

July 14, 1964

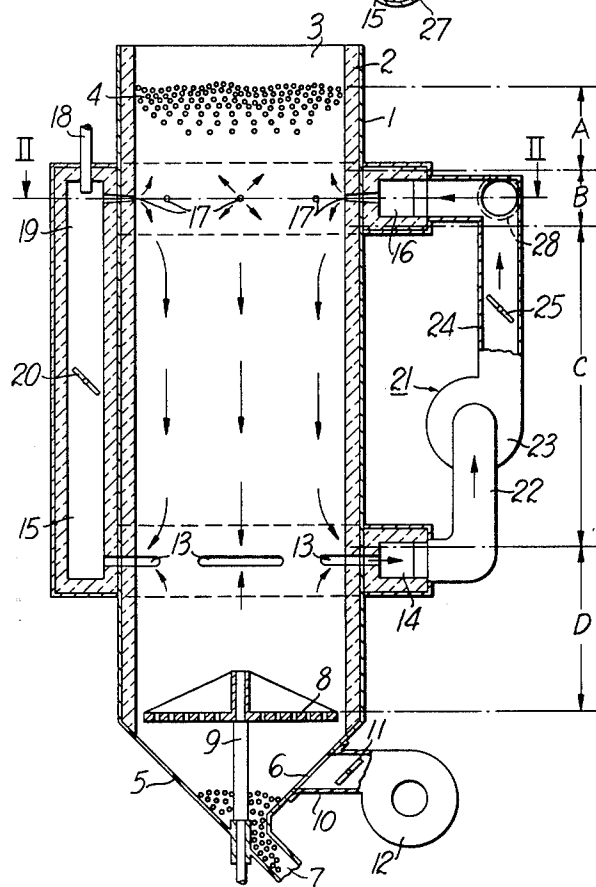
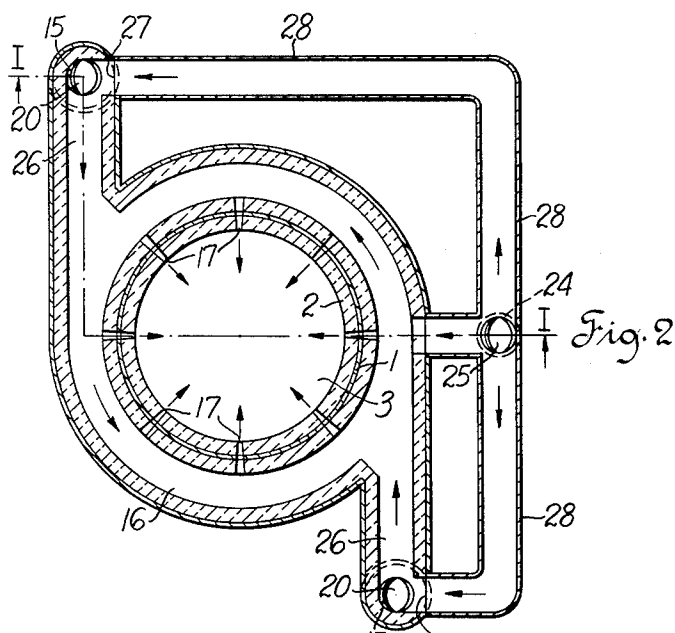
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3,140,864

SHAFT KILN

Filed Dec. 26, 1961

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

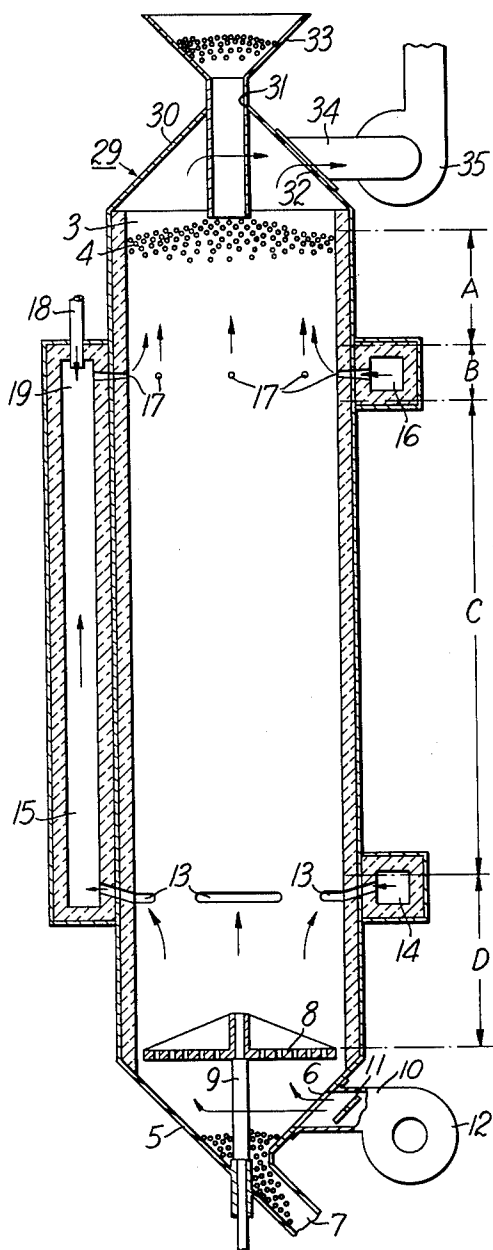


Fig. 3

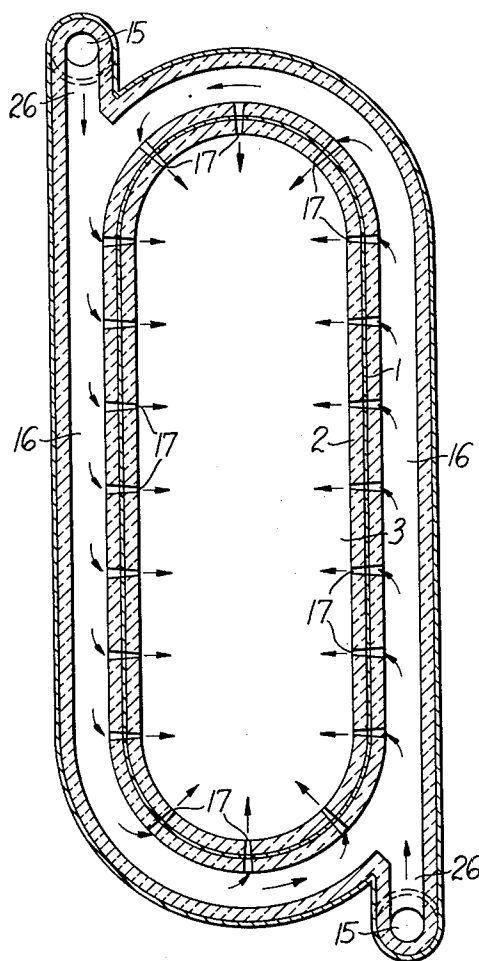


Fig. 4

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3,140,864
SHAFT KILN

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9 Claims. (Cl. 263—29)

This invention relates to shaft kilns particularly to shaft kilns used for sintering cement or similar materials.

One of the disadvantages of the shaft kiln when it is used for burning and sintering cement or similar materials is that the burned product may be of an uneven quality regardless of whether the raw material is introduced in a pelletized, briquetted or nonagglomerated state. This means that some of the material may be overburned and baked together into large lumps which often adhere to the wall of the shaft, thereby hindering the slow, regular descent of the material. Some of the material may also be discharged from the kiln in an underburned state. This is caused by the uneven distribution of the heating flame. Uneven burning also results when at least some of the burning takes place after the fuel is in the shaft because air rising through material of uneven gas permeability in the cooling zone provides an uneven air supply to support combustion.

Several approaches to eliminate this problem have been tried. One of these is to blow additional cold air under high pressure through nozzles in the side wall in order to force the hot gas deeper into the shaft and, if possible, into the center of the shaft, but a satisfactory equalization of burning especially in the sintering zone does not occur.

Another approach is to mix gas or oil with insufficient amounts of cold air, ignite the mixture in special chambers in the wall of the kiln, inject the mixture into the shaft through side openings and utilize additional air rising from the cooling zone for complete combustion within the shaft. This approach fails to create a uniform distribution of the flame in the sintering zone because the flames entering near the wall do not penetrate to the middle of the shaft, and because the secondary air rising from the cooling zone is itself unevenly distributed across the whole cross section of the shaft.

Another approach is to neglect a perfect distribution of the flame in the sintering zone and to use a soaking zone below the sintering zone, that is, a zone essentially without any gas or air flow rising from the cooling zone through it. In this soaking zone, which essentially retains the temperature of the sintering zone, an equalization of temperature between pieces of different temperature and in large pieces between their hotter outside surface and colder central part takes place. Introduction of a soaking zone relies on substantially all the air from the cooling zone being drawn out through openings in the side wall of the shaft. This air is heated in the cooling zone, then drawn out of the cooling zone and conducted into combustion chambers, arranged in the wall of the shaft or outside of the shaft. Fuel is injected into and burned in these combustion chambers. The hot gases of combustion are then conducted through ports in the wall of the kiln into the sintering zone. The soaking zone is undoubtedly a suitable means to equalize differences of temperature created in the sintering zone but this concept alone cannot prevent undesirable formations of clinker resulting from the temperature differences in the sintering zone caused by uneven distribution of the flame. For example, if the temperature of portions of the material is raised so high in the sintering zone that the material is baked together into larger lumps then these lumps cannot be converted back to small pellets in the soaking zone.

The sintering point for cement raw mixtures (i.e., the temperature at which an eutectic begins to form) is

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reached at about 2370° F. If the temperature rises considerably higher, for instance to 2550° F., then sufficient eutectic (liquid) forms so that adjacent pellets of cement raw material begin to stick together forming clusters and the gases cannot flow through these clusters but must flow around them.

This invention accomplishes the sintering process in the narrow range of temperature limited between the beginning of the formation of the eutectic or liquid phase and the beginning of baking together of the clinker grains into lumps. In order to make cement clinker at this comparatively low temperature and narrow temperature range, it is necessary that all the cement raw material reaches and remains within this temperature range for a sufficiently long period to calcine. It is also desirable to bring the material in the whole cross section of the sintering zone to this narrow limited range of temperature very rapidly.

To reach this condition, in accordance with this invention, the fuel is completely burned in the combustion chamber and injected through the inlet nozzles in the wall into the sintering zone at a velocity so high that pellets of cement raw material in the sintering zone are fluidized and each pellet is suspended and oscillated in the flame. This phenomenon is seen in the usual fluidized bed supported by a perforated bottom with gas blown through the bottom thereby causing the material to behave similarly to a liquid, that is, the grains or pellets move against each other almost without friction and the material forms a horizontal top surface similar to that of a liquid.

Experiments have shown that this condition can also be produced in a shaft kiln by injecting the flame through nozzles in the side wall at a very high velocity. Experiments have further shown that this fluidization takes place only in the narrow sintering zone and that the granules of material are not fluidized close above and below the nozzles.

The pressure in the combustion chamber necessary to produce the required high velocity of the flame in the nozzles remains within relatively moderate limits because the resultant velocity depends upon the relationship of pressure to weight of flame per unit of volume. This weight of burning gases is extraordinarily low and therefore relatively low pressures are sufficient to impart the necessary velocity. For example, in an experimental shaft kiln with a 13.6 inch inside diameter, a single combustion chamber, a 1.58 inch diameter nozzle in the side wall, and a 20 inch deep layer of 0.31 inch pellets of cement raw material over the nozzle, the flame is blown across the whole diameter of the shaft at a velocity of about 630 miles per hour when the pressure is only 5.2 feet water gauge in the combustion chamber. From this it becomes evident why blowing cold air, which has a much higher weight to volume ratio, at about the same pressure through the side wall into the shaft results in velocities which are six times less than in the present invention and cannot, therefore, penetrate very deeply into the raw material within the kiln.

According to this invention it is possible in a shaft kiln equipped with a number of nozzles on the periphery to fluidize the raw material in the sintering zone up to its center so that the temperature of the material will be within the desired limits. Because of the dispersed condition of the material, when fluidized, each grain (or pellet, if material is pelletized) of the material is surrounded completely by hot gas so that, contrary to the situation in the former shaft kilns, the heat does not need to be transmitted partially by conduction from one grain to the next. Therefore, a relatively short retention time is needed in the sintering zone for reaching the desired temperature, for example, 2460° F. At this relatively low temperature (for making cement) the material leav-

ing the sintering zone normally shows no formation of clusters. However, this temperature is high enough, and since it does not drop appreciably as the material descends through the soaking zone, the conversion of the raw material to cement clinker is completed before the material reaches the cooling zone. Experiments have shown that because discrete particles of cement raw material are quickly and thoroughly heated to about 2460° F. in the sintering zone, it is possible to increase the descending velocity of the clinker through the soaking zone, where conversion to cement clinker is completed, and thereby considerably increase the output of such a kiln compared to what it is in the usual shaft kilns.

The object of this invention is to diminish uneven heating conditions in the sintering zone of the shaft kiln by causing an even distribution of the flame in the shaft.

Other objects and advantages of this invention will be apparent from the following detailed description.

FIG. 1 is a vertical cross section view taken in the direction of the arrows along line I—I of FIG. 2 of a shaft kiln embodying this invention;

FIG. 2 is a horizontal cross section view taken in the direction indicated by arrows along line II—II of FIG. 1;

FIG. 3 is a vertical cross sectional view taken similarly to FIG. 1 of a modification of this invention; and

FIG. 4 is a cross sectional view taken similarly to FIG. 2 of another modification of this invention.

Referring to FIG. 1, a shaft kiln such as may be used to produce cement clinker, has a vertical tubular wall 1 (lined with thermal insulation 2) enclosing a generally cylindrical space 3 with an opening at the top of tubular wall 1 for the introduction of raw material 4. At the bottom of vertical tubular wall 1, a conical receptacle 5 encloses the bottom of the kiln and has an air inlet port 6 and a material discharge port 7 located at its lowermost point. A rotating perforated discharge grate 8 is located near the bottom of the shaft kiln port for controlling the discharge of raw material. A grate shaft 9 transmits power from an external source (not shown) for rotating the grate 8. Connected to conical receptacle 5 at air inlet port 6 is an air inlet pipe 10, an air inlet valve 11, and an air inlet blower 12. At a distance above the bottom of the shaft kiln there are radially disposed exhaust ports 13 passing through the vertical tubular wall and its adjacent thermal insulation. These exhaust ports communicate with an exhaust header 14 which forms a chamber around the kiln. Extending upward vertically from the exhaust header are two vertical conduits 15 (more clearly shown in FIG. 2) communicating between exhaust header 14 and a combustion chamber 16 to thereby form a header system. The combustion chamber is disposed about the vertical tubular wall 1 and communicates to space 3 through radially disposed inlet nozzles 17 which pass through the vertical tubular wall and the adjacent thermal insulation. Exhaust header 14, vertical conduits 15, and combustion chamber 16 are lined with thermal insulation similar to the insulation of vertical tubular wall 1. Communicating with combustion chamber 16 are fuel injectors 18. Within vertical conduits 15 there are air control valves 20 enabling a complete or partial closing of the vertical conduits. In addition to the header system formed by vertical conduit communication between exhaust header 14 and combustion chamber 16 there is another header system formed by a blower system 21 consisting of exhaust pipe 22, air blower 23, connecting pipe 24, conduits 28, ports 27, and blower control valve 25 located within connecting pipe 24.

FIG. 2, a cross sectional view from the top of combustion chamber 16, more clearly illustrates this section of a shaft kiln utilizing this invention. Connecting to combustion chamber 16 are combustion conduits 26. Vertical conduits 15 communicate at vertical conduit outlets 19 with the ends of combustion conduits 26 away from combustion chamber 16. Fuel injectors 18 (see

FIG. 1) are located adjacent to vertical conduit outlets 19. Also, as shown in FIG. 2, combustion conduits 26 at this point communicate with conduits 28 at ports 27. The other ends of conduits 28 communicate at a common junction with connecting pipe 24.

In the operation of the apparatus shown in FIGS. 1 and 2, raw material to be treated in the shaft kiln is introduced at the top of vertical tubular wall 1 and a column of the material is continually passed downward in vertical space 3 through discharge grate 8 and out material discharge port 7. The raw material passes through four treating zones: a preheating zone A, a heating or sintering zone B, a soaking zone C, and a cooling zone D. At the bottom of the shaft kiln, air enters through air inlet port 6 (assisted by air inlet blower 12) through air inlet pipe 10. Its passage is controlled by air inlet valve 11 and it flows evenly across the cross section of grate 8. The use of the air blower is not essential since the natural draft of the operation of the shaft kiln may be adequate under certain circumstances but the preferable installation includes air inlet blower 12 and its accompanying structure. The air flows from air inlet pipe 10 into the chamber formed by conical receptacle 5 and passes upward through the perforated grate and the raw material in the cooling zone D.

Air control valves 20 are normally kept closed and air blower 23 is operated so as to create a determined pressure differential in the header system between exhaust header 14 and combustion chamber 16 through blower system 21. Blower control valve 25 is adjusted to obtain the desired pressure differential for controlling the flow of some of the combustion gases down through soaking zone C as later described. Since the pressure at combustion chamber 16 is greater than the pressure at exhaust header 14, this pressure differential is communicated into vertical space 3 and the pressure in sintering zone B is therefore higher than the pressure at exhaust ports 13. Because of this pressure differential, almost all of the air flows out through exhaust ports 13 into exhaust header 14 and through blower system 21 into combustion chamber 16. Thus, the location of the exhaust ports determines the top of cooling zone D. In combustion chamber 16, fuel is injected through fuel injectors 18 and the rapidly expanding combustion gases and flame are caused to take a passage in a counterclockwise direction through combustion chamber 16 after passing from combustion conduits 26.

According to this invention the high pressure in relation to the weight to volume ratio of the combustion gases and flame will cause the flame and hot combustion gases to exit from the combustion chamber through inlet nozzles 17 into the raw material within vertical space 3 at such a high velocity that the flame and combustion gases will penetrate thoroughly through the material and cause the material to fluidize within sintering zone B. By controlling the pressure differences between the sintering zone B and exhaust ports 13 by blower control valve 25, some of the combustion gases are caused to pass down vertical space 3 through soaking zone C. Most of the combustion gases, however, pass upward through preheating zone A and are discharged out the top of the kiln. Because of the low weight to volume ratio of the combustion gases and flame exiting from combustion chamber 16, a high velocity is produced at an easily obtainable pressure and this insures the penetration of the flame and combustion gases into the center of the column. These gases after being cooled by contact with the material in the sintering zone pass partly upward to preheat the material and partly downward through the soaking zone to enhance the equalizing of the temperature differences remaining in the raw material and thereby thoroughly and rapidly treat the raw material.

The complete penetration of the flame and combustion gases into the center of the column and the fluidizing effect upon the material insures the rapid and complete heat transfer from the combustion gases and flame to the raw

material in the sintering zone. This fluidizing effect is particularly efficient because each particle is surrounded by the flame and combustion gas itself and there is little or no heat transfer by conduction from one particle to another thereby eliminating any baking together of the particles to form larger clusters. This envelopment of the particles by the flame and combustion gases also insures a most efficient and rapid transfer of the heat to the particles so that treatment is almost complete in the sintering zone. Any necessary remaining heat transfer is accomplished in the soaking zone where the conversion of the raw materials to cement clinker is completed.

By utilizing this embodiment of the invention, it is readily seen that the soaking zone can be comparatively short because of the efficient heat transfer in the sintering zone and the maintenance of relatively high temperature conditions in the soaking zone. This enables a particular size shaft kiln to have a larger output than has heretofore been accomplished.

Referring to FIG. 3, it is seen that a similar embodiment of this invention consists of the same structure as in FIG. 1 except that blower system 21 of FIG. 1 is not included and a covering structure 29 has been added. In this embodiment, temperature equalization within soaking zone C is achieved by a relatively long soaking zone and a therefore correspondingly long period of time for the temperature variances within the raw material to equalize. In this embodiment the air passing through cooling zone D passes from vertical space 3 through exhaust ports 13 because the greater resistance of the long soaking zone retards the passage of air up through the soaking zone. Rather, following the much lower resistance path, the air passes through exhaust ports 13 into the exhaust header system consisting of exhaust header 14, vertical conduits 15, vertical conduit outlets 19 and combustion chamber 16 where it is combined with the ignited fuel injected from fuel injectors 18 to create the same effect as discussed in explaining the embodiment shown in FIG. 1. The flame and hot gases injected into the column from combustion chamber 16 through inlet nozzles 17 pass upward through preheating zone A and out the top of the shaft kiln.

It is possible to utilize this embodiment of the invention by exhausting the combustion gases passed through preheating zone A directly to the atmosphere but a preferred embodiment and more efficient operation will result if the top of the shaft kiln is enclosed, as shown in FIG. 3, by a covering structure 29, consisting of a kiln cover 30, a material inlet feed port 31 and an air outlet port 32. With this arrangement, raw material is fed into the system through a raw material feeder cone 33 which communicates with vertical space 3 through material inlet feed port 31 as shown. The material within the raw material feeder cone will create a gas tight seal so that the combustion gases will not appreciably escape through the raw material in the feeder cone. The raw material will reach the height of the bottom of the feeder cone and will retain this height as it is drawn out through the bottom of the shaft kiln. From air outlet port 32, an air outlet pipe 34 connects to a discharge blower 35 which discharges the cooled combustion gases. This arrangement enables pressure within the kiln cover at the top of the kiln to be adjusted so that the passage of the combustion of the gases through preheating zone A is easily and accurately controllable. Therefore, the passage of the air and the combustion gases can be carefully controlled by adjusting the pressure at air inlet port 6 and the pressure at air outlet port 32. Covering structure 29 and discharge blower 35 and its accompanying structure may be utilized in the embodiment of this invention shown in FIG. 1 and thereby enable complete control of the pressure relationships throughout vertical space 3.

Referring to FIG. 4, a modification of this invention shows a shaft kiln having an oval cross section. The advantage of this cross sectional configuration is apparent since it is seen that the volume enclosed within vertical

tube wall 1 can be substantially increased without increasing the maximum distance that the flame and combustion gases must penetrate to reach the center of the column and thereby fluidize and heat treat all of the material within the sintering zone. Thus, this particular modification would be of benefit where a large volume of material is to be treated.

The embodiments of this invention herein described are illustrative only and the invention is not limited to such. It is apparent that many modifications, variations and adaptations of this invention are possible without departing from its spirit and scope.

Having now particularly described and ascertained the nature of my said invention and the manner in which it is to be performed, I declare that what I claim is:

1. A shaft kiln comprising: a vertical tubular wall for confining a downwardly moving column of material; at least one radial exhaust port through the tubular wall at a horizontal level spaced above the bottom of the tubular wall a distance less than the level is spaced downwardly from the top of the tubular wall; an exhaust header in communication with the column through the exhaust port; at least one inlet nozzle extending radially through and perpendicular to the tubular wall at a horizontal level spaced intermediate the exhaust port and the top of the tubular wall with a relatively great distance between said inlet nozzle level and the exhaust port level; a single combustion chamber transverse to said tubular wall and completely surrounding the tubular wall for burning fuel, said chamber being directly in communication with the column through the inlet nozzle; an air inlet means for furnishing air to the shaft kiln at the bottom of the vertical tubular wall; a vertical conduit connecting the combustion chamber to the exhaust header to thereby define a header system for directing a flow of substantially all the air furnished by the air inlet means upwardly from the bottom of the column out through the exhaust port and introducing such air to the combustion chamber; and a fuel injector communicating with the combustion chamber in substantially the same horizontal plane as the inlet nozzles.

2. A shaft kiln comprising: a vertical tubular wall having an inner surface defined by a locus of vertical straight lines, said tubular wall confining a downwardly moving column of material; at least one radial exhaust port through the tubular wall at a horizontal level spaced above the bottom of the tubular wall a distance less than the level is spaced downwardly from the top of the tubular wall; an exhaust header in communication with the column through the exhaust port; at least one inlet nozzle extending radially through and perpendicular to the tubular wall at a horizontal level spaced intermediate the exhaust port and the top of the tubular wall; a single combustion chamber transverse to said tubular wall and completely surrounding the tubular wall for burning fuel, said chamber being directly in communication with the column through the inlet nozzle; an air inlet means for furnishing air to the shaft kiln at the bottom of the vertical tubular wall; a vertical conduit connecting the combustion chamber to the exhaust header to thereby define a header system for directing a flow of substantially all the air delivered by the air inlet means upwardly from the bottom of the column out through the exhaust port and introducing such air to the combustion chamber; and a fuel injector communicating with the combustion chamber in substantially the same horizontal plane as the inlet nozzles.

3. A shaft kiln comprising: a vertical tubular wall, having an oval horizontal cross section configuration, for confining a downwardly moving column of material; at least one radial exhaust port through the tubular wall at a horizontal level spaced above the bottom of the tubular wall a distance less than the level is spaced downwardly from the top of the tubular wall; an exhaust header in communication with the column through the exhaust port;

at least one inlet nozzle extending radially through and perpendicular to the tubular wall at a horizontal level spaced intermediate the exhaust port and the top of the tubular wall; a single combustion chamber transverse to said tubular wall and completely surrounding the tubular wall for burning fuel, said chamber being directly in communication with the column through the inlet nozzle; an air inlet means for furnishing air to the shaft kiln at the bottom of the vertical tubular wall; a vertical conduit connecting the combustion chamber to the exhaust header to thereby define a header system for directing a flow of substantially all the air delivered by the air inlet means upwardly from the bottom of the column out through the exhaust port and introducing such air to the combustion chamber; and a fuel injector within the combustion chamber in substantially the same horizontal plane as the inlet nozzles.

4. A shaft kiln comprising: a vertical tubular wall, having an inner surface defined by a locus of vertical straight lines and an oval horizontal cross section configuration, for confining a downwardly moving column of material; at least one radial exhaust port through the tubular wall at a horizontal level spaced above the bottom of the tubular wall a distance less than the level is spaced downwardly from the top of the tubular wall; an exhaust header in communication with the column through the exhaust port; at least one inlet nozzle extending radially through and perpendicular to the tubular wall at a horizontal level spaced intermediate the exhaust port and the top of the tubular wall; a single combustion chamber transverse to said tubular wall and completely surrounding the tubular wall for burning fuel, said chamber being directly in communication with the column through the inlet nozzle; an air inlet means for furnishing air to the shaft kiln at the bottom of the vertical tubular wall; a vertical conduit connecting the combustion chamber to the exhaust header to thereby define a header system for directing a flow of substantially all the air delivered by the air inlet means upwardly from the bottom of the column out through the exhaust port and introducing such air to the combustion chamber; and a fuel injector within the combustion chamber in substantially the same horizontal plane as the inlet nozzles.

5. A shaft kiln comprising: a vertical tubular wall for confining a downwardly moving column of material; a blower having its discharge connected to the bottom of the tubular wall for blowing air upwardly through the column of material; at least one radial exhaust port through the tubular wall at a horizontal level spaced above the bottom of the tubular wall a distance less than the level is spaced downwardly from the top of the tubular wall; an exhaust header surrounding the tubular wall and defining a horizontal passage around the tubular wall and in communication with the column through the exhaust port; at least one inlet nozzle extending radially through and perpendicular to the tubular wall at a horizontal level spaced intermediate the exhaust port and the top of the tubular wall with a relatively great distance between said inlet nozzle level and the exhaust port level; a single combustion chamber for burning fuel transverse to said tubular wall and completely surrounding the tubular wall directly defining a horizontal passage around the tubular wall and in communication with the column through the inlet nozzle; an air inlet means for furnishing air to the shaft kiln at the bottom of the vertical tubular wall; a vertical conduit connecting the combustion chamber to the exhaust header to thereby define a header system for directing a flow of substantially all the air delivered by the air inlet means upwardly from the bottom of the column through the exhaust port and introducing such air to the combustion chamber; and a fuel injector within the combustion chamber in substantially the same horizontal plane as the inlet nozzles.

6. A shaft kiln comprising: a vertical tubular wall for confining a downwardly moving column of material; a

first blower having its discharge connected to the bottom of the tubular wall for blowing air upwardly through the column of material; a plurality of radial exhaust ports through the tubular wall at a horizontal level spaced above the bottom of the tubular wall a distance less than the level is spaced downwardly from the top of the tubular wall; an exhaust header surrounding the tubular wall and defining a horizontal passage around the tubular wall and in communication with the column through the exhaust ports; a plurality of inlet nozzles extending radially through and perpendicular to the tubular wall at a horizontal level spaced intermediate the exhaust ports and the top of the tubular wall; a single combustion chamber for burning fuel transverse to said tubular wall and completely surrounding the tubular wall and defining a horizontal passage around the tubular wall directly in communication with the column through the inlet nozzles; an air inlet means for furnishing air to the shaft kiln at the bottom of the vertical tubular wall; a vertical conduit connecting the combustion chamber to the exhaust header to thereby define a header system for directing a flow of substantially all the air delivered by the air inlet means upwardly from the bottom of the column through the exhaust ports and introducing such air to the combustion chamber; a fuel injector communicating with the combustion chamber in substantially the same horizontal plane as the inlet nozzles; and a second blower mounted external to the tubular wall and having its inlet in communication with the header system to continuously displace fuel and air from the combustion chamber through said inlet nozzles into the column and replace such displaced air with preheated air drawn outwardly through said exhaust ports.

7. A shaft kiln comprising: a vertical tubular wall having an inner surface defined by a locus of vertical straight lines and an oval horizontal cross section configuration, for confining a downwardly moving column of material; a first blower having its discharge connected to the bottom of the tubular wall for blowing air upwardly through the column of material; a plurality of radial exhaust ports through the tubular wall at a horizontal level spaced above the bottom of the tubular wall a distance less than the level is spaced downwardly from the top of the tubular wall; an exhaust header surrounding the tubular wall and defining a horizontal passage around the tubular wall and in communication with the column through the exhaust ports; a plurality of inlet nozzles extending radially through and perpendicular to the tubular wall at a horizontal level spaced intermediate the exhaust ports and the top of the tubular wall; a single combustion chamber for burning fuel transverse to said tubular wall and completely surrounding the tubular wall and defining a horizontal passage around the tubular wall directly in communication with the column through the inlet nozzles; an air inlet means for furnishing air to the shaft kiln at the bottom of the vertical tubular wall; a vertical conduit connecting the combustion chamber to the exhaust header to thereby define a header system for directing a flow of substantially all the air delivered by the air inlet means upwardly from the bottom of the column through the exhaust ports and introducing such air to the combustion chamber; a fuel injector communicating with the combustion chamber in the same horizontal plane as the inlet nozzles; and a second blower mounted external to the tubular wall and having its inlet in communication with the header system to continuously displace fuel and air from the combustion chamber through said inlet nozzles into the column and replace such displaced air with preheated air drawn outwardly through said exhaust ports.

8. A shaft kiln comprising: a vertical tubular wall having an inner surface defined by a locus of vertical straight lines, said tubular wall confining a downwardly moving column of material; a first blower having its discharge connected to the bottom of the tubular wall for blowing air upwardly through the column of material; a plurality

of radial exhaust ports through the tubular wall at a horizontal level spaced above the bottom of the tubular wall a distance less than the level is spaced downwardly from the top of the tubular wall; an exhaust header surrounding the tubular wall and defining a horizontal passage around the tubular wall and in communication with the column through the exhaust ports; a plurality of inlet nozzles extending radially through and perpendicular to the tubular wall at a horizontal level spaced intermediate the exhaust ports and the top of the tubular wall; a single combustion chamber for burning fuel transverse to said tubular wall and completely surrounding the tubular wall and defining a horizontal passage around the tubular wall directly in communication with the column through the inlet nozzles; an air inlet means for furnishing air to the shaft kiln at the bottom of the vertical tubular wall; a vertical conduit connecting the combustion chamber to the exhaust header to thereby define a header system for directing a flow of substantially all the air delivered by the air inlet means upwardly from the bottom of the column through the exhaust ports and introducing such air to the combustion chamber; a fuel injector within the combustion chamber located generally in the same horizontal plane as the inlet nozzles; and a second blower mounted external to the tubular wall and having its inlet in communication with the exhaust header and its outlet with said combustion chamber to continuously displace air and fuel from the combustion chamber through said inlet nozzles into the column and replace such displaced air with preheated air drawn outwardly through said exhaust ports.

9. A shaft kiln comprising: a vertical tubular wall having an inner surface defined by a locus of vertical straight lines, said tubular wall confining a downwardly moving column of material; a first blower having its discharge connected to the bottom of the tubular wall for blowing air upwardly through the column of material; a plurality of radial exhaust ports through the tubular wall at a horizontal level spaced above the bottom of the tubular wall a distance less than the level is spaced downwardly from the top of the tubular wall; an exhaust header

surrounding the tubular wall and defining a horizontal passage around the tubular wall and in communication with the column through the exhaust ports; a plurality of inlet nozzles extending radially through and perpendicular to the tubular wall at a horizontal level spaced intermediate the exhaust ports and the top of the tubular wall; a single combustion chamber for burning fuel transverse to said tubular wall and completely surrounding the tubular wall and defining a horizontal passage around the tubular wall directly in communication with the column through the inlet nozzles; an air inlet means for furnishing air to the shaft kiln at the bottom of the vertical tubular wall; a vertical conduit connecting the combustion chamber to the exhaust header to thereby define a header system for directing a flow of substantially all the air delivered by the air inlet means upwardly from the bottom of the column through the exhaust ports and introducing such air to the combustion chamber; a fuel injector within the combustion chamber located generally in the same horizontal plane as the inlet nozzles; and a second blower mounted external to the tubular wall and having its inlet connected to the top of said tubular wall and in communication with the header system to continuously displace air and fuel from the combustion chamber through said inlet nozzles into said column and replace such displaced air with preheated air drawn outwardly through said exhaust ports.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,140,864

July 14, 1964

Otto G. Lellep

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 7, line 62, for "directly" read -- and --; line 63, for "and" read -- directly --.

Signed and sealed this 17th day of November 1964.

(SEAL)

Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents