

May 3, 1966

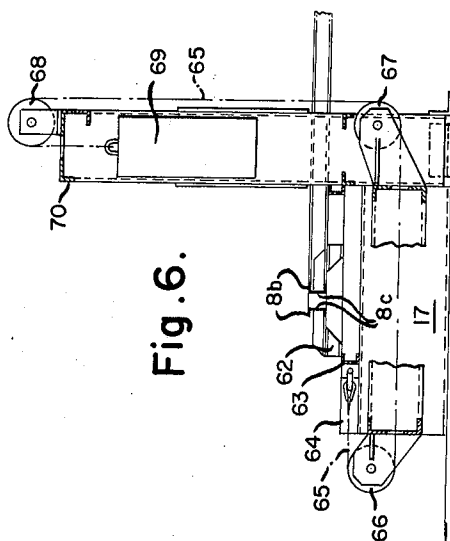
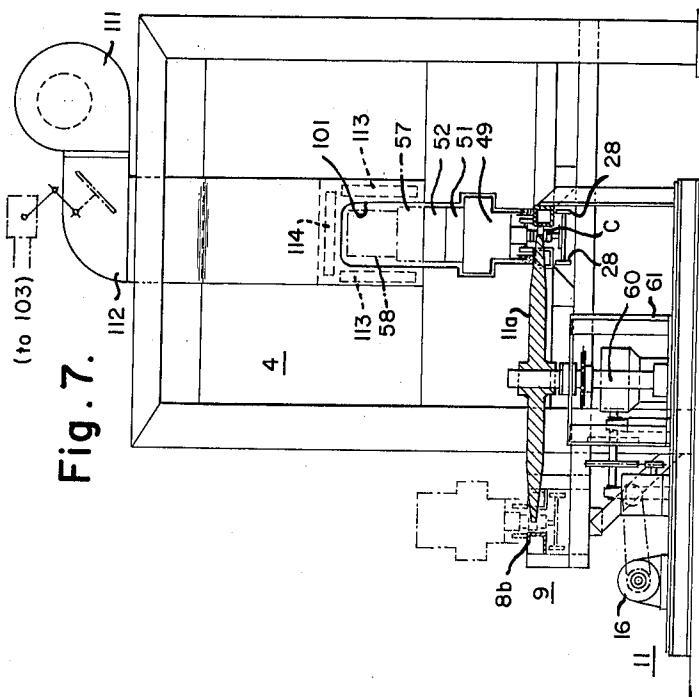
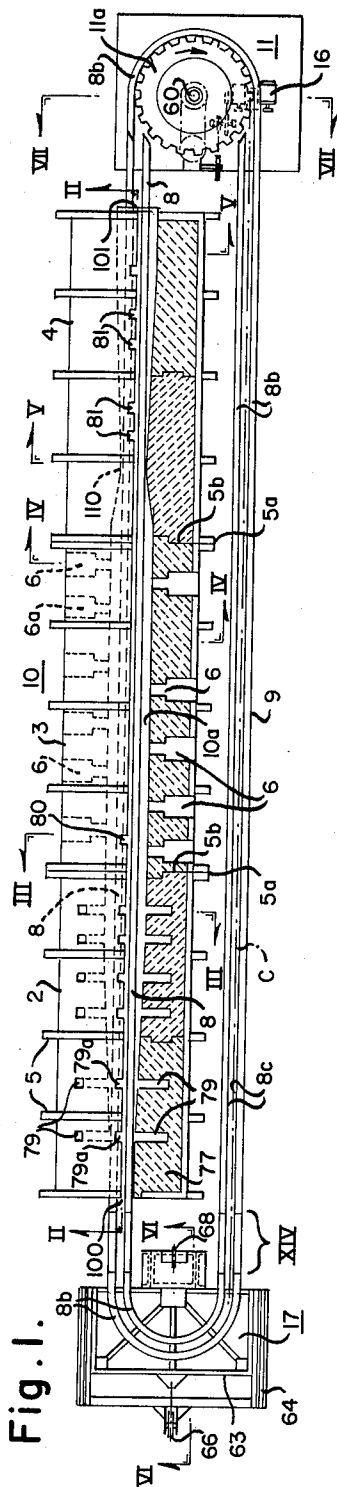
P. D'H DRESSLER

3,249,663

TUNNEL KILN SYSTEM

Filed July 16, 1963

5 Sheets-Sheet 1



INVENTOR
Philip d'H. Dressler

By *Hopewell, Leonard & Paul*
his attorneys

May 3, 1966

P. D'H DRESSLER

3,249,663

TUNNEL KILN SYSTEM

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5 Sheets-Sheet 3

Fig. 8.

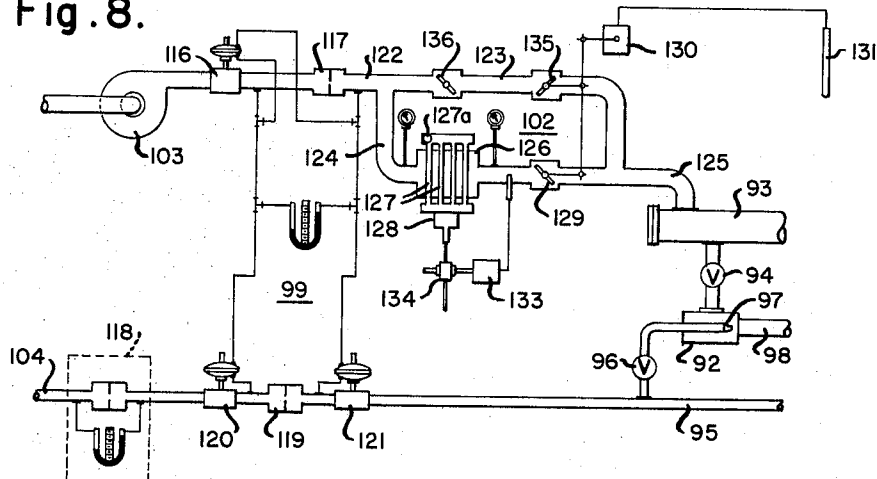


Fig. 9.

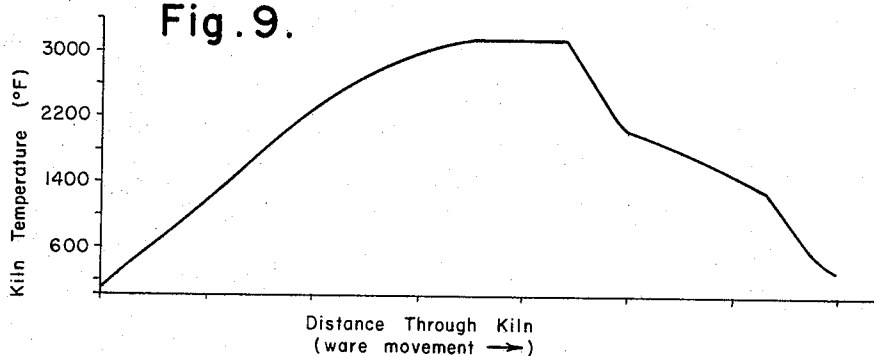


Fig. 14.

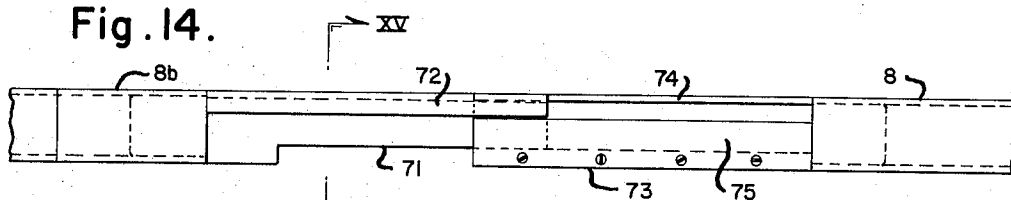
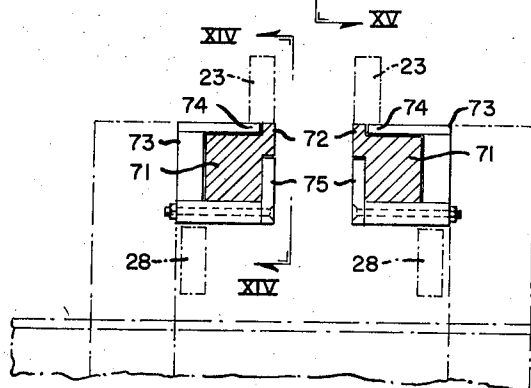


Fig. 15.



INVENTOR

Philip d'H. Dressler

James Leonard & Duff
his attorneys

May 3, 1966

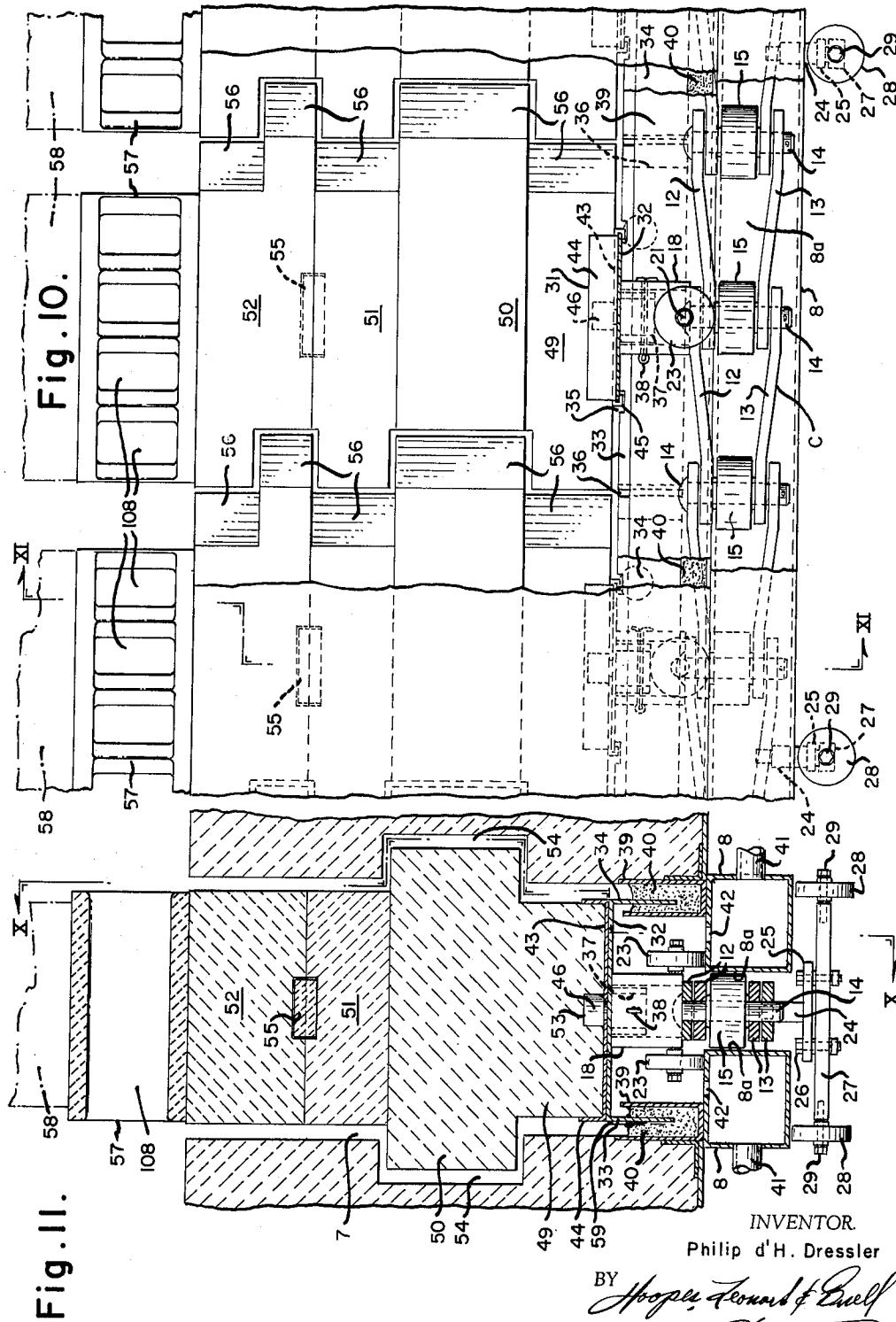
P. D'H DRESSLER

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TUNNEL KILN SYSTEM

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5 Sheets-Sheet 4



INVENTOR.

Philip d'H. Dressler

BY

Hooper, Leonard & Quill
his attorneys

May 3, 1966

P. D'H DRESSLER

3,249,663

TUNNEL KILN SYSTEM

Filed July 16, 1963

5 Sheets-Sheet 5

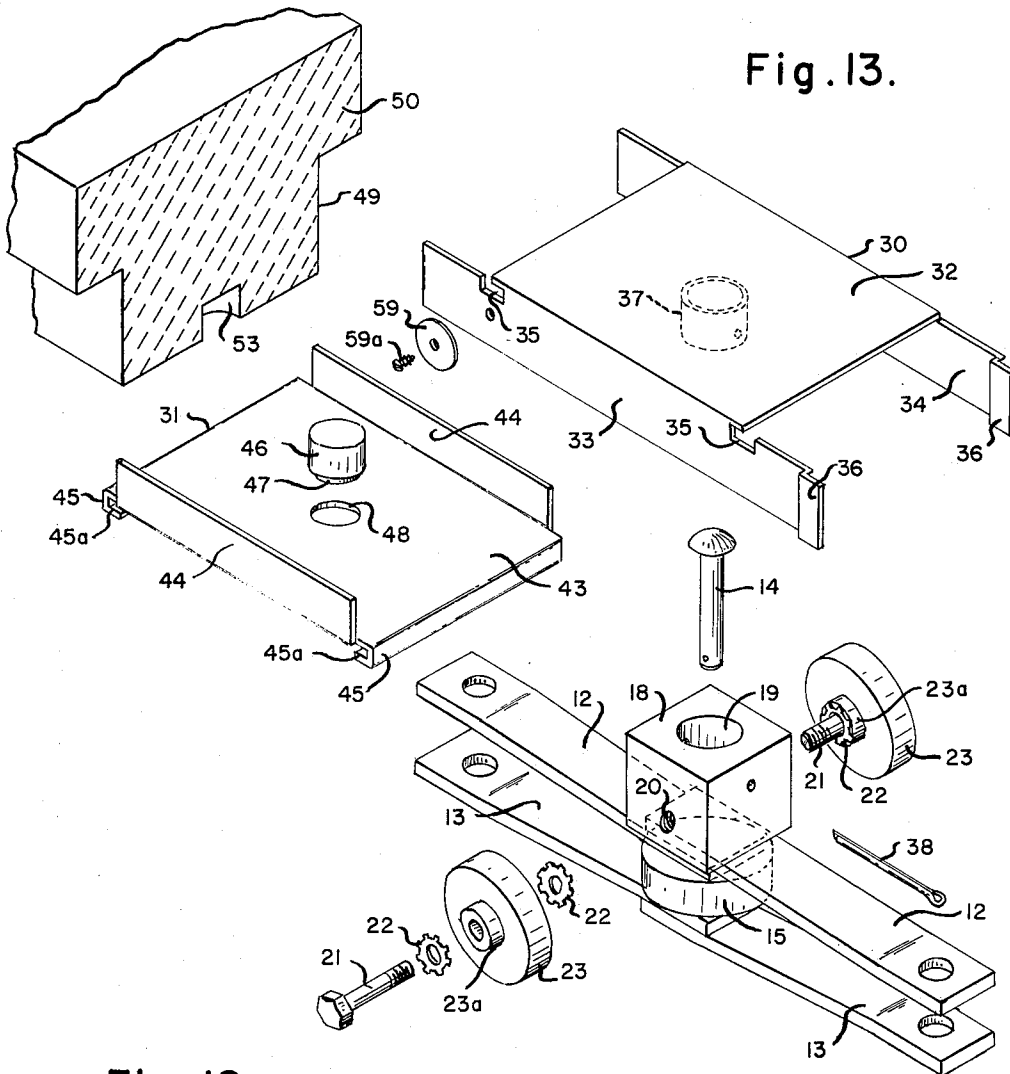


Fig. 13.

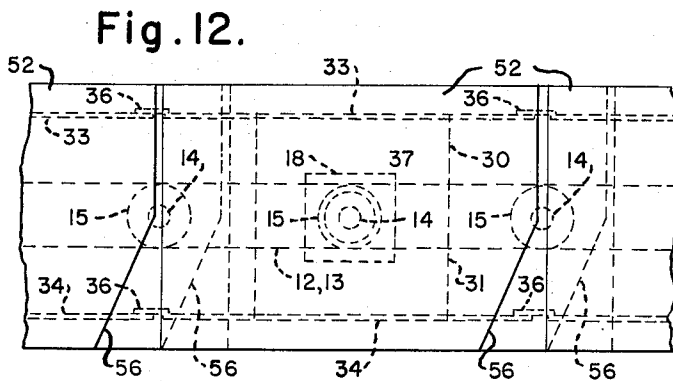


Fig. 12.

INVENTOR.

Philip d'H. Dressler

BY *Hooper, Leonard & Bull*
his attorneys

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3,249,663

TUNNEL KILN SYSTEM

Philip d'H. Dressler, Pittsburgh, Pa., assignor, by mesne assignments, to Pullman Incorporated, a corporation of Delaware

Filed July 16, 1963, Ser. No. 295,335

8 Claims. (Cl. 264—66)

This invention relates to a tunnel kiln system of the direct-firing kind which can be relatively closely and quickly regulated and controlled even at very high temperatures and/or even with relatively small loads, whether constant or variable. More particularly, this invention pertains to such a tunnel kiln capable of heating ware, such as, for example, small ceramic items and the like, to temperatures approaching theoretical flame temperature and including, if and when necessary or desirable, quickly varying the firing response by control of the combustion air temperature when variations occur in the size or quantity of the load being fired. The tunnel kiln system of this invention, further, includes when desired, continuous conveyor mechanism of unique design with provision for the shielding thereof from kiln temperatures and cooperation in maintenance of the regulation of combustion and gas flows within such tunnel kiln.

Thus, I have devised a kiln having a tunnel extending therethrough which may be fired with conventional fuel such as fuel gas and which will remain substantially on the selected ratio of combustion air and fuel gas for the achievement in such kiln of very high temperatures, including those producible above the flame temperature achievable with the utilization of combustion air at ambient temperature. Moreover, I can regulate and control such a kiln even though it is of relatively tiny size as in the case of one used to fire the purer forms of alumina in the making, for example, of ceramic electronic components and the like in quantity. Further, not only may the temperature of the kiln of this invention be held to within a very few degrees of the selected ware-firing temperature, but that firing temperature in the kiln firing section may be relatively close to the theoretical flame temperature. Such is possible even though when the load is small as aforesaid so that substantial masses are not available to preheat much air in the cooling section of the tunnel. Thus, in my kiln I have also provided what is substantially an orifice restriction which assists in regulating the amount of air passing from the cooling section into the firing chamber section for what in effect amounts to a metered flow operation to keep the selected combustion ratio practically constant even though the kiln is open at both ends and throughout the length of the tunnel therein. Further, the flexibility of a kiln of my invention is such that even though the load be small and also variable, with the desired firing temperature extremely high, I can still regulate and control the kiln promptly to hold the desired kiln firing temperature by a relatively rapid change, by the direct burning of heating fuel, in the temperature of the combustion air supplied to the firing chamber section through the burners to raise the flame temperature almost instantaneously. Thereby, there is virtually instantaneous temperature control response in such firing chamber section consonant with any such variation in the load as it passes through the firing chamber section of the tunnel. Such is of extreme importance when working with relatively minute thermal heads because if efforts are made to increase the amount of fuel fed to the burners firing into the firing chamber section, the response is too sluggish relative to the selected time cycle in the kiln for the firing of the ware passing therethrough and the same too great lag results if the use of recuperative heat exchange is attempted. Hence, in the teaching of my tunnel kiln system herein, by direct fuel combustion heating of com-

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bustion air in selected proportion, the temperature of the combustion air, particularly in small ware mass kilns, can quickly be varied in accordance with the temperature desired in the firing chamber section to correspond with and take care of any change in conditions such as the size, weight and/or fill of the load which made such response action necessary, or desirable.

Still further, in the illustrated embodiment disclosed herein, I dispose the load or ware to be fired and spacer means atop refractory means preferably in the form of stacked refractory shapes which move through a passageway parallel to the firing chamber of the kiln, the passageway being below and communicating with the firing chamber and the refractory means extending upwardly in the passageway to a level such that ware to be fired disposed atop the refractory means passes through the whole of the tunnel including the preheating, firing and cooling sections. Such refractory shapes form a relatively and substantially continuous kiln bottom or hearth cooperating with the balance of the kiln system. Further, the load and spacer means cooperate in maintaining orifice conditions within the tunnel which conduce to heating the ware to very uniform selected temperature in a kiln of this invention even though the load be relatively small and/or variable; and/or even though the ware temperature to be achieved approaches the theoretical flame temperature.

Means constituting a guideway extend through the passageway and a continuous succession of supporting means are guided by the guideway, the supporting means supporting the refractory means upon which the ware being fired is disposed. Means are provided for moving the continuous succession of supporting means along the guideway. The refractory means when in the passageway below the tunnel preferably at least largely span the passageway transversely substantially throughout the lengths of the refractory means and the refractory means carried by adjacent supporting means preferably also have generally horizontal overlapping portions extending longitudinally at their ends to protect the supporting means from heat and radiation present in the tunnel. Overlapping sealing means are preferably carried by the supporting means sealing the supporting means to the sides of the passageway. Such sealing means preferably comprise elongated flanges with offset overlapping ends carried by the supporting means projecting into longitudinal continuous upwardly open channels at opposite sides of the passageway to cooperate with sealing material in the channels and about the flanges. The sealing means are preferably disposed at a level approximating the level of the bottom of the refractory means.

The refractory means are preferably in the form of refractory shapes disposed in stacks with shapes of successive layers of each stack arranged in longitudinally staggered relation and with the refractory shapes of adjacent stacks overlapping at their ends.

At least certain of the supports carrying refractory shapes at spaced intervals along the supporting means are preferably laterally withdrawable for replacement of expended or damaged refractory shapes. Desirably a support carrying a stack of refractory shapes is laterally withdrawable so that any shapes in the stack which are expended or damaged can be replaced. I normally cement together into a composite unit the lower refractory shapes of each stack and position the top refractory shape or the top two refractory shapes atop the underlying refractory shapes of the stack so that the top refractory shape or the top two refractory shapes may be quickly lifted off and replaced. Key means are preferably provided for positioning the refractory shapes which are not held in place by mortar to insure their maintaining their proper stacked or vertically aligned positions in relation to the underlying shapes.

It is not necessary to provide for lateral withdrawal of each stack of refractory shapes although each such stack may be made laterally withdrawable if desired. Withdrawal of a stack of refractory shapes renders refractory shapes in an adjacent stack replaceable even though that stack as a whole is not laterally withdrawable.

The supporting means with the refractory means thereon move in a closed conveyor path with curved ends as illustrated herein. The ends of the refractory means preferably are shaped so that refractory means on adjacent supports can be substantially continuous and yet not interfere with each other when passing about a curved portion of the path. Thus, corners of the refractory means which pass on the inside of the curve are preferably cut off so that adjacent refractory means do not interfere with each other on a curve. Alternatively, the ends of longitudinally adjacent refractory shapes may be complementarily curved along radii to interfit while providing for traversing a curved portion of the path without interference between longitudinally adjacent shapes.

The supporting means for the stacks of refractory shapes may include base elements and supporting elements carried by the base elements with connections between each base element and the corresponding supporting element holding the supporting element down on the base element but permitting the supporting element while guided by the base element to be laterally withdrawn preferably from the outer side of the conveyor mechanism. Each supporting element may interfit with its base element for guided lateral movement. A portion of each base element preferably acts as a stop to limit inward movement of the supporting element carried thereby when the supporting element is centered over the base element and means may be provided to keep such elements from separating when in use together.

My kiln in a preferred form has a generally tunnel shape, a passageway parallel to the firing chamber below and communicating with the tunnel, means constituting a closed guideway having a portion extending through the passageway and a return portion outside the passageway, an endless operating element guided by the guideway, means for driving the endless operating element and refractory shapes adapted to carry ware to be fired mounted atop the endless operating element to move therewith. The endless operating element may be a chain. Adapters may be mounted on the endless chain and supporting means may be mounted on the adapters for carrying the refractory shapes. The endless chain may have its pintles arranged vertically and means whereby the endless chain is guided by the guideway and the adapters may be mounted atop links of the endless chain.

Spaced apart guide members preferably constitute parts of the closed guideway and extend through the passageway, the endless chain or other operating element being disposed between the guide members and guided thereby, carrying means connected with the endless operating element may ride on the guide members for supporting the endless operating element and other means may extend below to prevent tipping. Other means may be provided for driving and keeping the endless operating element under tension and to take-up wear therein or to allow for expansion and contraction thereof.

The guide members may be hollow at least in the passageway and means may be provided for introducing coolant thereinto. Coolant also may be introduced between the guide members and into the space between and below the sealing means. In this way a controlled quantity of coolant, normally air, may be introduced into contact with the chain or other endless operating element and the means cooperating therewith to maintain them at suitable temperatures below the temperatures. Means are preferably connected with the endless operating element engaging the guide members top and bottom to maintain the endless operating element at a predetermined level.

The spaced apart guide members may have substan-

tially upright opposed faces and the endless operating element when in the form of a chain with its pintles arranged vertically may have guide rollers carried by the pintles disposed between the substantially upright opposed faces of the guide members to guide the chain. In a preferred form the guide members in the passageway are in the form of tubes of rectangular cross section.

Other objects, features and advantages of this invention will be apparent from the following description and the accompanying drawings, which are illustrative of one embodiment only, in which

FIGURE 1 is a plan view of one embodiment of a tunnel kiln system of this invention with the kiln itself in staggered line partial section taken along line I—I of FIGURE 3 and with the hoods, burners and burner blocks omitted for purposes of clarification;

FIGURE 2 is a view in vertical elevation and section through the center line of the kiln tunnel itself taken in the direction of line II—II of FIGURE 1 with, as in FIGURE 1, the refractory shapes carried by the supporting means, load and spacer means also omitted for purposes of clarification and except that the exhaust hoods have been shown in position in chain outline;

FIGURE 3 is a view in staggered vertical cross section taken along line III—III of FIGURE 1;

FIGURE 4 is a view taken in staggered vertical cross section taken along line IV—IV of FIGURE 1;

FIGURE 5 is a view in staggered vertical cross section taken along line V—V of FIGURE 1;

FIGURE 6 is a view in side elevation and cross section taken along line VI—VI of FIGURE 1 illustrating a take-up means for the endless operating element which also embodies one mode of curved end of the conveyor mechanism at the entry end of the kiln;

FIGURE 7 is a view in vertical elevation and cross section taken along line VII—VII of FIGURE 1 showing one mode of drive and tensioner for the endless operating element comprising a curved end for the conveyor mechanism at the exit end of the kiln which also is shown in end elevation;

FIGURE 8 is a schematic diagram showing one mode of a combustion air and fuel gas ratio regulator combined with means for selecting the temperature of the combustion air to provide relatively rapid response in the firing chamber section of the kiln in accord with the sensing of a temperature element;

FIGURE 9 is an illustrative diagram of kiln temperature against time such as is achievable by a practice of this invention;

FIGURE 10 is a fragmentary side view with portions broken away generally along line X—X of FIGURE 11 to illustrate the conveyor mechanism in the illustrated embodiment and associated supported parts in position within the kiln;

FIGURE 11 is a cross-sectional view taken along line XI—XI of FIGURE 10;

FIGURE 12 is a fragmentary detail view in plan of the conveyor mechanism and refractory shape construction illustrated in FIGURES 10 and 11;

FIGURE 13 is an exploded isometric view showing one unit of the supporting means and a portion of the refractory shapes in the endless operating element designed to carry the load and spacer means through the kiln;

FIGURE 14 is a detail view in side elevation of a telescoping element portion of the guideway provision viewed along line XIV—XIV of FIGURE 15; and

FIGURE 15 is a detail view in cross section taken along line XV—XV of FIGURE 14.

Referring now more particularly to the drawings, the kiln 10 in the illustrated embodiment comprises a pre-heating chamber section 2, a firing chamber section 3 and a cooling chamber section 4. The kiln is supported by steelwork designated generally by reference numeral 5 the details of which may be conventional and do not con-

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stitute the invention. The kiln has a continuous tunnel 10a extending longitudinally therethrough with its axis perpendicular to the paper in FIGURES 3 to 5, inclusive, and 7. The firing chamber 3 has burner port 6 along opposite sides and like the tunnel 10a is otherwise completely surrounded by built-in refractory structure except for a passageway 7 which is parallel to and below tunnel 10a into which it opens as shown in FIGURES 2 to 5 when no refractory shapes fill the passageway. In the form shown the passageway 7 is substantially narrower than the firing chamber 3.

The kiln system of this invention has conveyor means for the ware which in the illustrated embodiment comprise a closed guideway, although other apparatus may be used. Such means include spaced apart guide members in the form of square tubes 8 suitably carried by the steelwork 5 which extend through the passageway 7 and in the form of spaced apart channels 8b in the return portion or reach 9 outside the passageway, the ends of the closed guideway being constituted by curved ends comprising sprocket mechanism 11 and take-up mechanism 17.

An endless operating element shown as in the form of a chain designated generally by the letter C is provided for operating in the closed guideway. The chain has top links 12 and bottom links 13 pivotally connected by pintles 14, the axes of the pintles being vertical. Each pintle 14 carries intermediate the link ends a guide roller 15. The rollers 15 are disposed between the opposed upright faces 8a of the tubes 8 on the kiln reach and faces 8c of channels 8b on the return reach and guided thereby. As the chain passes around the sprocket 11a, the rollers 15 leave the inside tube 8 and are engaged between the teeth of the sprockets. The drive sprocket 11a rotates in a clockwise direction when viewing FIGURE 1. It is driven by an electric motor 16 through suitable connections and reduction gearing shown in FIGURES 1 and 7. The sprocket itself is fixed to a vertical spindle 60 journaled in a frame 61 and rotated by motor 16. The sprocket is mounted in the plane of the guideway to revolve at the selected speed in uninterrupted continuous fashion, or in intermittent continuous fashion, as desired.

Mounted atop an end of each alternate top link 12 is an adapter 18. Each adapter 18 is in generally the form of a cube as shown and may be welded to the link. Each adapter 18 has a vertical central bore 19. It also has a horizontal bore 20 intersecting the vertical bore and tapped in from opposite sides. Mounted on each side of the adapter through the horizontal bore 20 by a screw 21 and lock washers 22 is a carrying roller 23. Each roller 23 turns about a bearing sleeve 23a which is locked to the adapter by the screw 21, which threads into the bore 20, and the lock washers 22. The rollers 23 roll upon the upper surfaces of the tubes 8 and channels 8b. At least certain of the lower links 13 (perhaps every fourth link) have mounted thereto and projecting downwardly therefrom studs 24 each having at its lower extremity a plate 25 to which is fastened by bolts 26 a transverse wheel support 27 having lower rollers 28 mounted thereon by screws 29. The rollers 28 and their mounting means may be similar to the rollers 23 and their mounting means. The rollers 28 are normally slightly spaced from the bottoms of the tubes 8 as shown in FIGURES 10 and 11 but are adapted to engage the bottoms of the tubes and channels respectively if any force tends to raise the chain or if there is any tendency for the load to tilt or become unsteady. Thus the endless chain is effectively guided by the tubes 8 and channels 8b and driven by the driving sprocket 11a. The chain moves in a clockwise direction viewing FIGURE 1 and as the inner guide tube 8 becomes tangent to the diameter of sprocket 11a, such inner guide tube 8 terminates and is blanked off. The outer tube 8 is blanked off at approximately the same location and the outer guide is continued around the curved end by the outer channel 8b. The carrying rollers 23 are supported around such curved end on the outer side by channel 8b

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and on the inner side by the upper side of the peripheral margin of the sprocket 11a itself. The inner guide 8b on the return reach 9 resumes again at the delivery end of mechanism 11 as shown in FIGURE 1 when the inner rollers 23 transfer again from the sprocket 11a to such inner rail 8b in reach 9. The blanking off of the respective ends of the tubes 8 in the kiln reach of the conveyor mechanism make it a hollow tube through which coolant as aforesaid may be circulated through circulation pipes 41 preferably located adjacent the respective ends of such blanked off tubes 8. In going around the curved end where mechanism 11 is located, the lower rollers 28 hang with the outer one close to the underside of the outer curved channel portion 8b. If desired, an annular ring may be placed on the underside of sprocket 11a to be in proximity to the inner roller 28 for steadying, chain control and/or anti-tipping purposes. Thus, the turning of the sprocket 11a not only keeps the endless operating chain element C straight in the kiln reach and under tension particularly as the ware proceeds through the kiln 10, but also regulates with precision the kiln time of the ware.

The take-up mechanism 17 provides the other curved end of the closed guideway at the entry end of kiln 10 as illustrated in FIGURES 1 and 6. As shown, the guides at that end comprise curved channel portions 8b between the return reach 9 and the kiln reach. Such curved portions are fixed to brackets 62 connected to a rigid frame 63 which is slidable in rigid frame 64 fastened to the plant floor. A cable 65 is reeved around sheaves 66 and 67 pivotally mounted on frame 64 and then passes over a top sheave 68 for connection to a counterweight 69 in a vertical portion 70 of frame 64. In that way, the chain C is kept taut and any slack or wear in the pintles or otherwise is constantly taken up due to the gravity pull of the counterweight 69, suitable telescoping elements being provided in the inner and outer rails of the return and kiln reaches between the take-up mechanism 17 and the transverse plane at the entry end of kiln 10, the location of such telescoping elements being indicated by the bracket marked XIV in FIGURE 1.

Such telescoping elements in each guide comprise a male portion 71 having an upstanding guide track flange portion 72 and a female portion 73 having a horizontal guide track portion 74, a removable cover strip 75 being used to keep the male portion 71 in place in element 73 and elements 71 and 73 to slide in telescoping relation to one another, with the horizontal upper edge of flange 72 always being on the level of upper surface of flange portion 74 and overlapping the same longitudinally. Thus, in passing over the telescoping elements, the respective rollers 23 shown in chain outline track on and are supported by portions 74 of the female element along the length thereof which is not in overlapping relation to the male element 71 and on the flange 72 in the portion of the male element 71 that is not in overlapping relation with female element 73, as indicated by FIGURE 15. Hence, any take-up, or any expansion or contraction of the chain element C, can readily be accommodated by the telescoping elements 71 and 73 in the respective guides without interruption of the supporting surface of the guides for rollers 23 around the entirety of the closed guideway. If desired, the entry curved end of the guideway contained in mechanism 17 may be replaced by a synchronized driving or idler sprocket arrangement.

Mounted atop each adapter 18 are supporting means including a base element 30 and a supporting element 31. Each base element 30 has a horizontal body 32 with parallel downwardly extending flanges 33 and 34 at its sides. The flanges 33 are the outside flanges and the flanges 34 are the inside flanges having relation to the closed path. Each of the outside flanges 33 has a notch 35 adjacent each end of the body 32 as shown in FIGURE 13. The flanges 33 and 34 extend beyond the body 32 at both ends and each of the flanges is offset at one end at 36 to interfit with the end of the corresponding flange of an adjacent

base element. Disposed centrally of each base element and projecting downwardly therefrom is a hub 37. The hub 37 may be welded to the base element. Each hub 37 enters the bore 19 of one of the adapters 18 and a cotter pin 38, or a taper pin, extends through the adapter and the hub as shown to fasten the base element to the adapter.

Mounted atop the tubes 8 in passageway 7 are longitudinally extending continuous upwardly open channels 39 into which the flanges 33 and 34 project. Sealing material 40 shown as being sand, although other sealing material may be used, is disposed in the channels 39 and about the flanges 33 and 34 to seal the space beneath the base members from the outside and form access by hot gases from the firing chamber. Coolant, normally air, may be introduced into the tubes 8 through pipes 41; and tubes 8 may be provided with ports 42 for passage of the coolant upwardly through ports 42 into the space between the seals to cool the chain and its supporting structure, or a further perforated cooling pipe 109 may be provided.

Each supporting element 31 has a body 43 and opposed upward flanges 44 at opposite sides with downwardly and inwardly extending flanges 45 at both ends forming channels 45a. Each supporting element is adapted to be laterally applied to and withdrawn preferably from the outside of the corresponding base element 30 by interfitting the ends of the body 32 of the base element into the channels 45a formed by the flanges 45 of the supporting element, which flanges 45 pass through the notches 35 in the outer flange 33 of the base element, and moving the supporting element laterally to and from a position centered atop the base element. When the inner ends of the flanges 45 engage the inner face of the flange 34 the supporting element is properly centered on the base element. A pan retaining washer 59 with a self-tapping screw 59a to hold it in place on flange 33 overlapping notch 35 will keep the elements 31 and 32 in assembled relation during use. An upstanding refractory holding pin 46 is applied to the top center of each supporting element 31, the pin having a reduced downward extension 47 which enters but does not pass beyond a bore 48 in the body 43 of the supporting element 31 to which it may be welded.

Each supporting element 31 carries a stack of refractory shapes. In the drawings three-high stacks of refractory shapes are shown. The bottom shape in each stack is designated 49, the middle shape is designated 51 and the top shape is designated 52. Each shape 49 has a well 53 in its bottom center receiving the pin 46 projecting upwardly from the corresponding supporting element 31. The bottom of the shape 49 fits between the flanges 44 of the supporting element 31 which hold it against lateral movement and it is held against longitudinal movement by the retaining pin 46. The bottom portion of the shape 49 when in the passageway 7 substantially spans the passageway transversely and substantially throughout the length of the shape with suitable clearance for movement thereof along the passageway, as shown in FIGURES 10 and 11.

Each shape 49 has a relatively wider upper portion 50 which at both sides extends into longitudinal channels 54 in the walls of the passageway 7 as shown in FIGURE 11. Also the portion 50 preferably is longitudinally offset relatively to the bottom portion of the shape 49 as shown in FIGURE 10.

Each refractory shape 51 is disposed atop the corresponding shape 49 in substantially vertical alignment with the lower portion thereof as shown in FIGURE 11. It also largely spans the passageway 7 substantially transversely and throughout its length.

The top refractory shape 52 of each stack has a lower portion which substantially overlies the upper portion 50 of the bottom shape 49 and an upper portion which substantially overlies the bottom portion of the shape 49 and also overlies the shape 51. The shape 52 like the other shapes largely spans the passageway 7 substantially

transversely and throughout its length. And, longitudinally adjoining stacks on longitudinally adjoining elements 31 also interfit at their respective ends to provide what is virtually a continuous, articulated refractory support adapted to move in passageway 7 and support ware in tunnel 10a during the passage of such ware therethrough.

The shape 51 of each stack is mortar bonded or keyed to the shape 49 to form a composite unit. However, the top shape 52 is simply laid upon the middle shape 51 and is kept in central position thereon by a key 55. This is done because the top shape is usually the one which is most likely to become expended or damaged so that it has to be replaced. The supporting element 31 with its stack of shapes thereon may be withdrawn laterally relatively to the base element 30 as above explained. When the channels 45a formed by the flanges 45 of the supporting element 31 interfit with the ends of the body 32 of the base element 30, relative vertical or longitudinal movement between the supporting element and the base element are prevented while permitting the supporting element to be laterally withdrawn and replaced preferably, as shown, from the outside of closed guideway exteriorly of kiln 10.

The stacks of refractory shapes are also uniform and as they interfit longitudinally with one another and transversely with the sides of passageway 7 as shown in FIGURES 10 and 11, they form an effective resistance against gas flow through passageway 7 and barrier against radiation downwardly from tunnel 10a inclusive of the firing chamber 3. One inner corner of each of the refractory shapes is cut back so that adjoining refractory shapes in the same layer do not interfere with each other when passing about a curved portion of the guideway. FIGURE 12 shows an inner corner of each shape cut away at 56. Thus clearance is provided for the adjacent corner of the next shape as the stacks of shapes transverse the curved portions of the guideway.

Mounted atop each stack of refractory shapes on spacers 57 on which are set trays 58 in which small items of ware may be placed for firing in kiln 10, or the ware may be placed directly on setters 57. As above indicated, each stack of refractory shapes extends upwardly to a level such that the setters and ware to be fired are disposed atop the stack and are within the tunnel 10a to pass through the firing chamber 3 therein.

Sections 2, 3 and 4 of kiln 10 may be prefabricated, if desired, horizontally aligned and secured together through the adjoining end bindings 5a of such respective sections, the adjoining refractory surfaces being transversely stepped to interfit as indicated at 5b and other transverse stepped portions in the refractory walls and roof 77 may be provided along therewith to accommodate thermal expansions and contractions in the course of the use of the kiln. Preferably, the outside surface of refractory walls and roof are covered with stainless steel sheathing 78 inside of the kiln bindings 5 to further reduce heat loss. Side flues 79 extend outwardly and upwardly through the refractory 77 in preheating section 2, while crown flues 79a in the preheating section, 80 and 81 in the cooling section 4 extend between tunnel 10a and the outside of the kiln. Normally, there is a flue tile 84 positioned on top of the kiln adjacent the exit end of each flue to regulate the size thereof in accordance with the flow of gases and pressures desired inside the kiln at respective points along the length of the tunnel 10a, suitable manometer readings being taken for such purpose in providing for that aspect of kiln regulation as will be understood by the skilled in the direct-fired kiln art. Transverse roof offsets 85, 86 and 87 may be provided in tunnel 10a to aid as baffles in controlling flows of gases within tunnel 10a. Preferably, exhaust hoods 82 and 83 are used to vent flue gases upwardly to the outside of the building in which kiln 10 normally would

be located. Other flue arrangements may be constructed in a kiln of this invention.

Firing chamber section 3 is provided with a sprung arch 88 in the roof of section 3 made of laid-up refractory brick to withstand the very highest of temperatures when kiln 10 is so operated. As shown, kiln 10 is provided with premix burners 89 adapted to fire through inwardly flaring burner blocks 90 positioned at the inner end of the burner ports 6. Each burner port is lined with refractory brick 91 in an inverted U-shape which may be pulled outwardly slightly at the edge of the stainless steel sheathing to protect it against any flame licking out. Each of the burners 89 has a nozzle located at the burner block for the discharge of a selected combustible ratio mixture of combustion air and fuel gas which are admixed in a mixer 92. As shown in FIGURES 4 and 8, combustion air is supplied from a combustion air header 93 through a valve 94 in the pipe to each mixer 92 and therein meets and mixes with gas from a fuel gas header 95 which passes through a preset regulatory valve 96 into an injection mixer nozzle 97, the resulting combustible premixture flowing out through pipe 98 into the nozzle at the inner end of burner 89. Such premixture preferably is held in close to theoretical combustion ratio by a ratio regulator 99 and remains relatively close to ratio in the combustion thereof in the firing chamber section 3 of kiln 10 even though the entry portal 100 and exit portal 101 of kiln 10 are always open.

As hereinafter more fully described, ratio regulator 99 also has associated therewith a selectively operative combustion air heater 102. Combustion air for header 93 is supplied by a fan 103, while the fuel gas enters the kiln system through a gas main 104. Cooling air from an independent source may be supplied through pipes 105 and branches 106 having valves therein form small streams of cooling air to be discharged into the outer ends of the burner ports when it is desired to keep such ports relatively cool. In general, the same number of burners in the same general location on each side will be used depending upon the service in which the kiln 10 is employed. Burners not in use in a particular operation of the kiln generally will be disconnected and removed from the port and the port will be closed with loose brick until it is put back in service. It will be noted that the respective burner ports 6 and burners 89 on the respective sides of kiln 10 are preferably longitudinally offset insofar as respective pairs thereof are concerned, for the purpose of providing transverse circulation in the firing chamber 3 portion of tunnel 10a. Such circulation may be enhanced by having one of the burner ports and burners on each side at a higher location 6a as indicated in FIGURES 2 and 4. Such circulation occurs in that the combustion gases upon discharge move forward in the direction of the axis of the burner, normal to the axis of the kiln, toward the opposite wall of the tunnel which may be provided with a filleting refractory piece 107 after passing through the laterally extending spaces 108 in the spacers 57 on which rest the ware-containing refractory trays 58. Thus, there will be a tendency opposite each burner for the combustion gases to loop around the axis of the tunnel at that location for most effective heating of the ware. The same source of air which supplies the pipes 105 may be used to supply coolant air to pipes 41 and to a longitudinally extending pipe 109, if desired, the top of which is perforated along the length thereof to blow such coolant air upwardly toward the underside of passageway 7 between the guide tubes 8. Pipe 109 may be supported along and by the undergirding framework of kiln 10.

Adjacent the discharge end of the portion of firing chamber section 3 the side walls of tunnel 10a converge rearwardly to form a venturi-like portion 110 which acts as a meterable restriction or orifice in the normal operation of the kiln 10. Restriction 110 assists in regulating the amount of air which moves from the cooling section 4 into the firing section 3 in the quantity desired and co-

operates with the predetermined quantity of such air supplied at portal 101 toward the entry end of cooling section 4 and the firing section 3. Such air for the cooling chamber is provided by a fan 111 at selected pressure through a downwardly extending duct 112 having inwardly and longitudinally directed slotted leg openings 113 and lintel opening 114 surrounding the portal. Such openings preferably are provided with lips 115 to direct the air from the slotted openings 113 against the side walls of tunnel 10a and the air from slot 114 against the flat roof of section 4, such cooling air moving forwardly toward the entry end of kiln 10 in heat exchange relation to the ware and associated elements moving through section 4, such air being exhausted to a predetermined extent through flues 81 and the remainder passing through restricted portion 110. Gases in the firing chamber section 3 circulate around the ware heating it to selected firing temperature therefor and pass forwardly toward the entrance end for discharge in regulatable proportions through the flues 79, 79a and 80. Control of gas flow through tunnel 10a is greatly assisted in that the end conforming configuration of entry portal 100 to the entering endless operating element C, refractory shapes, setter and load minimizes leakage and restricts passage of gas there-through, as similarly does the closeness of the sides of the portal 101 to the exiting fired ware and associated moving parts.

Such a controllable kiln 10 has unique advantage in terms of the relative rapidity and efficiency of heating and achievement of temperatures desired in the ware firing section of the kiln and ware respectively. And when desired, the kiln temperature can be made to closely approach and remain near the theoretical flame temperature. Such occurs to the best of my belief because the burners can be made to burn and remain substantially on selected ratio, even when that ratio is, say, within one or two percent of the theoretical combustion ratio between combustion air and fuel gas being used at the time being, the selected quantity and pressure of cooling air supplied by fan 111 cooperates therein together with the relatively closed nature of the passageway 7 and open portals 100 and 101, and the controlled movement of air between the cooling zone 4 and the firing zone 3 through the restricted portion 110 which also may closely conform to the shape of the spacer and load passing through tunnel 10a at that location. Thus, one can substantially maintain ratio and keep the flame temperature relatively close to its theoretical maximum, and, thereby attain a fired ware temperature depending upon the selected time that the ware is in the firing zone, which is extremely high as is desirable for certain high quality ceramic parts demanded by the electronic and other industries.

Ratio controller 99 is but one of many forms thereof which may be employed. Therein, for a particular operation, a predetermined flow of combustion air is selected for delivery by blower 103 in accordance with the cooperating settings of a diaphragm valve 116 and orifice 117 of selected size. Fuel gas from gas main 104 passes through a meter 118 and a gas orifice 119 between two diaphragm valves 120 and 121 respectively connected across the upstream and downstream sides of the air orifice 117 and gas orifice 119 for constant proportioned flow of fuel gas in accord with the selected flow of combustion air provided by blower 103. Such quantity of combustion air supplied by blower 103 is made with due allowance for the flow of air through restricted portion 110 into firing chamber 3 from cooling chamber 4 when the firing chamber is to achieve extremely high temperatures including those near theoretical flame temperature for the selected ratio. The selected quantity of combustion air supplied by blower 103, which may be operatively interconnected with blower 111 for joint control of the two blowers, then enters the burner air heater mechanism 102 from combustion air pipe 122. Pipe 122 has two branch pipes 123 and 124 which rejoin at pipe 125 lead-

ing into combustion air header 93. Branch 123 conducts any combustion air passing therethrough to pipe 125 without heating thereof, whereas any combustion air passing through branch 124 passes through a plenum 126 having fire tubes 127 extending therethrough for hot combustion gases caused by the burning of fuel issuing from burner 128 to indirectly heat the air in plenum which bathes the heated surfaces of such tubes 127 in passing. The tubes 127 lead to a flue 127a. Burner 128 automatically turns on whenever damper 129 is opened to any amount by a temperature-sensing controller 130 responsive to a temperature-sensing element 131 which may be inserted into a narrow arch opening 132 therefor to sense temperature at the top of firing section 3. A temperature sensing control 133 for burner 128 admits air and gas into a mixer fitting and valve 134 to operate burner 128 and keep constant the temperature of that portion of the combustion air that passes through branch 124, if and when damper 129 opens.

Damper valve 129 is in operatively connected inverse relation to damper valve 135 and controlled by the same controller 130 so that a selected proportional flow is obtained through each of the branches 123 and 124, or all of the flow is obtained through one or the other branch, as required by the need of the kiln at the time being in response to the sensing element 131. A resistance damper 136 may be installed in branch 123 to cause the branch 123 approximate the resistance in branch 124 through the burner air heater 126-127. The consequence of the use of mechanism 102 is to enable kiln 10 to respond virtually instantly to correct any departure from the desired kiln temperature, which, for example, might be occasioned in the case of a small ware mass kiln by a variation in the size, weight, fill, and/or thermal co-efficient of ware passing therethrough at the time being, or other variable. And, such instantaneous response will be achieved even though the conditions of operation of that kiln 10 call for a kiln temperature in the hottest portion of the firing zone 3 relatively closely approaching the theoretical flame temperature produced by the flames of burners 89; and, whether or not the kiln temperature setting at the time being does not require the use of preheated combustion air, or does occasioning at least some flow of combustion air through branch 124 at all times in the latter case. Thus, inasmuch as the combustion conditions in the kiln can be maintained substantially close to the selected ratio, preferably making allowance for the air entering the firing chamber through restricted portion 110, any action of the sensing element 131 indicating an unwanted rise in the kiln temperature would correspondingly throttle branch 124 and inversely open branch 123 wider to produce a correspondingly lowered temperature blend of heated and unheated combustion air in pipe 125 and header 93 for lowering of the kiln temperature to the level preset by the sensing element 131 and control 130. Conversely, a fall in the desired maximum kiln temperature indicated by element 131 would throttle branch 123 and correspondingly open branch 124 wider; and there would be a corresponding increase in the combustible mixture quantity burned in a given time by burner 128, thereby heating to a preset temperature an increased proportion of the ratio combustion air, to raise the temperature of the combustion air in header 93 and thereby the flame and kiln temperature by restoring the latter at once to the desired level. Further, if a deliberate change in kiln temperature is desired at any time, the same means may be used to obtain and to maintain such changed kiln temperature. Alternatively, when higher flame temperature is required, particularly when working on relatively small or minute thermal heads, or ware masses, in the kiln 10, oxygen may be supplied to the burners 89 in part or wholly in lieu of combustion air, although in general the use of oxygen is not practicable for tunnel kilns, particularly small ware mass kilns.

As an example of the operation of this invention, a kiln 10 using "cold" combustion air, that is combustion air at ambient temperature, may have a kiln temperature as set forth in FIGURE 9 showing the preheating, firing and cooling temperatures of the kiln, and to a related extent the maximum temperature reached by the ware. In such diagram, assuming an overall kiln time of six hours for small mass ceramic ware to be fired at a temperature in excess of 3000° F., the maximum kiln temperature at least toward the rear of the firing zone may be maintained at about 3200° F. with but a few degrees variation therefrom using a fuel such as natural gas. Such kiln temperature may be raised without lag and as required, or desired, by burner 128 heating, or by electric resistance heating, of at least a portion of such combustion air as discussed above in connection with mechanism 102 under the control of sensing element 131 and controller 130 in those situations where there is a variation in the load, or some other occurrence requiring a kiln temperature response adjustment. Such is of especial importance in very high temperature small ware mass kilns in which but little preheating of combustion air takes place by exchange with the ware as it passes through the cooling zone.

Various changes may be made in the tunnel kiln system of this invention, in details of the kiln itself and conveyor mechanism and other conveyor mechanism may be employed without departure from the spirit of this invention or the scope of the appended claims.

I claim:

1. A relatively small ware mass kiln having a tunnel extending therethrough comprising, in combination, a preheating section, a cooling section and a firing section between said preheating and cooling sections, said cooling section having an orifice-like restriction between said cooling and firing sections with relatively small predetermined clearances relative to a load passing through said restriction, means for introducing cooling air forwardly into said cooling section such that a generally predetermined portion representing a minor portion of the combustion air passes through said restriction into said firing section, means for introducing fuel and combustion air through burners into said firing section in substantially predetermined major amounts with allowance for said predetermined portion to obtain a selected ratio with desired combustion characteristics in said firing section, whereby close control of temperature in said firing section is obtainable and maintainable and including means for heating any selected portion of said predetermined major amounts of combustion air to a selected constant temperature, means for admixing the same with the remainder of said predetermined major amounts to provide heated combustion air for introduction through said burners at a predetermined elevated temperature, and means for sensing said temperature in said firing section to control the quantity of said selected portion of combustion air to be so heated, whereby a rapid change in the temperature of the flames from said burners may be obtained in response to any change in weight, size, fill, or other variable, of said load which otherwise would substantially adversely affect said temperature in said firing section.

2. A relatively small ware mass tunnel kiln having direct firing burners comprising, in combination, means for rapidly heating any selected portion of the combustion air fed to said burners to a selected constant temperature, means for admixing said any selected portion with the remainder of said combustion air to provide heated combustion air for introduction through said burners at predetermined elevated temperature, and means for sensing the temperature in said kiln to control the quantity of said selected portion of combustion air to be so heated, whereby a rapid change in the temperature of the flames from said burners may be obtained in response to any change in weight, size, fill, or other variable, of said load which otherwise would substantially adversely affect said temperature in said kiln.

3. A kiln having a firing section adapted to be fired by burners, comprising, in combination, ratio regulator means for determining a substantially selected proportion between fuel and combustion air fed to said burners for combustion in said kiln, a pipe for combustion air from said ratio regulator means having two branches, means for apportioning the flow of said combustion air through said branches in accordance with a temperature sensitive element operatively associated with said firing section, indirect heat exchange means in one of said branches to heat any portion of said combustion air selected to be passed therethrough, said indirect heat exchanger means being direct combustion fired in accordance with a selected constant temperature to which said portion of said combustion air is to be heated, and means into which both said branches discharge for blending of the portions of combustion air passing therethrough respectively to supply said combustion air at selected elevated temperature to said burners, whereby extremely high temperatures may be maintained in said firing section of said kiln approaching theoretical flame temperature for the selected ratio and corresponding heating of a load passing through said firing section.

4. A kiln having a firing section adapted to be fired by burners, comprising, in combination, ratio regulator means for determining a substantially selected proportion between fuel and combustion air fed to said burners for combustion in said kiln, means for dividing combustion air from said ratio regulator means into two branches, means for apportioning the flow of said combustion air through said branches in accordance with a temperature sensitive element operatively associated with said firing section, rapid heat exchange means in one of said branches to heat any portion of said combustion air selected to be passed therethrough to a selected constant temperature and means for blending of the portions of combustion air passing through said branches to supply said combustion air at selected elevated temperature to said burners, whereby extremely high and desired temperatures may be maintained in said firing section of said kiln.

5. In a method for regulating a kiln system, the steps comprising, in combination, providing burners to heat a kiln to a prescribed kiln temperature, or prescribed kiln temperatures, feeding fuel and combustion air in predetermined ratio quantities to said burners to provide flame of one temperature for the purpose of such heating, and rapidly changing the temperature of such combustion air before it reaches said burners to change such flame temperature without lag in response to any new condition requiring such change either to keep said kiln temperature constant if so prescribed, or to vary it in accord with a different prescribed kiln temperature.

6. In a method for regulating a direct fired kiln system, the steps comprising, in combination, providing di-

rect firing burners to heat a kiln to one or more prescribed kiln temperatures, feeding fuel and combustion air to said burners in predetermined ratio quantities with said combustion air at predetermined temperature to provide flame of a predetermined temperature for the purpose of such heating of said kiln, sensing the temperature of said kiln and rapidly changing the temperature of at least a part of said combustion air in accord with said sensing before it reaches said burners to change said flame temperature without lag and thereby substantially immediately satisfy whatever the kiln temperature demand may be as indicated by said sensing.

7. A method for regulating a kiln system as set forth in claim 6, comprising, subjecting said at least a part of said combustion air to flow over a heated surface having a relatively high thermal head relative to said at least a part of said combustion air, changing the temperature of said heated surface substantially immediately in accord with the outlet temperature of said at least a part of said combustion air to keep said outlet temperature of said part relatively constant, and mixing said at least a part of said combustion air so heated with the remainder of said combustion air before feeding said combustion air mixture to said burners.

8. A method for regulating a kiln system as set forth in claim 7 comprising controlling the quantity of flow of said at least a part of said combustion air over said heated surface in accord with said sensing by increasing said quantity when higher flame temperature is required in said kiln, and vice versa.

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WILLIAM J. STEPHENSON, *Primary Examiner.*