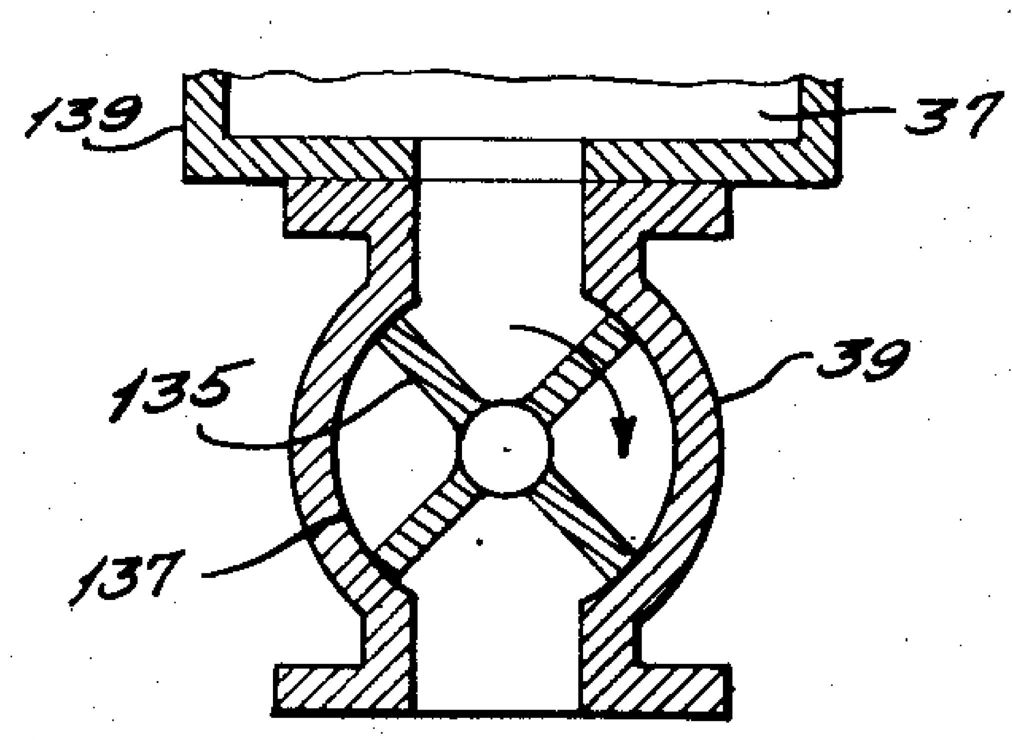


FIG. 13



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UNITED STATES PATENT OFFICE

2,653,809

KILN

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Application July 23, 1949, Serial No. 106,376

7 Claims. (Cl. 263—32)

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This invention relates to kilns, and more particularly to rotary kilns for burning lime, cement, magnesite, et cetera.

Briefly, the invention comprises the combination of a rotary kiln element (including endwise circular sections and a longitudinally sectored part extending into the calcining zone) with a combination stone preheater and dust collector at the inlet; a stationary shaft at the outlet comprising a finishing and a cooling zone; and firing means at the outlet of the rotary element which includes recirculating heat recuperator means supplied both from the inlet and from the stationary shaft. The invention also includes improvements per se in the constituent elements of the stated combination. By means of the invention, a smaller-sized kiln of lower first cost and upkeep may be employed for a given capacity operating at a much higher thermal efficiency and at a considerably lower temperature peak than heretofore. The lower temperature peak allows for more effective heat insulation without incurring refractory failure, scale adhesions and ring problems in the rotary elements. The invention also provides a kiln of the rotary type which is more easily controlled and less critical in its stone size acceptance than was the case with prior rotary kilns and one in which the dust hazard usually associated with rotary kilns is reduced. Moreover, a superior but more economical product is obtained. Other features will be in part obvious and in part pointed out hereinafter.

The invention accordingly comprises the elements and combinations of elements, features of construction, and arrangements of parts which will be exemplified in the structures hereinafter described, and the scope of the application of which will be indicated in the following claims.

Fig. 1 is a diagrammatic side elevation on a reduced scale, showing the invention in gross;

Fig. 2 is a chart of gas temperatures (upper curve) and per cent of heat transferred from gas to charge (lower curve), being longitudinally related to Fig. 1 so as to indicate conditions throughout the kiln;

Fig. 3 is a detailed axial section of the left end inlet portions of Fig. 1, showing a stone contact preheater and dust collector;

Fig. 4 is a detailed axial section (parts being broken away) illustrating the intermediate rotary portion of the kiln;

Fig. 5 is a detailed axial section of the right-hand portion of Fig. 1, showing certain firing, finishing and recuperating cooling apparatus;

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Figs. 6 and 7 are horizontal sections taken on lines 6—6 and 7—7, respectively, of Fig. 5;

Fig. 8 is a cross section taken on line 8—8 of Fig. 4;

Fig. 9 is a cross section taken on line 9—9 of Fig. 5;

Fig. 10 is an illustrative cross section of certain prior open-type rotary kilns, showing the usual stratification of charge therein;

Figs. 11 and 12 are views similar to Fig. 10 except that they illustrate corresponding conditions at successive angles of operation in the rotary kiln elements employed in the invention, being taken on line 11—11 of Fig. 4; and,

Fig. 13 is a detailed section taken on line 13—13 of Fig. 5.

Similar reference characters indicate corresponding parts throughout the several views of the drawings.

Referring now more particularly to Fig. 1, the board outlines of the apparatus will first be described. These comprise a sloping rotary drum section 1, consisting of a steel tube 3 lined with refractory and heat insulating material 5. This tube 3 is carried by rings 7 riding on supporting rollers 9. This drum also carries a ring gear 11 driven by a pinion 13, the latter being driven from a motor 15 through a speed-reduction gear box 17.

At the upper open inlet end 19 of the drum 1 is located a heat economizer and dust chamber 21. In the dust chamber is a stone preheater cone 23 which receives stone or like material to be burned from a bunker 25. The stone finds its way from the bunker 25 through the preheater 23 to the open end 19 of the drum 1, in a manner to be detailed below.

At its opposite or lower end, the drum 1 has an outlet 27 leading into a firing hood 29, surrounding a burner assembly 31. The firing hood forms the top of a vertical shaft 33 constituting (Fig. 5) an upper finishing zone 2 and a lower cooling zone 4 through which passes the not quite finished discharge from the drum 1. The finally finished and cooled product is finally discharged through a variable capacity feeder 35 to a pressurized outlet chamber 37 from which it escapes through an air lock 39 to an outside conveyor 41.

Recirculating heat economizer means in two parts are employed. One of these is the firing hood 29 which, as will be shown below, receives air that has been warmed in the cooling zone 4 of the shaft 33 but which by-passes the finishing zone 2. The hood also receives gases from the zone 2. The hood delivers its warm gases to the outlet 27 of the drum 1, these being injected into the drum by the discharge from the burner assembly 31. The second part of the recirculating system comprises a recirculating pipe 43 leading from the chamber 21 and to the burner assembly through a recirculating fan 45.

Details of the elements broadly outlined above are as follows, starting with the drum 1. This drum has an open section 47 near its upper outlet 19 wherein preheating takes place. The preheating zone is indicated at 53. At the other end of this open section are spiral fins 49 (see also Figs. 4 and 8). At the lower end of the drum 1 is a second open section 51, wherein fuel carburetion takes place. Between the fins 49 and the section 51 is a divided or quadrated section which includes a part of the preheating zone 53 and a calcining zone 55. The quadrating construction is indicated generally by the numeral 57 and is shown in particular in Figs. 11 and 12. It is constituted by cruciform refractory walls 59, which divide the section 57 into four axial sectors into which under rotation of the drum the charge is distributed by the spiral fins 49. The effect of these sectors upon the charge may be noted by comparing Fig. 10 with Figs. 11 and 12. Fig. 10 shows how a charge acts in an ordinary non-quadrated rotary kiln. As rotation takes place (anticlockwise) there is an anticlockwise rolling action applied to the charge. This causes the formation of an outer stratification of coarse particles 61, which in turn surround a stratification of mixed particles 63, which in turn surround a central stratification of fine particles 65. Thus the finer the particles are, the more they are blocked off from the reception of heat. Heretofore, high temperatures were required in rotary kilns applied for long periods in order to penetrate the stratifications in order to complete the calcining of the fine particles. The increased time needed required an increase in the length of the drum and the high temperatures precluded carrying any quadrating structure into the calcining zone. As demonstrated in Figs. 11 and 12, all of the categories of coarse particles 61, mixed particles 63 and fine particles 65 are tumbled, so that at some time or times during the rotary process they become exposed to radiant heat.

At its left end the drum 1 carries an annular end seal 67 with the dust chamber 21, the seal being provided with a negative internal pressure by bleeding to the recirculating duct 43 via a connection 69 wherein there is a control valve 71. At this end the drum also carries an inwardly directed stone spill dam 109. At its other (lower) end, there is also arranged a seal 73 between the drum 1 and the firing hood 29. At this point the refractory 5 is stepped inwardly to form a dam 75 beyond which is a nose ring 77. This ring is interiorly channel-shaped and may include openings or foraminations 79, to act as a classifier. However, this classifier function is not always necessary, in which event the nose ring is made without openings through its channel section.

Referring to further details of the dust chamber 21, it will be seen to include a dust hopper 81 at the bottom of which is a gate 83; also a stone-spill hopper 85 at the bottom of which is a gate 87. The preheater 23 is in the upper part of the dust chamber 21 and includes an internal spreader hood 89, which causes the rock entering from the rock supply bunker 25 to assume a surface of repose such as indicated at 91. This surface is within a conical portion 93, wherein are louvers 95 through which hot gases may enter the interior mass of stone. This spreads the rock over the louvers. These gases traverse the stone, which acts as a filter to settle much of the entrained dust. Heat is also transferred from the gases to the stone for initial preheating. The filtered gases are drawn off through an exhaust duct 97 which is connected to the spreader hood 89, being pulled off by an exhaust fan 99. A by-pass duct 101 connects the chamber 21 with the duct 97. Control dampers 103 and 105 are used in the ducts 97 and 101. It will be noted that not all of the gases leave the chamber 21 via pipes 97 and 101, but that some of them are drawn off over the hot gas recirculating duct 43. The function of this will appear.

At the lower end of the cone 93 is an outlet pipe 107 to which is pivoted a feed spout 111 controlled in position by adjustable suspension means 113. The spout 111 may take a lowered position shown in solid lines, or a raised position shown in dotted lines. In the lower position, the level of the stone in the open section 47 will be less than it is in the raised position, since when the level of the stone reaches the outlet of the feed spout, no more stone will flow until this level is reduced by the stone proceeding down the section 47.

Referring now to the details of the stationary shaft 33 at the lower opening outlet end of the drum 1, it comprises the firing hood 29 around the nose ring 77. Below the outlet of the drum 1 the shaft is constructed as shown in Fig. 6, wherein it is divided into six downwardly extending chambers 115 having tapered lower outlets 117. The exact number of these is optional. They are viewed from the bottom in Fig. 7. They carry air inlet louvres 6 and are surrounded by an air plenum chamber 8. Under the outlets 117 are doors 119 carried adjustably upon reciprocating bars 121, the latter being carried in bearings 123 and being joined by a crosshead 125. The crosshead 125, and consequently the rods 121 and doors 119, are reciprocated by connections 127 with cranks 129 driven from a suitable actuator 131. Thus through adjustment of the doors 119 on the rods 121 and the reciprocation of the rods, the finished material may be drawn from the respective chambers 115, thereby providing a variable capacity output for each of these. Below the outlets 117 is a conveyor belt 133 which delivers all of the material withdrawn from the chambers 115 to the outlet 39 from whence it is delivered to the belt 41 for delivery to storage. In the outlet 39 is an air lock as illustrated in Fig. 13, which consists of a rotary vane member 135 in a cylindric passage 137. This member upon rotation passes solid material out without permitting continuous flow of air. The reason for this air lock is that the outlets 117 are surrounded by an air-pressure plenum chamber 139 from which it is desired to allow air to escape only by passage through the openings 117 to the chambers 115 as the finished material shakes therefrom. This air is obtained through an air pressure connection 141 (in which is a control valve 142) with an air manifold 143 supplied by a cooling fan 145. The manifold 143 also has connections 147 (in which are control valves 148) which supply cooling air individually to the lower ends of the plenum chamber 8. This air enters the louvers 6 and cools the charges as they approach their outlet gates. As will be shown, it is desired to have a heat-soaking finishing operation occur at the upper ends of the chambers 115 and to have a portion of the cooling air by-pass the resulting finishing zone. This is accomplished by means of horizontal offtake pipes 149 across the passages 115 at an intermediate point thereof, each having lower openings 151 and a control valve 153. These pipes include risers 155 which are reconnected at points near the firing hood, as shown at 157. Thus the region below the pipes 149 constitutes a cooling zone and a substantial portion (but not all) of the air used in that zone by-passes the finishing zone above the pipes 149. The remainder passes through the finishing zone. All of the air finally enters the firing hood 29 and most of it is directly injected as secondary air along with fuel into the carbureting section 51 of the drum 1. Some is drawn off through the recirculation duct 43 via offtake 167, to be used as primary air in the burner 31.

The burner assembly 31 includes a flaring fuel nozzle 159 appropriate to the fuel being used, such as natural or artificial gas, oil, powdered coal, etc. This nozzle is surrounded by a flaring manifold jacket 161 supplied with hot recirculating gas over line 163. In line 163 is a recirculating fan 45 drawing hot gases from the recirculating duct 43. Thus both spent gases (from the dust chamber) and some air (from the firing hood) are delivered to the manifold 161 by the fan 165. Additional air for temperature control may be obtained from bleeders 169 controlled by valves 171. The flare of the burner provides a wide-angle entry of combustible into the drum 1, wherein it spirals to aid carburetion. If spiralling is not inherent suitable spiral baffles may be incorporated between the nozzle 159 and the manifold jacket 161. While the walls 59 stop spiralling action of the gases, it is reinstated the section 47 by the spiral fins 49. The flaring dam 75 cooperates with the flaring burner to carburet, and with the adjustable feed spout 111 maintains a desired level of material passing out of the drum 1.

Since some scale is encountered in the material leaving the drum 1, agitator grates 173 are provided, which screen out scale material and send it toward a clean-out door 175 for delivery to a suitable hopper 177 via chute 179.

Operation is as follows:

The drum 1 is rotated and the feed spout 111 adjusted to the depth of charge to be carried in the inlet section 47. Stone (or any similar material to be burned or calcined) leaves the supply 25 by gravity and is spread into the shape 91 (within the cone 93) by the spreader hood 89. Here it is preliminarily preheated by hot gases traversing it, while it acts as a dust filter for the gases. From here it descends the spout 111 and rotation of the drum 1 carries it down the slope of the open section 47 at the end of which it is picked up by the spirals 49 and distributed amongst the sector-shaped passages determined by the quadrating walls 59. During this stage the material is further preheated. It then proceeds down the walls, being tumbled and adequately brought to the surface at intervals, passing through the hot calcining zone (into which the walls 59 extend) and finally entering the open carbureting section 51. Its level is maintained by the elevation of spout 111 and the dam 75, over which it finally spills through the nose ring 77 and enters the finishing and cooling chambers 115. The finer portions may pass the openings of the nose ring and fall into the closest set of passages 115. Most of the remainder passes mostly to the remaining passages 115 and spalls are deflected by the grates 173.

In the above it has been assumed that the burner assembly 31 has been lighted. This injects fuel, air and recirculating gas into the carbureting section 51; also entraining air which has risen into the firing hood from the operations in the stationary shaft 33. Thus preheated secondary air, as well as preheated primary air, is obtained, along with injection of hot recirculating gases, the latter having the desirable effect of properly modulating combustion to avoid producing hot spots.

Referring to Fig. 2, it will be seen that the spent but hot gases passing through the entering rock in the cone 43 cause this cone to act as a preliminary contact preheater, the temperatures being of the order of 600° to 900° F. These spent gases have also had their preheating effect in the open section 47 as indicated by the chart. As the stone reaches the quadrated section of the drum 1, it enters a zone of higher preheat preliminary to calcining, in which the temperature rises until the calcining zone is reached. A large segment of this calcining zone is constituted by the quadrated section, the remainder being in the carburetting open section 51. The maximum temperature of 2500° F. or so is reached at the lower region of the quadrated section. In the open section 51 the temperature is high at the upper end but drops off rapidly toward the dam 75 due to the time required for the gases properly to mix and ignite in passing through the section 51. Since in a rotary kiln it is difficult to reach the ideal condition wherein all material is completely calcined before leaving the drum, I cause the material to be sent to the stationary shaft 33 for final finishing by a self soaking action supported by the heat carried in the material itself. Any unfinished nodules have their calcining finished by this soaking action. As indicated in the temperature chart, the final finishing is done with a high, but not the highest, temperature used in the process. Then as the finished material descends through the chambers 115, it encounters the cooling zone 4 below the pipes 149, wherein finishing action ceases, and heat is abstracted by the cooling air, the latter returning to the drum. This air by-passes the finishing zone 2 above the pipes 149 so as not to interfere with the heat-soaking action required in the finishing zone. However, some air is permitted to pass through the fiinishing zone to carry on the finishing process. Finally, the material reaches a position at the gates 119 where it is controllably shaken out into the pressure chamber 139, from whence it escapes through the air lock 39 to the conveyor 41. In order to maintain the temperature required in the chambers 115, these are properly heat-insulated.

The chart of Fig. 2 shows the percentage of heat transferred to finished material as progress is made through the apparatus. The largest gain in heat transfer occurs in the calcining zone into which the quadration of the drum 1 enters. Heretofore it has not been feasible to enter a calcining zone of a rotary kiln with any similar quadrating structure because of the destructive high temperatures used (about 3000° F.). In the present apparatus, the highest temperature is 2500° F., which is considerably below the usual practice in rotary kilns, and safe for available refractory and insulating materials. This reduction in temperature is made possible by the fact that the rotary drum element is not used entirely to complete the calcining operation, this being done in the stationary vertical shaft **33**, wherein, as the chart discloses, a substantial additional heat transfer is effected. The result is that the drum **1** may be made much shorter since retention time is shorter, which in turn reduces the rather large heat losses associated with long drums. Moreover, the temperature being lower since calcining is not driven to the limit in the drum, the heat radiating losses are much lower. The size of the apparatus for a given capacity is also reduced.

The ordinary rotary kiln requires in excess of 50 cubic feet of clear kiln volume per ton of capacity, and at times as much as 100 cubic feet. The present kiln requires only about 20–30 cubic feet of corresponding kiln space per ton of capacity. This considerably reduces the first cost, operating and maintenance cost, and radiation heat losses. In addition, the thermal efficiency is about doubled from about 30% to 60%.

Another advantage of carrying the quadrating section into the calcining zone within the drum is that during calcination a thorough tumbling action is obtained without stratification thus exposing all material to radiant heat. This permits the drum to accept a wider range of stone sizes than heretofore. Hence there is eliminated all the apparatus usually required for close sizing of stone heretofore required for rotary kilns.

Another advantage of the invention is that a substantial amount of preheating is done outside of the drum **1**, although some preheating is accomplished in the open section **47** and the upper part of the quadrated section. Preheating accomplished in the dust chamber by passage of the spent gases through the rock in the cone **93** is more efficient and, moreover, has the stated effect of reducing the escaping dust. It is to be noted in this connection that the spent gases pass through a limited and uniform stone-bed thickness, assuring proper gas distribution. It is to be noted in this connection that the by-pass pipe **101** is to take care of the condition encountered during shut down, when stone flow is interrupted. During such period the bed in the cone **93** may become choked with dust and the by-pass pipe **101** allows operation until active stone flow is again established.

One of the advantages of the use of the stationary shaft **33**, which acts as a secondary calciner, is the utilization of the sensible heat of lime which is discharged by the rotary drum to do additional calcination work outside of the drum. By means of the present invention, as much as 10% of the total calcination work can be accomplished in this secondary calciner, which 10% in the ordinary rotary kiln requires about 30% of the energy besides requiring large high-cost apparatus.

The purpose of the multiple chambers **115** in the shaft **33** is to prevent gaseous flow stratifications. By means of the separate chambers **115**, discharge, as well as air admission, can be independently controlled to avoid this difficulty.

Over all control is simple, both as to air supply and material withdrawal. Control of initial combustion temperatures is obtained either by controlling the mixture of air and combustibles, or controlling the amount of spent gas (CO_2) obtained from the recirculating duct **43**. Control over the luminosity of the flame is obtained by creating conditions conducive to cracking of hydrocarbon, that is, creation of stratified flow and retarded access of air to the combustible gases. However, the present kiln is less dependent on high luminosity of flame, since it contains an abundance of heat-absorbing surfaces.

In view of the high temperatures encountered in an ordinary rotary kiln, it is not feasible to insulate them; whereas with the relatively low temperatures used in the rotary drum herein, insulating material may be combined with the refractory lining of the drum **1** without danger of excessive deterioration due to high temperatures.

Air to the cooling zone **4** is regulated in accordance with the lime drawn, and air by-pass of the finishing zone above pipe **149** is regulated in accordance with the temperature of lime leaving the finishing zone. If additional air is needed for combustion in the drum **1**, this enters through the burner assembly **31** or leakage air at the kiln front induced by the general kiln draft created by the exhaust fan **99**. This draft is regulated by the thermal orifice established by the dam **109**, this being the choke, besides preventing rock spillage in the dust chamber.

In view of the above, it will be seen that the several objects of the invention are achieved and other advantageous results attained.

As many changes could be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

I claim:

1. In a kiln, the combination of a rotary primary calcining drum sloping from a combination material inlet and gas outlet to a combination material outlet and fuel inlet, means at the lower end of the drum adapted to drop calcined material into several different streams of partially calcined material, a stationary vertical shaft located at the lower end of the drum having means to determine said streams and having an upper hood enveloping the material outlet and the fuel inlet, said shaft having separate lower compartments adapted respectively to receive the different streams of material for further and individual secondary calcining and cooling, means for withdrawing individual streams of material from the individual compartments, means for introducing cooling air to the lower ends of said compartments, and means for extracting air from intermediate points of said compartments to establish a cooling zone and reintroducing said air into said hood whereby self-calcination may continue in the upper portions of said compartments, the gaseous product of calcination in said upper portions of the compartments and by-passed air and also fuel from said fuel inlet passing through the hood into said drum for primary tempered calcination in the drum in the presence of combustion of fuel.

2. A kiln made according to claim 1 including means for individually controlling said self-calcination in said compartments.

3. A kiln comprising a sloping rotary drum of constant diameter throughout for down-flowing material from an upper open end to a lower open end and for up-flowing gases from the lower to the upper end, means dividing only a mid-

portion of the drum into radially disposed sectors, the ends of which sectors are substantially spaced from the respective ends of the drum to provide unobstructed endwise drum lengths, a burner nozzle adjacent the lower end of the drum adapted to inject a combustible mixture into said lower end, the distance from said lower end of the drum to one end of the dividing means being substantial and sufficient to allow thorough mixing of said combustible mixture without interference from any sectors, in order to provide for efficient carburetion, the lengths of said sectors being sufficient to effect substantial calcination, the unobstructed drum length from the other ends of said sectors to the upper open end of the drum being sufficient to effect a substantial perheating of material approaching the sectors.

4. A kiln comprising a rotary drum having an upper combined material inlet and gas outlet, a dust chamber enclosing said outlet, a rock container in the dust chamber having a rock inlet from the outside and a rock outlet pipe leading into said drum, gas passages in the wall of the rock container for admitting gas from the dust chamber into the rock container independently of said rock outlet to the drum, whereby a substantial amount of gas may enter the rock container to pass through the rock to settle dust from the entering gas and to preheat the rock, said rock container having an outlet for said gas.

5. A kiln made according to claim 4, wherein said rock outlet pipe leading to the drum is movable in a manner to adjust the position of its outlet relative to the inside bottom of the drum.

6. A kiln made according to claim 4, wherein said gas passages consist of louvers in the rock container and wherein said rock container is of downwardly tapered form containing the louvers, and a spreader in the container adapted to

spread rock over the louvers in its passage to said outlet pipe.

7. In a kiln, a dust chamber having an opening, a rotary calcining drum having an end rotary in said opening and introducing hot gases into the dust chamber, a peripheral enclosure around said opening, circular running sealing means between said peripheral enclosure and the drum and axially spaced from said opening, and means other than said opening for drawing and leading off hot gases from said peripheral enclosure, hot gases being supplied to the enclosure by outward flow through said opening, whereby infiltration of cold outside air to the dust chamber is positively prevented.

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