July 14, 1964 A. J. COHEN 3,140,865

FURNACE FOR BURNT CLAY AND FLEXIBLE ROAD BASE MATERIAL

Filed July 11, 1960 2 Sheets-Sheet 1

Fig. 1

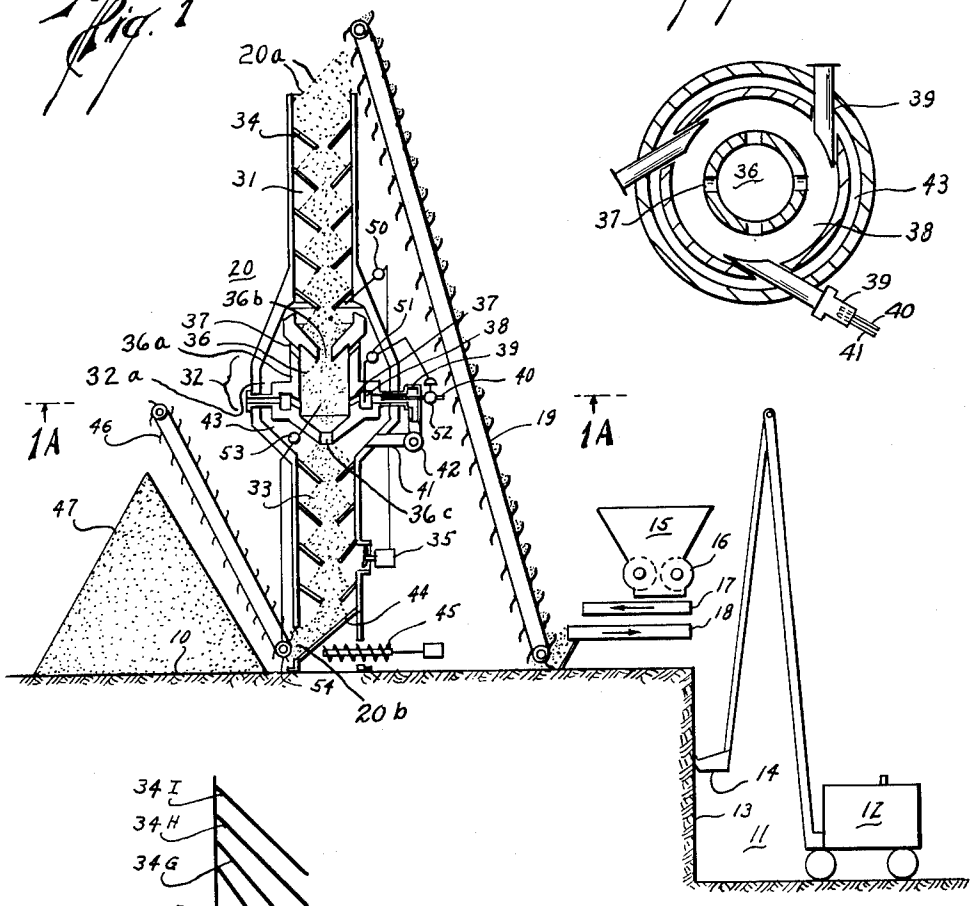
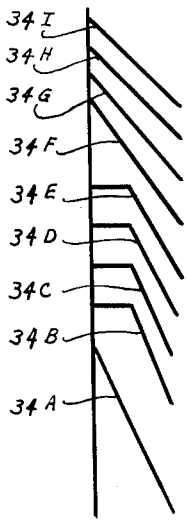


Fig. 1A

Fig. 3



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Filed July 11, 1960 2 Sheets-Sheet 2

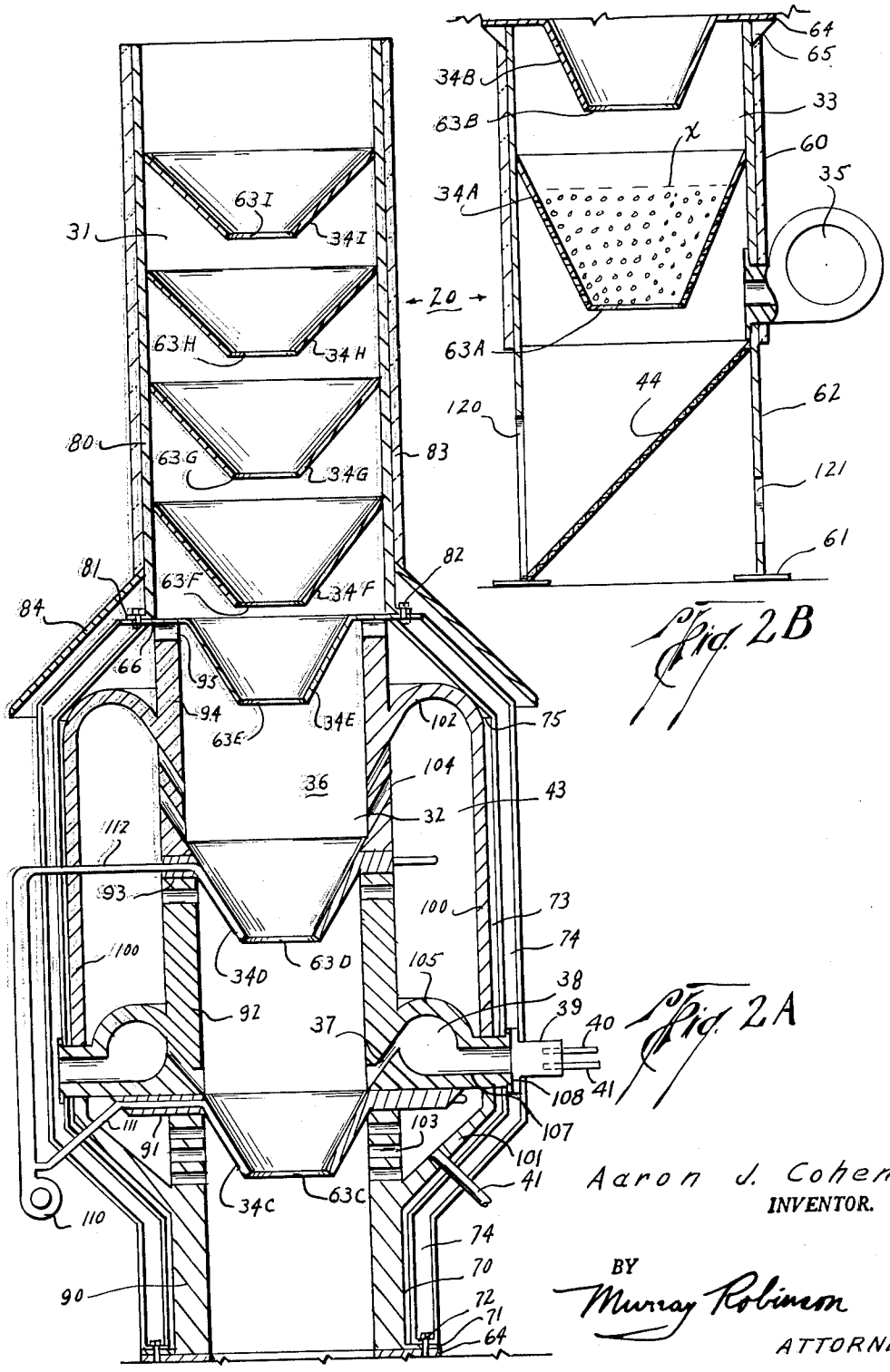

Fig. 2B

Fig. 2A

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FURNACE FOR BURNT CLAY AND FLEXIBLE ROAD BASE MATERIAL

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This invention relates to kilns, and is particularly concerned with kiln structures and methods of kiln operation adapted for treating raw clay to form clay aggregate therefrom suitable for use in flexible road beds.

Along many roadways over which a road is to be constructed, there exist so-called "clay pits." Many of such clap pits include raw or fresh clay disposed above the local water table. Where the clay does not exist in natural condition above the water table, the water table can be lowered by pumping well points. Thus, it is possible to choose at spaced locations along a right-of-way a series of clay pits containing suitable raw clay of low-moisture content, i.e., a moisture content preferably below 25%.

As well known to those familiar with road construction, and/or those familiar with devices for processing raw clay, the clay as existent in nature in a clay pit is not readily adapted for direct use in providing a flexible road bed. Accordingly, it is necessary to treat the raw clay to form therefrom an aggregate of suitable hardness and size.

Consistent with the foregoing, the present invention has as one of its primary objects the provision of a multichamber shaft-type kiln for progressively drying, burning, and cooling clay particles, which kiln is adapted to be transported from location to location for use comparatively close to the location at which the clay processed therein is to be used. More generally, one of the primary objects of the present invention is to provide a kiln structure adapted to treat clay particles "on site" so as to eliminate substantial transportation costs and take advantage of the raw material existent along or adjacent a right-of-way on which a road is to be constructed.

Still further, it is an object of the present invention to provide a kiln conforming with the preceding objects, which kiln is adapted to be operated in such a manner as to eliminate the need for any substantial or time-consuming air drying of the raw clay.

Still further, yet additional and important primary objects of the present invention are to provide a multichamber shaft-type kiln for progressively drying, burning, and cooling clay particles: (*a*) wherein the kiln is constructed in separable sections adapted to be coupled in vertical alignment to provide for successive drying, burning and cooling of the particles processed therein; (*b*) wherein the separable sections of the kiln can be and are dimensioned so as to be transportable from location to location with comparative ease due to the light-weight nature thereof; (*c*) wherein refractory coatings are utilized on kiln components so as to minimize the quantity of refractory or fire brick incorporated and thereby make the overall kiln lighter and more easily manipulatable; and (*d*) wherein the kiln is constructed so as to have an output of aggregate suitable for use in concrete, and free of any fines as well as any quicklime.

Other, yet more specific objects of the present invention are: (*a*) to provide a multichamber shaft-type kiln for progressively drying, burning and cooling clay particles, which kiln is vertically disposed in operation and controlled in temperature to eliminate tumbling and resultant smoothing of clay bits such as is inherent in a rotary horizontal-type kiln; (*b*) to provide such a kiln incorporating perforated baffles which preclude agglomeration of clay bits or particles treated in the kiln and thus permit the proper "sizing" of the clay preceding the entry thereof into the kiln; (*c*) to provide such a kiln wherein

the dryer section thereof is integrated with but separable from the burner section thereof so as to provide for portability and at the same time thermal efficiency; (*d*) to provide such a kiln incorporating a dryer section having a series of baffles therein cooperating with one another to guide clay particles along zig-zag paths within the kiln; (*e*) to provide such a kiln wherein the baffles of the dryer section further are disposed to cooperate with one another so as to prevent the discharge of clay fines and the corrosive ingredients thereof (e.g. quicklime) into the atmosphere through the top of the kiln; (*f*) the provision of such a kiln incorporating means for separating clay fines from the clay aggregate produced thereby whereby the aggregate is suitable for use in concrete, and free of any lime or quicklime; (*g*) to provide such a kiln wherein the processing sections thereof incorporate means disposed and arranged to provide for automatic cooling of the outside of the kiln burner and increased thermal efficiency within the kiln; (*h*) to provide such a kiln which includes vertically stacked and releasably coupled cooler, burner, and dryer sections, wherein each of the sections incorporates means for transferring air from the cooler section to the dryer section and in outer cooling relation to a burning chamber and heating means therefor incorporated within the burner section; and (*i*) to provide such a kiln which can be constructed from available base materials at comparatively low cost, and yet which is durable and trouble-free with continued operation.

The invention will be better understood, and objects other than those set forth above will become apparent when consideration is given to the following detailed description of the invention. Such description makes reference to the annexed drawings presenting preferred embodiments hereof.

In the drawings:

FIGURE 1 is a schematic vertical section taken through a kiln constructed in accordance with the invention, and presents in side elevation apparatus associated with the kiln in normal operation thereof;

FIGURE 1A is a fragmental horizontal sectional view taken on the line 1A—1A of FIGURE 1 and showing the preferred arrangement and disposition of cooperating combustion chamber and burning chamber components incorporated in the kiln of FIGURE 1;

FIGURES 2A and 2B together provide a vertical section through a modified kiln constructed in accordance with the present invention, FIGURES 2A and 2B being drawn to a larger scale than FIGURE 1; and

FIGURE 3 is a schematic fragmental vertical sectional view taken partially through one side of the kiln of FIGURES 2A, 2B, FIGURE 3 showing a preferred variable angle disposition of baffles incorporated within a kiln constructed in accordance herewith.

Referring now to FIGURE 1, the earth's surface is indicated at **10** and a clay pit at **11**. A crane **12** removes clay from a vertical side wall **13** of the pit with a scoop **14** and deposits it in hopper **15** of pug mill **16**. The pug mill reduces the size of the raw clay fed into the hopper. The pug mill may be of the type employing two coaxial rollers rotating downward toward each other with a space therebetween equal approximately to the desired size of the clay bits. The rollers may be provided with nonengaging knobs or teeth to grip the clay and force it to move down through the mill between rollers. The clay should have a moisture content less than about 25% so that it will not pass through the mill as a continuous plastic extrusion but will be broken up into bits. To determine the moisture content of the soil, a neutron moisture meter may be used (see Soil Mechanics Review, No. 1, May 1959, prepared by McClelland Engineers, Inc., Houston, Texas).

The reduced clay falls out of the bottom of the pug

mill onto vibrating or reciprocating screens **17**, **18**. The material retained on the 1½" screen **17** is returned to the hopper or to the pit. The material passing the ¼" screen **18** is discarded. The material passing screen **17** and retained on screen **18** is of the desired range of sizes and is discharged onto conveyor **19**. The reduced and size-graded clay bits are carried by the conveyor to the top of kiln **20** and discharged into the kiln.

The kiln **20**, as is apparent from the drawings, is a multichamber shaft-type kiln and serves to progressively dry, burn, and cool clay particles. The kiln comprises an elongated hollow housing section having a particle inlet port **20***a* at the upper end thereof, and having a particle outlet port **20***b* at the lower end thereof. A burning chamber **36** is disposed within the housing section between and spaced from the ends **20***a* and **20***b*. The burning chamber **36** is located in the intermediate enlarged portion **32** of the housing section forming the kiln, and the outer side wall **36***a* of the chamber **36** is spaced interiorly from the adjacent wall **32***a* of the housing section. The spacing between the walls **36***a* and **32***a* forms a gas flow passageway **43** within the housing section, or portion **32** thereof, about the burning chamber **36**.

The burning chamber **36** has a particle inlet port **36***b* at the upper end thereof, and a particle outlet port **36***c* at the lower end thereof. First baffle means, or baffles **34** are disposed within the upper portion **31** of the housing section between the inlet port **20***a* thereof and the inlet port **36***b* of the burning chamber. The baffles or baffle means **34** direct particles between the particle inlet **20***a* and the particle inlet **36***b* along progressive paths extending angularly to the vertical axis of the housing section, as explained more fully below.

Another or second baffle means is disposed within the lower portion **33** of the housing section between the outlet port **36***c* of the burning chamber and the outlet port **20***b* of the housing section. This other baffle means serves to direct particles between the outlet port **36***c* and the outlet port **20***b* also along progressive paths extending angularly to the vertical axis of the housing section.

A selectively operable conveyor means **46** is provided to remove particles from the housing section, or more particularly the outlet **20***b* thereof, i.e. particles that have progressively traversed the upper baffle means, the burning chamber, and the second baffle means. Still further, fan means **35** are provided for blowing air within the lower portion **33** of the housing section past the particles therein, through the passageway **43**, and into the upper portion **31** of the housing section. Additionally, a combustion chamber **38** is incorporated and disposed within the passageway **43**, the combustion chamber, as explained more fully below, serving as means for heating the chamber **36**.

While the kiln **20** has been described above as having upper, middle, and lower portions **31**, **32**, and **33** respectively, such portions may just as well be described as sections. Accordingly, the kiln **20** would comprise, consistent with this alternate phraseology, three sections. The upper section **31** is the drying section. The middle section **32** is the burning section. The lower section **33** is the cooling section. As the clay bits fall through the series of baffles **34** in the kiln, they are contacted by the counter-flowing gases forced upwardly by fan means or blower **35**. The bits are first dried by a mixture of hot air and hot gas in the dryer section. Then the bits are burned in the burning chamber or oven **36** forming the interior of the burner section. Hot gas enters the oven through ports **37** from the combustion chamber annulus **38**.

For purposes of convenience and in order to more clearly define the instant invention in the specification and appended claims, the upper part of the elongated housing section may be designated as a first upper portion or section, the bottom portion of the housing may

be designated as the second lower portion or section and the burning chamber portion may be designated as a third portion or section. Such language merely being interchangeably used for the purpose of clarity and convenience.

The hot gas from the combustion chamber **38** is the product of combustion from burners **39** to which are fed fuel gas and air. As best shown in FIGURE 1A, the burners are tangentially directed relative to the combustion chamber torus to prevent burn-out of the side walls of the torus and to give more even heat distribution. As shown in FIGURE 1, and schematically in FIGURE 1A the burners are fed fuel gas through pipe **40** leading to a source not shown and preheated air drawn off from the kiln through pipes **41** by suction fan **42**. The preheated air drawn off through pipes **41** is but a small portion of the air coming from the cooling section below where the burnt clay bits are brought to a handling temperature. The large remaining portion of the air flowing up the cooling section passes through the passageway **43** around the burning chamber and joins the products of combustion flowing up the dryer section.

It will be noted that the burning chamber **36** and combustion chamber **38** are disposed within the enlarged portion **32** of the kiln, and it will be remembered that a passageway **43** extends about the combustion chamber and the burning chamber. By virtue of this construction, air passing from the lower portion or section **33** of the kiln travels in cooling relation to the burning chamber and combustion chamber through the central portion or section of the kiln and into the upper or dryer section thereof. Accordingly, clay bits in the upper portion of the kiln are dryed by the hot gases rising not only through the inlet port **36***b* of the burning chamber, but also by the gases rising from the lower portion of section **33** of the kiln and passing around and about the burner chamber and combustion chamber during passage through the passageway **43**.

At the bottom of the kiln, the fines fall through ¼" screen **44** and may be removed therefrom by a helical conveyor **45** either continuously or at intervals. The burnt clay aggregate collecting on the screen falls onto conveyor **46** which discharges into stock pile **47** or into a truck or railway car as desired.

The air forced into the kiln by the blower and traveling upwardly through the cooling section of the kiln not only cools the burnt clay but absorbs heat from the clay which increases the effectiveness of the air in the burning and drying sections. The hot air from the cooler and the hot gases from the burner convert the water in the raw clay entering inlet port **20***a* into steam which rises through the dryer section and goes out the top of the kiln along with the air and gaseous products of combustion.

The entire process is very simply controlled by temperature controls at three points. The temperature of the gases (air and products of combustion) entering the dryer is controlled by thermostat **50** located in the air space just below the bottom baffle of the dryer, the thermostat controlling the speed of blower **35** which may have an outlet pressure of around 5 p.s.i. The temperature of the burner is controlled by thermostat **51** located in the combustion chamber annulus, thermostat **51** controlling the degree of opening of fuel gas valve **52** in pipe **40**. The temperature of the finished product is controlled by thermostat **53** located, in the bottom e.g., of the oven where it is covered with clay bits, thermostat **53** controlling the starting and (by a timer) the stopping of the drive motor **54** for conveyor **46**. The clay bits will usually be in the oven part of the kiln about 2 hours.

Referring now to FIGURES 2A and 2B, there is shown in detail a form of kiln generally similar to the kiln **20** shown schematically in FIGURE 1. The lower or cooling section **33** of the kiln comprises a tubular metal shell **60** having a ring **61** at its lower end. The shell is covered on its outside with thermal material such as an asbestos

wrapping 62. Inside the shell is affixed, e.g. by welding, a conical baffle 34A having a central opening 63 and having circular perforations of the order of ¼" in diameter (or equivalent slots) covering around 50% of the area of the baffles between bottom opening 63*a* and line "X" demarcating the outer lower periphery of a pile of clay bits extending up to the bottom of baffle 34*b* thereabove. Baffle 34*b* is similar to baffle 34*a*, being conical and having a lower opening 63*b* and being similarly perforated; however, the part of the baffle above the perforated area is flared outwardly horizontally to provide a flange 64 supporting the baffle on top of the shell 60. Flange 64 is supported by and secured to gusset plates 65 welded on the outside of the shell 60.

It will be appreciated that the baffles or baffle means 34 shown in FIGURE 1 preferably correspond to the baffles described in this paragraph which specifically relates to FIGURE 2.

The middle or burner section 32 comprises a metal shell 70 having an outturned flange 71 at its lower end resting upon and suitably fastened to flange 64, e.g., by bolts 72. The central part of shell 70 bulges outwardly or is diametrically enlarged at 73. Shell 70 is provided on its exterior with a plurality, e.g., six, supporting I-beam ribs 74 spaced apart around its periphery. The ribs flare outwardly at the middle portion of the burner section to follow the bulging diametrically enlarged mid-portion 73 of the shell, and converge above the upper edge 75 of the shell, returning to the same diameter as shell 60. To the upper ends of the ribs 74 is affixed the outturned horizontal flange 75 of a baffle 34*e* similar to baffle 34*b*.

The upper or drying portion or section of the kiln comprises a metal shell 80 having a lower outturned flange 81 resting on flange 75 and secured thereto, e.g. by bolts 82. The exterior of shell 80 is covered with thermal insulation, e.g. asbestos wrapping 83. Around the lower periphery of shell 80 there is secured a conical skirt 84 providing a rain shield for the lower part of the kiln. Within shell 80 are secured a series of conical perforated baffles 34*f–i* similar to baffle 34*a*, all open at their lower ends.

Within the tube 70 of the burner section and resting on flange 64 is disposed a cylindrical wall 90 of fire brick or similar refractory material. The wall 90 extends straight up to the lower part of the bulging or enlarged portion 73 of shell 70. Supported on top of wall 90 is the horizontally outwardly extending flange 91 of conical baffle 34*c*. On top of flange 91 is a further cylindrical wall 92 of refractory material similar to wall 90. Wall 92 extends about half way up the inside of enlarged portion 73 of shell 70. On top of wall 92 is the horizontally outwardly extending flange 93 of conical baffle 34*d*. On top of flange 33 is a further cylindrical wall 94 of refractory material similar to walls 90 and 92. On top of wall 94 is a cylindrical expansion joint 95 of asbestos, extending up snugly between flange 66 of baffle 34*e*.

The interior of diametrically enlarged portion 73 of shell 70 is covered with refractory material 100 which connects with wall 90 by a conical portion 101 and with wall 94 by an arching portion 102. The by-pass annulus or gas flow passageway 43 is formed between wall means 90, 92, 94 and the refractory lining 100 of enlarged portion 73 of shell 78. Ports 103 in wall 90 provide inlets from the cooler section 33 to the passageway or by-pass annulus 43 and downwardly directed ports 104 provide outlets from the passageway or by-pass annulus 43 to the top of the oven 36 formed inside the burner section by walls 90, 92, 94 and expansion joints 95.

Within passageway or by-pass annulus 43 is disposed refractory torus 105 forming combustion chamber 38. Downwardly directed ports 37 provide outlets from the combustion chamber whereby the hot products of combustion can enter the lower mid-part of the oven just above baffle 34*c* through the communication provided by such ports 37. Pipes 107 extend tangentially outwardly from the combustion chamber to enlarged portion 73 of shell 70 and terminate in flanges 108. Gas burners 39 are attached to flanges 108 by any suitable means (e.g. bolts). Air for the burners is withdrawn from the lower part of the passageway 43 through pipe 41 by a blower 42 (see FIG. 1).

The series of baffles 34*a, b, e–i,* are all perforated like baffle 34*a* and all the baffles 34*a–i* are of truncated conical or frustro-conical shape. As best shown in FIGURE 3, the angles of inclination of the baffles vary, being about 45 degrees at top baffle 34*i* and increasing to about 60 degrees at baffle 34*a*, such angle being taken with respect to the adjacent interior wall of the particular kiln section or portion, or otherwise phrased, with respect to the interior wall of the housing section. The central openings where the cones are truncated are of variable size. The diameter of the central holes 63–*c–i* of the dryer and burner sections are about three-tenths the inner diameter of the tube 70 while the openings 63*a–b* in the cooler section are about four-tenths that diameter. This contrasts with the uniform angle and central openings of baffles 34 of FIGURE 1.

Baffles 34*c* and *d* are double walled leaving an interior space through which air is blown to cool them. The air is provided by a blower 110 whose intake is connected to atmosphere and which discharges through pipes 111, 112 into the horizontal flange portions of the baffles. The baffles 34*c* and 34*d*, and any other baffles if desired, are further protected by an adhered coating of refractory fused material such as aluminum oxide.

In the lower part of the cooler section is disposed screen 44, which will be elliptical in outline to fit in a sloping, e.g. 45 degree, position within the shell 62. Outlet opening 120 in shell 62 provides a passage through which aggregate retained on screen 44 can be removed. Outlet opening 121 in shell 62 provides a passage through which fines passing screen 44 can be removed. The blower 35 for forcing air from the atmosphere into the kiln and upwardly therethrough is connected to the side of shell 62 above the screen 44, just below baffle 34*a*.

Although basic structural aspects of kilns constructed in accordance with the present invention have been discussed in detail in the preceding paragraphs, there are other structural features incorporated in a kiln constructed in accordance with the preferred embodiment hereof. More particularly, by again referring to FIGURE 1, it will be noted that the top and bottom walls of the particle burning chamber 36 are frusto-conical in contour, and that the taper thereof is in the downward direction. Each of the walls terminate in the respective inlet and outlet openings 36*b* and 36*c* of the burning chamber. The top and bottom walls of the burning chamber shown in FIGURE 1 correspond to the baffles designated by the numerals 34*c* and 34*d*, respectively, in FIGURE 2A. At least these particular baffles, as noted above, are preferably air-cooled. Moreover, the baffles in the burner chamber, and also other baffles incorporated if desired, are coated to prevent them from oxidizing and to thermally insulate them. The coating may be any one of the following or equivalent materials: (*a*) aluminum oxide; (*b*) silicone dioxide; (*c*) resins; and (*d*) ceramics. The coatings are continuous, e.g. fused, and can be applied with a plasma torch or cast on and fixed, or imbedded thermal-curing resin sprayed, painted, or troweled onto the baffles.

Preferably, the only baffles of the burning chamber are the top and bottom walls thereof since heat is transferred largely by radiation at the high burner temperature so that contacting of the product with the hot gas is unnecessary. A larger number of baffles is incorporated in the dryer section of the kiln in order to effect maximum transfer of the heat from the hot gases to the clay bits or particles passing therethrough. Moreover, sufficient baffles are provided in the cooler section of the kiln to insure that the product is uniformly cooled.

Operation

Initially, as discussed above, clay particles which have been delivered to the pug mill **15** by the scoop **14** are ground within the pug mill **15** by the rollers thereof, and are deposited on the reciprocating screens **17** and **18**. The particles of selected size leaving the screens **17** and **18** are delivered by the conveyor **19** to the particle inlet port **20***a* of the kiln.

In building up the charge of clay bits in the kiln, the clay bits falling through the central opening of the baffle **34** from one side of the baffle are directed toward the opposite side of the baffle **34** therebelow and then fall along the latter baffle toward its central opening and the opposite side of the baffle next below. The clay bits thus travel in a zig-zag path through the kiln or successive paths extending angularly to the vertical axis of the kiln. If the conveyor **46** is not operated to remove the clay bits falling to the bottom of the kiln, the clay bits begin to build up in the lower portion **33** of the kiln, blocking the outlet opening of the lowest baffle. The clay bits accumulate in a pile on the baffle with the pile having side walls sloping at the angle of repose for the clay bits. The pile builds up until it blocks the central opening of the baffle next above, after which clay bits begin to pile up on that baffle. This continues until the kiln is full.

It is to be noted that even when the kiln is full and there is a solid column of clay bits extending through the center openings of the baffles **34** from the top or inlet **20***a* to the bottom or outlet **20***b* of the kiln, there are annular spaces in the kiln below each baffle adjacent the shells of the dryer and cooler and the walls of the oven that are not occupied by clay bits. The clay bits are not close enough an approximation to a fluid to allow the pressure of the solid column to cause a rise in the clay bits above the bottom central opening of a baffle around the outer lower side of the baffle. Therefore, there is always an air space beneath the perforated part of each baffle. This helps to prevent the perforations from becoming completely blocked by clay bits as might otherwise occur if the clay bits were pressed against the under surfaces of the baffles. The provision of the air spaced beneath the perforated part of each baffle is achieved by utilizing a series of vertically spaced downwardly tapering frusto-conical baffles and by locating the baffles in cooperating relation with one another and the adjacent interior wall of the particular kiln section to define the angular space disposed circumferentially of the lower portion of each baffle and outside of the path of particles traveling through the kiln between the inlet port **20***a* and the outlet port **20***b* thereof.

During the initial filling of the kiln, the removal conveyor **46** is stopped. However, when the discharge conveyor is started, removal of the clay bits from beneath the lowest baffle starts clay bits to fall from the bottom of the solid column. This continues until the pile on the bottom baffle collapses separating it from the baffle next above. Thereupon clay particles start to fall from the bottom of the solid column terminating in the next above baffle on top of the collapsed pile on the bottom baffle and material on the latter falls through its central opening. Thus all the material on the next to the bottom baffle must fall on top of the pile in the bottom baffle and work its way out through the bottom baffle, effecting a thorough contacting with the air passing through the kiln in the process.

When enough material has fallen from the bottom of the solid column terminating at the next to bottom baffle, the pile on the next to bottom baffle collapses and separates from the solid column terminating at the baffle thereabove. The process of fall, collapse, and further fall is repeated at each baffle, working its way up the kiln. Preferably the lower baffles have greater inclination and outlet opening than those above as already discussed in connection with FIGURE 3, so that the material falls away from each baffle faster than it enters thereby assuring that the converse is not true which would tend to maintain the kiln solid at all times and prevent the desired hourglass-type mixing action. However, baffles of uniform inclination and outlet opening can be used.

The operation of the kiln can best be described starting with a condition in which the kiln is solid with burnt clay bits in the cooler section, preheated clay bits in the burner section and raw clay bits in the dryer section. After sufficient time has elapsed to bring all the preheated clay bits in the burner up to the desired temperature the discharge conveyor is started and operated long enough to remove from the bottom of the cooler section of the kiln a volume of cooled burnt clay bits equal to the volume of freshly burnt clay bits in the burner section. Since this volume is less than the total volume of clay bits in the cooler section, there will still remain a solid column in the kiln extending upwardly from a certain level in the cooler section through the burner section and dryer section to the top of the kiln. Upon stopping of the discharge conveyor the clay bits continue to work their way down through the kiln, the solid column therein disappearing progressing upwardly from said certain level through the top of the cooler section, the burner section and the dryer section to the top of the kiln. As soon as the solid column has been removed clear to the top of the kiln, the feed conveyor is started and clay bits are fed in at the inlet port **20***a*, meanwhile the solid column is building up again starting from the bottom since the discharge conveyor is stopped. The solid column finally builds up all the way to the top and the feed conveyor **19** is then stopped. The starting condition is thus achieved.

It will be noted that the freshly burnt clay from the burner section is discharged into the top of the cooler section and is there during the cooking period of the next batch of clay in the burner section. This gives it plenty of time to cool. When this batch finally works its way down to the discharge conveyor it will have been thoroughly contacted by the cooling air and brought to ambient temperature. Likewise, the charges of clay bits in the top of the kiln in the dryer section will remain there during the entire cooking time of at least one batch of clay bits in the burning chamber, the volume of clay bits in the dryer section being greater than that in the burning chamber just as the volume of clay bits in the cooling section is greater than that in the burning chamber.

The starting of the discharge conveyor **46** is preferably controlled by a thermostat in the burning chamber as described above, and the stopping is controlled by a timer set to stop the conveyor after the desired volume of material has been removed, but the starting can also be controlled by the timer. If a large enough storage space without baffles is provided above the top baffle of the dryer section, the feed conveyor can be operated continuously.

The kiln is temperature controlled at three points. The temperature of the gas entering the dryer section is controlled by varying the blower speed (i.e. speed of fan **35**) thereby controlling the ratio of hot gas from the burning chamber to preheated air from the cooler section. This not only protects the dryer section against excessive temperatures but also protects the burner chamber and cooler section since the temperature of the preheated air depends on the temperature in the passageway and the cooler section. The temperature of the burning chamber **36** is controlled by varying the fuel gas valve **52** in response to a thermostat in the combustion chamber **38**. The temperature of the product leaving the burning chamber is controlled by a thermostat therein which starts the discharge conveyor **46** whenever the burnt clay has reached the intended temperature. The conveyor is stopped after a volume of cooled burnt clay equal to that of the freshly burnt clay in the burning chamber has been removed from the kiln.

The clay bits are heated in the burning chamber 36 sufficiently to burn all of the carbonaceous matter, and the temperature may be raised higher toward the point of insipid fusion depending on the desired hardness of the aggregate.

While it has been suggested above that fines are removed or separated from the clay bit aggregate by the screen 44 disposed at the base of the kiln, it is to be understood that fines can be added to the burnt clay aggregate along with finely ground raw clay in suitable proportion if desired, to produce a flexible road base material having particular characteristics. A suitable formula for the flexible road base material is 70% aggregate from the kiln, and 30% fines. The fines need not be burned but if they are the triaxial strength of the resultant material is increased. The fines may be composed of any one of the following or equivalent materials or a mixture thereof: (*a*) crushed aggregate from the kiln; (*b*) fines from the kiln; (*c*) ground raw clay passing a hundred mesh screen; and (*d*) fine sand.

Particular Structural and Operational Data

As an example of a typical installation of the type above described, the following numerical specifications are given:

Output	10 cu. yd. burned clay per hour.
Cooler section height	20 ft.
Burner section height	25 ft.
Dryer section height	12 ft.
Cooler section shell diameter	8 ft.
Burner section shell diameter	14 ft.
Dryer section shell diameter	8 ft.
Gas consumption	12,000 c.f./hr. natural gas.
Feed conveyor	36,750 lb. clay/hr.
Aggregate conveyor	30,300 lb. clay/hr.
Kiln blower	8,000 cu. ft. air/min. at 5 p.s.i.

Additional data for this example is given in the following chart wherein reference is made to different points or stations of the kiln as follows:

Station	Location
a	Clay at top of dryer.
b	Clay at top of oven just above baffle 34D.
c	Clay lower middle part of oven just above baffle 34C.
d	Clay at bottom of cooler adjacent aggregate outlet.
e	Air at forced draft below outlet.
f	Fuel air at burner inlet.
g	Air at bottom of by-pass annulus.
h	Gas in combustion annulus.
k	Mixture of air and burned gas in bottom of dryer just above baffle 34E.
l	Air-gas mixture leaving top of dryer.

Chart

Station	*a*	*b*	*f*	*c*	*d*	*e*
Clay:						
wt./c.f.	127				113	
Rate-lb./hr.	36,750	30,300		30,300	30,300	
Moisture-lb./hr.	6,450	0		0	0	
Temp., ° F.	64	350		1,800	350	
Sp. Heat	.224				.224	
Pressure:						
lb./sq. in. ga.	0	3	5	3	0	5
Fuel:						
lb./hr.			563			
cu. ft./hr.			12,000			

Station	*f*	*g*	*e*
Air:			
Temp., ° F.	1,140	1,140	64
lb./hr.	11,640	37,800	37,800
cu. ft./min.	8,916	19,800	8,100
Sp. Heat	.254	.247	.240

Station	*l*	*k*	*h*
Exit Gas:			
lb./hr.	44,814	38,364	12,204
cu. ft./min.	16,433	24,500	35,750
Sp. Heat		.27	.262
Temp., ° F.	.350	1,380	1,800

Although the foregoing tables set forth particular operating characteristics, it should be noted that the following miscellaneous factors and/or structural particulars exist in an optimum unit constructed in accordance with the present invention:

Kiln Foundation	Monolithic Concrete Slab with Underreamed footing.
Burnt Clay Aggregate Density	104 lb./cu. ft.
Raw Clay Moisture Content	17½%.
	80%.
Thermal Efficienty of Kiln	30% natural clay, and
Flexible Road Base Material	70% burnt clay aggregate.

It will be appreciated that the range of sizes of the product will depend on the feed material. To prevent the baffle perforations from clogging the feed preferably includes no material smaller than the perforations and preferably no smaller than ¼" diameter. Smaller burnt clay can be produced by crushing the kiln product, and inevitably some fines also collect in the bottom of the kiln below the screen.

If a product having a particular distribution of sizes within a range of sizes is desired, suitable proportions of material of each desired size can be included in the feed, requiring a plurality of sets of screens and either an attendant or a proportioning apparatus to maintain the desired feed mix.

For concrete aggregate, the feed may be composed of material passing a ¾" mesh screen and retained on a ¼" mesh. For a flexible road base aggregate, larger material, e.g., passing only a 1½" screen may be used. A typical distribution of burnt clay suitable as aggregate to be mixed with fines in the ratio of 60–80% aggregate to 40–20% fines for flexible road base material would be:

	Diameter Round Opening					Mesh Spacing	
Screen Opening in Inches	1½	1	¾	½	¼	1/10	1/20
Percent Material Retained	3	21	38	58	79	91	100

After reading the foregoing detailed description, it will be understood that the objects set forth at the outset of this specification have been fully satisfied. While preferred embodiments of the invention have been shown and described, many modifications thereof can be made by one skilled in the art without departing from the spirit of the invention. Accordingly,

I claim:

1. In a multichamber shaft-type kiln for progressively drying, burning and cooling clay particles, the combination comprising an elongated hollow housing section having interior walls, said housing section having a particle inlet port at the upper end thereof and a particle outlet port at the lower end thereof; a burning chamber having exterior side walls and being disposed within said housing section between and spaced from the ends of said housing section, said exterior side walls of said burning chamber being spaced apart from and inwardly of the adjacent interior walls of said housing section and providing a gas-flow passageway within said housing section about said burning chamber, said burning chamber having a particle inlet port at the upper end thereof and a particle outlet port

at the lower end thereof; first baffle means disposed within a first upper portion of said housing section between said inlet port of said housing section and said inlet port of said chamber for directing particles therebetween along progressive paths extending angularly to the vertical axis of said housing section; second baffle means disposed within a second lower portion of said housing section between said outlet port of said chamber and said outlet port of said housing section for directing particles therebetween along progressive paths extending angularly to the vertical axis of said housing section; selectively operable conveyor means for removing particles from said housing section that have progressively traversed said first baffle means, said burning chamber, and said second baffle means; means operatively associated with said housing sections for blowing air within said second portion of said housing section past the particles therein and through said passageway into said first portion of said housing section; and means for heating said burning chamber including a combustion chamber disposed in said gas-flow passageway within said housing section.

2. The combination defined in claim 1 wherein each of said baffle means comprises a series of vertically spaced downwardly tapering frustro-conical baffles, each of said baffles having a perforate lower portion, said baffles cooperating with one another and the interior walls of said housing section to define an annular space disposed circumferentially of the lower portion of each baffle and outside of the path of particles traversing said housing section between the inlet and outlet ports thereof.

3. The combination defined in claim 1 wherein the angle of taper of said baffles with respect to the adjacent interior wall of said housing section increases with the proximity of the baffles to said outlet port of said housing section.

4. The combination defined in claim 1, wherein a third central portion of said housing section between said first and second portions thereof is diametrically enlarged with respect to said first and second portions; wherein said burning chamber comprises an inner housing disposed in said third central portion; and wherein said means for heating said burning chamber includes a combustion chamber housing disposed circumferentially of said inner housing and means supporting said combustion chamber housing in spaced relation to the adjacent interior walls of said housing section, said inner housing having gas inlet passageways therein communicating said combustion chamber housing with said inner housing.

5. The combination defined in claim 4 wherein said inner housing has downwardly tapering frustro-conical top and bottom walls terminating respectively in said particle inlet and outlet ports of said chamber.

6. In a multichamber shaft-type kiln for progressively drying, burning and cooling clay particles, the combination comprising an elongated hollow housing section having interior walls, said housing having a particle inlet port at the upper end thereof and a particle outlet port at the lower end thereof; a particle burning chamber having exterior walls and being disposed within said housing section between and spaced from the ends of said housing section, the exterior walls of said burning chamber being spaced apart from and inwardly of the adjacent interior walls of said housing section and providing a gas-flow passageway within said housing section about said burning chamber, said burning chamber having a particle inlet port at the upper end thereof and a particle outlet port at the lower end thereof, first baffle means disposed within a first upper portion of said housing section between said inlet port of said housing section and said inlet port of said chamber for directing particles therebetween, second baffle means disposed within a second lower portion of said housing section between said outlet port of said chamber and said outlet port of said housing section for directing particles therebetween, selectively operable conveyor means disposed at the outlet port of said housing for removing particles from said housing section that have progressively traversed said first baffle means, said chamber, and said second baffle means, variable speed fan means operatively associated with said housing sections for blowing air within said second portion of said housing section past the particles therein and through said passageway into said first portion of said housing section, means for heating said burning chamber including burner means, a fuel inlet conduit to said burner means and valve means in said conduit, a combustion chamber disposed in said passageway adjacent said burning chamber and communicating therewith, said burner means communicating with said combustion chamber, first thermostat means for sensing a first temperature at the base of said first upper section and varying the speed of said fan means in accordance with variations in said first temperature, second thermostat means for sensing a second temperature in said combustion chamber and operating said valve means in accordance with variations in said second temperature, and third thermostat means for sensing a third tempertaure at the base of said burning chamber and operating said conveyor means in accordance with variations in said third temperature.

7. The combination defined in claim 6 wherein said combustion chamber is at least substantially circular and is disposed in adjacent surrounding relation to said particle burning chamber and communicates therewith, and wherein said burner means includes a plurality of gas burners and conduit means directing the combustion products of said gas burners tangentially of said combustion chamber.

8. The combination defined in claim 6 and further including auxiliary conduit means communicating said passageway with said gas burner means to feed pre-heated air to said burner means.

9. The combination defined in claim 8 and further including suction fan means in said auxiliary conduit means.

10. In a multichamber shaft-type kiln for progressively drying, burning and cooling clay particles, the combination comprising an elongated hollow housing having interior walls, said housing having a particle inlet port at the upper end thereof and a particle outlet port at the lower end thereof; said housing comprising first, second and third releaseably joined coaxially aligned sections, said first and second sections being disposed respectively above and below said third section, a burning chamber disposed within said third section of said housing between and spaced from the ends of said housing, said burning chamber having exterior side walls spaced interiorly from the adjacent interior walls of said third section of said housing and providing a passageway through said third section of said housing about said burning chamber, said burning chamber having a particle inlet port at the upper end thereof and a particle outlet port at the lower end thereof, first baffle means disposed within said third section of said housing between said inlet port of said housing section and said inlet port of said chamber for directing particles therebetween along paths extending angularly to the vertical axis of said housing, second baffle means disposed within said second section of said housing between said outlet port of said burning chamber and said outlet port of said housing for directing particles therebetween along paths extending angularly to the vertical axis of said housing, means operatively associated with said housing sections for blowing air within said second section of said housing section past particles therein and through said passageway into said third section of said housing and a combustion chamber means disposed in said passageway for feeding hot gases to said burning chamber.

11. The combination defined in claim 10 wherein said third section is diametrically enlarged relative to said first and second sections, and wherein said combustion chamber means comprises an auxiliary housing disposed with-

in said elongated hollow housing in said passageway and in surrounding relation to said burning chamber.

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