March 9, 1965 G. B. REMMEY 3,172,647

CONTINUOUS KILN

Filed March 26, 1963 3 Sheets-Sheet 1

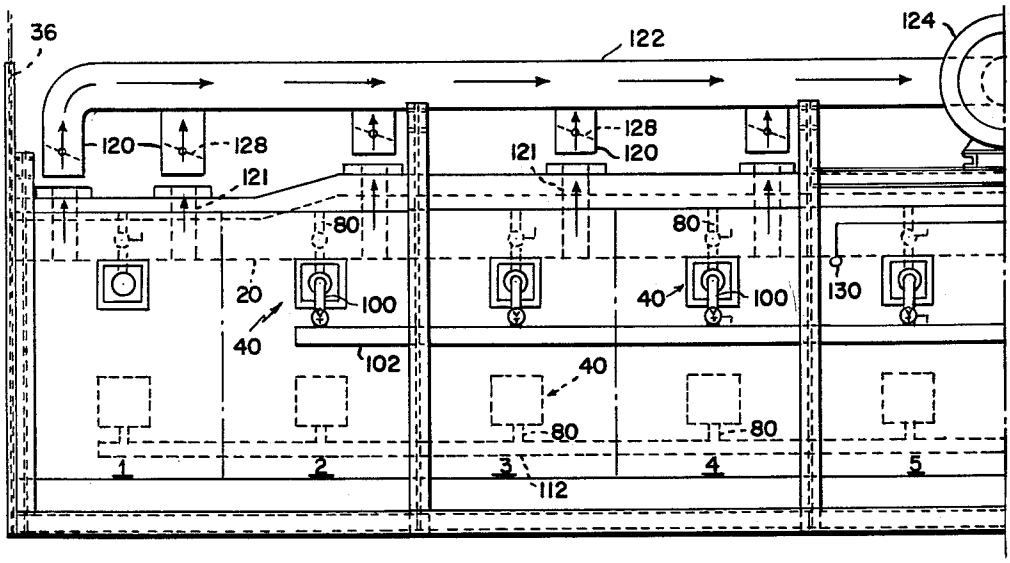
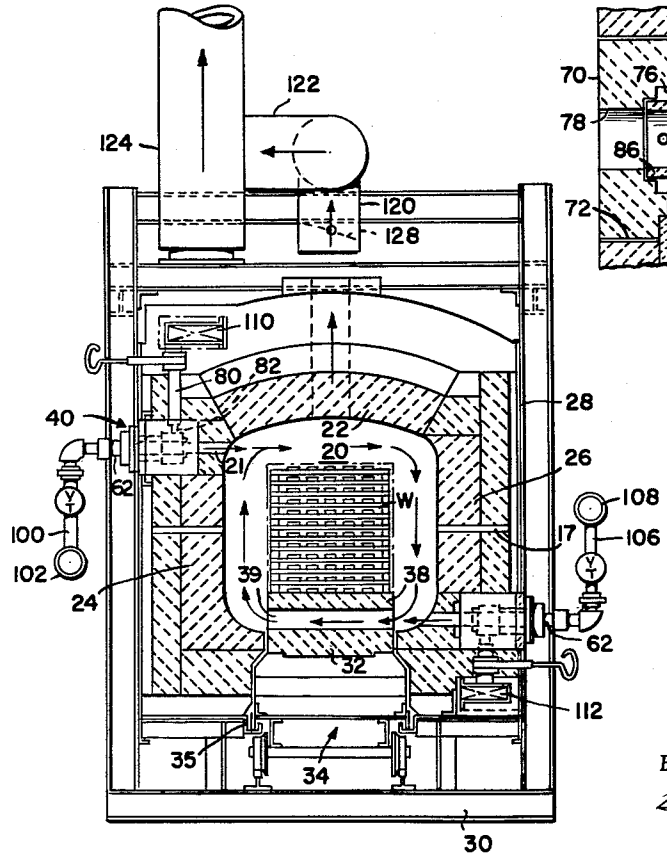


FIG. 1A.



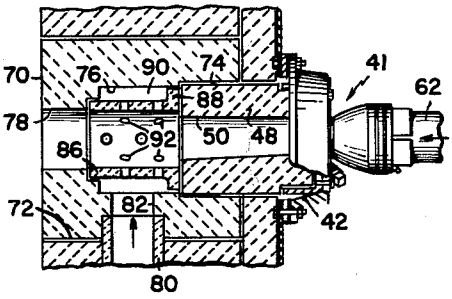


FIG. 5.

FIG. 2.

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CONTINUOUS KILN

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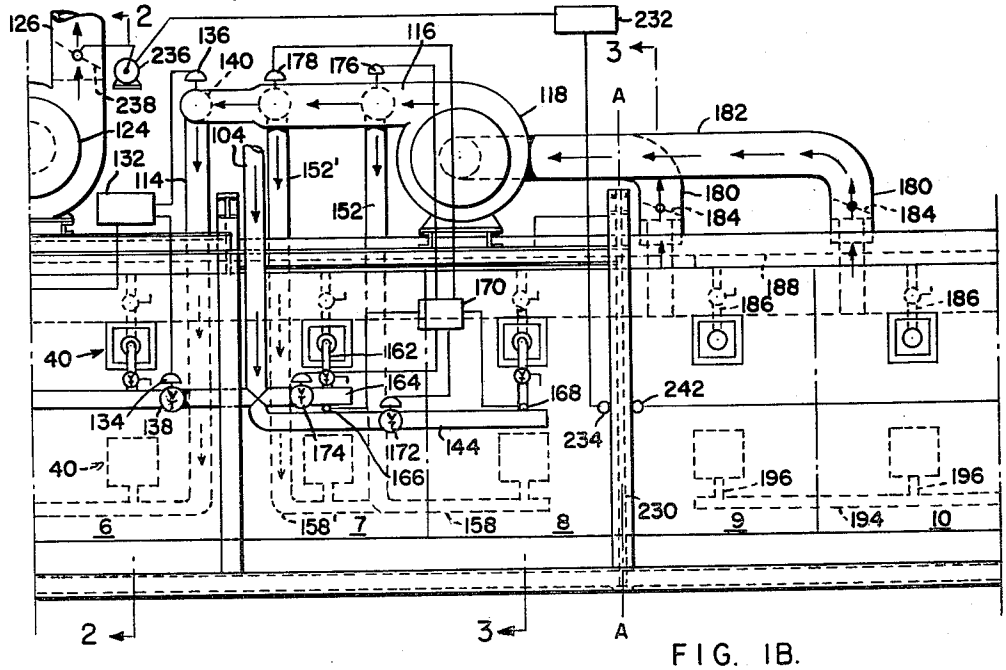


FIG. 1B.

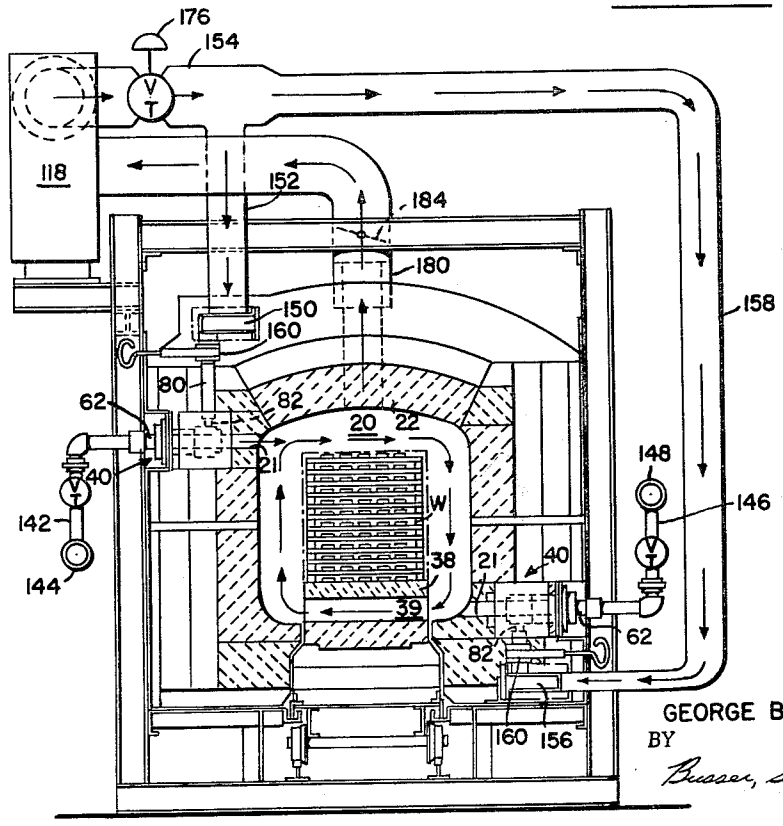


FIG. 3.

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CONTINUOUS KILN

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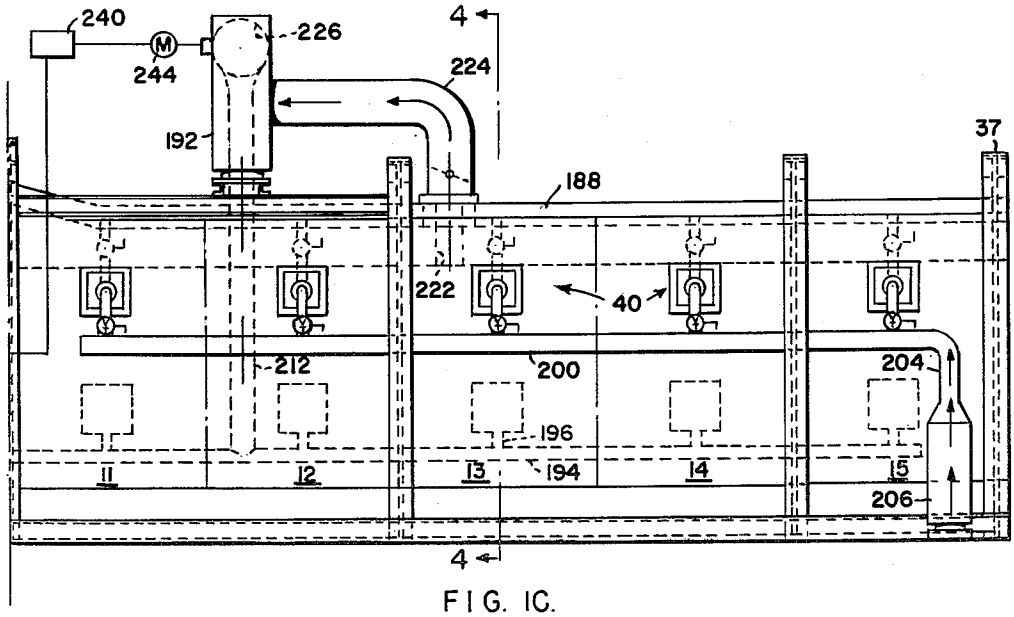


FIG. IC.

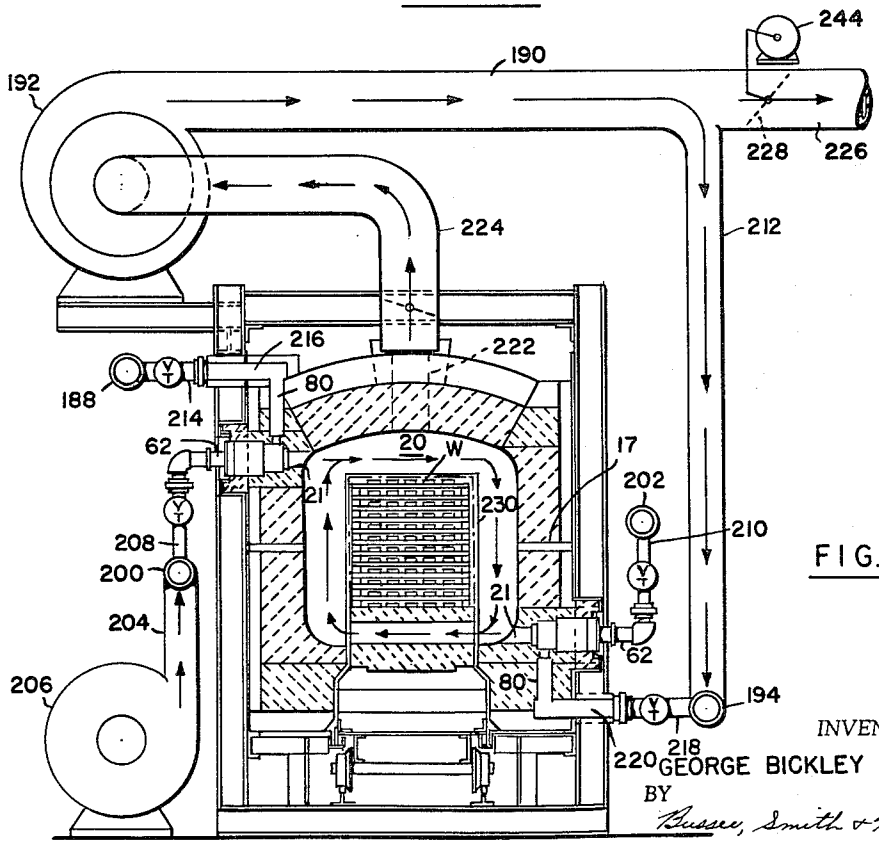


FIG. 4.

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3,172,647
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3,172,647

CONTINUOUS KILN

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Filed Mar. 26, 1963, Ser. No. 268,203
13 Claims. (Cl. 263—28)

This invention relates to a firing system for a continuous kiln or the like and is applicable to other continuous heat-treating furnaces.

Continuous kilns in use heretofore have several disadvantages involved in their firing systems. For example, prior continuous kilns have been unable to achieve a predictable and settable temperature in zones along the length of the kiln. Accordingly, prior continuous kilns are not adjustable with accuracy to various heating cycles and require considerable time in placing them into operation and in adjustment of the firing system during operation. It is one object of this invention to provide a firing system which is settable to achieve and maintain desired temperatures in zones along the length of a continuous kiln.

One of the reasons for the inability for conventional kilns to obtain controllable temperature zones is that these kilns employ the counterflow principle wherein a current of air is moved continuously through the kiln in the direction opposite to the movement of the ware through the kiln. This longitudinal flow creates a condition that does not permit temperature adjustment along the longitudinal zones of the kiln and results in fuel inefficiency. It is an object of this invention to provide a firing system for continuous kilns or the like in which air flow between the zones is minimized whereby the kiln temperatures may be adjusted with accuracy.

Another problem involved in conventional kilns is the uneven temperature distribution in the kiln chamber caused by the hot gases stratifying along the upper portion of the kiln chamber as a result of their buoyancy. This problem is accentuated in the heating up and cooling down regions wherein considerable temperature differentials exist between the top and bottom of the kiln chamber. In most cases, this temperature differential is several hundred degrees and often more. Accordingly, the ware on top of the kiln is considerably hotter than the ware at the bottom. This requires that at a critical temperature range of the ware the necessary slow heating rate must be extended from the time the high temperature ware passes through the critical temperature range to include the time for the low temperature ware to also pass through this critical temperature range. This results in the necessity for increasing the length of time the ware passes through the kiln. Another object of the invention is to provide a firing system for a continuous kiln in which there is maintained a substantially constant temperature throughout the height of each zone of the kiln whereby time savings are achieved.

A further object of the invention is to provide a firing system for continuous kilns in which there is achieved good circulation throughout each temperature zone so that effective heat transfer may take place between the gases and the ware.

The above and other objects and features of the invention will appear more fully from a consideration of the following detailed description in conjunction with the accompanying drawings wherein:

FIGURES 1A, 1B and 1C are longitudinal sectional views of adjacent sections of a continuous kiln in accordance with this invention;

FIGURE 2 is a section taken on line 2—2 of FIGURE 1B;

FIGURE 3 is a section taken on line 3—3 of FIGURE 1B;

FIGURE 4 is a section taken on line 4—4 of FIGURE 1C; and

FIGURE 5 is a sectional view of a burner assembly used in the kiln in accordance with this invention.

The continuous kiln in accordance with this invention comprises a horizontally extending structure defining a longitudinal tunnel or kiln chamber 20 defined by a lining of suitable refractory material. The chamber defining refractory walls include an arched ceiling 22 supported on vertical side walls 24 and 26. The type and the size of the refractory at various locations of the kiln is chosen in accordance with the particular temperature occurring in zones within the kiln chamber 20 at such locations. Preferably the lining consists of prefired burner blocks and bricks of a high purity sintered mullite composition and is backed up with a layer of insulating brick which, in turn, is backed up with insulating block. The refractory walls are supported in a steel plate casing 28 with welded structural steel reinforcement. The kiln chamber is supported above the floor level and steel cross-members 30 are provided to tie the bottom of the kiln together and to support rails for the kiln cars. The structural aspects of the kiln are in accordance with conventional practice and will be apparent to those skilled in the art.

The bottom of the kiln chamber 20 is defined by refractory walls 32 supported on the kiln cars 34. The cars ride on horizontally extending rails and are provided with conventional sand sealing means 35 for closing the kiln chamber at the bottom thereof. A vertically sliding door 36 is provided at the inlet of the kiln to close the same when necessary. A baffle 37 is provided at the outlet of the kiln. The baffle is constructed to close off the outlet end of the kiln and has a central opening sized to permit movement of the kiln cars through the outlet end of the kiln. The cars 34 are moved through the kiln by any suitable means well known in the art, as for example, a hydraulic pusher. The cars 34 are provided with a horizontal platform 38 for supporting the ware indicated at W. The ware supporting structure is provided with transversely extending openings 39 to permit circulation of the hot gases as will be described more fully hereafter.

The kiln consists of a plurality of individual zones or firing sections 1–15 throughout its length, each section extending an equal longitudinal distance. Means are provided at each section for producing a settable predetermined temperature therein. By way of a typical example, a kiln for 3100° F. firing of a ware setting or size of eighteen inches by eighteen inches may comprise firing sections extending four feet along the kiln chamber.

The individual firing sections 1 to 6 comprise a "heat-up" zone in which the temperature of the ware is raised under controlled conditions. The firing sections 7 and 8 comprise a "soak" zone in which the ware is heated to the maximum temperature for the heating cycle. Firing sections 9 and 10 comprise a "pre-cool" zone in which the ware is cooled rapidly to lower the temperature beneath the soak temperature. Firing sections 11 to 15 comprise a "cooling" zone in which the ware temperature is gradually reduced by the use of cooling air. The number of individual firing sections comprised in each of the composite zones may be varied in accordance with the particular kiln application.

The means for producing a predetermined settable temperature in each individual zone comprises a pair of burner or nozzle assemblies for introducing gas into the kiln chamber tangentially at the top and at the bottom thereof as is best shown in FIGURES 2, 3 and 4. These gas introducing means are arranged in the same vertical plane centrally of the zone and to direct gases into the kiln chamber tangentially in the same circumferential direction by way of tangentially extending inlet nozzle passages 21. While in accordance with the broadest aspect

of the invention various gas introducing means may be used, it is preferable to use a burner assembly such as that disclosed in U.S. Patent No. 3,055,652. The advantage of using such a burner assembly is that this apparatus is designed to maintain a sufficient gas stream mass velocity so that all the gases introduced into the zone circulate around the kiln.The introduced gases sweep continuously from top to bottom around the ware as is shown by the arrows in FIGURES 2, 3 and 4. The passages **39** in the supporting structure of the kiln cars **34** permit passage of the gases across the bottom of the kiln chamber **20**.

The velocity of gas streams should be set slow enough so that the ware is not disturbed and high enough to make a few revolutions around the kiln chamber each second. This full time high velocity gas circulation eliminates stratification of the gases and avoids any substantial temperature differential between the top and bottom of the kiln chamber.

Since the above-mentioned patent discloses the details of the burner assembly for achieving the desired results, only a brief description of this burner assembly will appear herein. As shown in FIGURE 5, each burner assembly **40** comprises a suitable burner **41** adapted to be mounted on the shell of the kiln. The burner **41** comprises a body **42** cemented to a refractory block **48** defining a combustion tunnel **50** communicating with the interior of the body **42**. Preferably the burner **41** is of the type having a plug defining an annular burner port as is more fully described in said patent. A rectangular diffusion air block **70** of refractory material is positioned in a rectangular opening **72** in the vertical side wall of the kiln. Block **70** has a recess **74** adapted to receive the downstream end of block **48**. Block **70** has a central cavity **76** adjacent the upstream end of recess **74** and a bore **78** communicating with the downstream end of central cavity **76**. Cavity **76** and bore **78** define a passageway through which the products of combustion from tunnel **50** pass and leading to the inlet nozzle passage **21** communicating with the kiln chamber **20**.

A ceramic conduit **80** is mounted in the refractory wall and communicates at its downstream end with a passageway **82** formed in block **70**. Passageway **82** communicates with central cavity **76**. Conduit **80** and passageway **82** provide a path for the flow of diffusion air into cavity **76** from the air supply conduits which are connected to the upstream ends of the conduits **80**. Since air is diffused with the products of combustion from tunnel **50** in cavity **76**, this cavity may be termed a diffusion chamber.

A cylindrical diffuser member **86** is mounted in central cavity **76** and defines, at the inner wall thereof, a passageway between tunnel **50** and bore **78**. The inner wall of diffuser member **86**, tunnel **50** and bore **78** are all in alignment. Diffuser member **86** has a radially extending flange **88** which positions the diffuser member **86** within cavity **76** so that the diffuser member outer wall is spaced from the wall of cavity **76** whereby an annular chamber **90** is formed adjacent the diffuser member outer wall. Diffuser member **86** has a plurality of radial openings **92** extending therethrough and circumferentially and longitudinally spaced thereabout. Openings **92** serve to meter or control the amount of air passing from chamber **90** through the diffuser member **86** into the products of combustion passing from combustion tunnel **50** of burner **41**. Diffuser member **86** is made of a material which can withstand extreme thermal shock and thermal stress, such as silicon carbide, silicon nitride, mullite, alumina or other ceramics.

In the firing of the kiln, a fuel-air mixture is supplied to the burners **41** through conduits **62**, valves being provided for regulating the amount of fuel-air mixture passing to the burners **41**. Air is supplied to conduits **80** through distribution connections which have valves connected therein for regulating the amount of air passing to the chambers **90**. The regulating valves are adjusted

to provide the desired flame temperature and the mass velocity of the gas stream passing from the burner assemblies. In order to insure that all of the ware is heated uniformly, the mass velocity of the gas stream passing from the burner assemblies are adjusted so that the gas stream completely encircles the ware. When preheated diffusion air is used, the fuel-air mixture comprises 20 to 33 percent pre-mixed air, the rest of the air being supplied through the diffusion passages. The diffusion air control has a minimum low flow rate so that the circulation pattern is maintained at all times, it being better to have inefficient gas burning than to have too low a mass velocity.

The products of combustion leave combustion tunnel **50** and pass into the central opening in diffuser member **86**. The secondary air passes from conduit **80** into annular chamber **90** from which the air passes through openings **92**. Diffuser member **86** serves to meter the air and cause it to mix in small jets with the fully burned combustion products passing from the combustion tunnel **50**. The diffuser member **86** insures that there is a thorough mixture or diffusion of the air and the products of combustion by reason of the plurality of openings **92** which direct the small jets of air at right angles into the products of combustion.

In the heat-up zone, the gas introducing means of firing section **1** comprises what may be termed a nozzle assembly which introduces only hot air into this section of the kiln chamber **20**. Although there are no burners provided in this firing section, each nozzle assembly may have a construction similar to the burner assembly shown in FIGURE 5 so that a burner may be added if desired. The firing sections **2** to **6** are provided with burner assemblies constructed as shown in FIGURE 2 which illustrates the arrangement of firing section **6**. It is to be noted that in FIGURES 2, 3 and 4 the burner and nozzle assemblies are shown in outline form for simplicity of illustration. Each of the upper burner assemblies of firing sections **2** to **6** receives an air-gas mixture by way of a distribution connection **100** providing communication between the burner inlet conduit **62** and a manifold line **102**. The manifold line **102** is connected to the inlet line **104** which receives a supply of the air-gas mixture from a gas premixing machine (not shown). Each of the lower burner assemblies of firing sections **2** to **6** receives the air-gas mixture by way of a distribution connection **106** providing communication between the burner inlet conduit **62** and a manifold line **108**. The manifold line **108** is connected to the inlet line **104** from the fuel supply. Each of the distribution connections **100** and **106** has connected therein a manually adjustable throttle valve which is set in accordance with the desired fuel input for a particular firing section.

Each of upper and lower burner assemblies for firing sections **1** to **6** receives a supply of hot air by way of conduits **80** providing communication between the diffusion inlet passageways **82** and manifold ducts **110** and **112**, respectively. The manifold ducts **110** and **112** are connected to an inlet line **114** which is connected to the discharge conduit **116** of a hot air blower **118**. The blower **118** draws hot air from the pre-cool zone as will be described hereafter. Each of the hot air conduits **80** is provided with a manually adjustable throttle valve which is set in accordance with the desired hot air input for the particular firing section in accordance with the air-gas input.

Means are provided for exhausting gases from the heat-up zone at various longitudinal locations of the kiln chamebr **20**. Such means comprises a plurality of vertical conduits **120** communicating at their lower ends with the crown of the kiln chamber through ducts **121** and at their upper ends with a horizontally extending exhaust duct **122** communicating with the intake end of an exhaust blower **124**. The discharge duct **126** of the blower or exhauster **124** may be connected to the outside

of the building containing the kiln. Each of the vertical conduits is provided with a manually adjustable damper valve 128 for regulating flow therethrough. Two of the vertical conduits 120 communicate with firing section 1 and one of the conduits communicates with each of firing sections 2, 3 and 4. The exhaust conduits 120 closest to the charging end of the kiln draw gases at the lowest temperature of the heat-up zone so that a minimum amount of heat is removed from the kiln and maximum fuel efficiency is achieved. The exhaust conduits 120 which are located toward the central region of the heat-up zone are located to make it possible to draw off gases from this zone before they cool enough to permit condensation of alkalies or other volatile materials within the zone.

Control means are provided for maintaining automatically a desired temperature in the heat-up zone. Such means comprise a pyrometer 130 arranged to sense the temperature in the heat-up zone and to actuate a suitable controller 132. The controller 132 operates control motors 134 and 136 which adjust throttle valves 138 and 140 connected in the air-gas input manifolds 102, 108 and the hot air intake line 114, respectively. In operation, if the pyrometer senses a drop in temperature, the controller is actuated to effect an increase in the flow of air-gas mixture and of the hot air into the supply lines for the burner assemblies. The controller may comprise suitable differential pressure transmitters and ratio relays for regulation of the air supply pressure as a function of the fuel supply pressure. The specific details of the control means is in accordance with techniques well known in the control art and will be readily apparent to those skilled in the art.

The construction of the firing sections 7 and 8 forming the soak zone is illustrated by FIGURE 3 which shows firing section 7 in cross-section. The upper burner assembly of firing section 8 receives the air-gas mixture by way of a distribution connection 142 providing communication between the burner inlet conduit 62 and a line 144 connected to the fuel inlet line 104. A manually adjustable throttle valve is connected in the distribution line 142 to regulate flow therethrough. The lower burner assembly of firing section 8 receives the gas-air mixture by way of a distribution connection 146 providing communication between the burner inlet conduit 62 and a line 148 connected to the fuel inlet line 104. A manually adjustable throttle valve is connected in the distribution line 146 to regulate flow therethrough.

The upper burner assembly of firing section 8 receives a supply of hot air by way of a distribution conduit 80 providing communication between the diffusion inlet passageway 82 of the burner assembly and a duct 150. The duct 150 is connected to the discharge line 116 of the hot air blower 118 by connections 152 and 154. The lower burner assembly of firing section 8 receives a supply of hot air by way of a distribution conduit 80 providing communication between the diffusion inlet passageway 82 of the burner assembly and a duct 156. The duct 156 is connected to the discharge line 116 of the hot air blower 118 by connections 158 and 154. Manually adjustable throttle valves 160 are connected in the distribution conduits 80 to regulate flow therethrough.

The upper burner assembly of firing section 7 receives the air-gas mixture by way of a distribution connection 162 providing communication between the burner inlet conduit 62 and a line 164 connected to the fuel inlet line 104. A manually adjustable throttle valve is connected in the distribution connection 162 to regulate flow therethrough. A similar air-gas mixture supply arrangement is provided for the lower burner assembly, this arrangement being omitted from the drawings for simplicity of disclosure.

The hot air supply for the firing section 8 is identical to the supply for firing section 7 whereby corresponding parts have been given the same reference numerals with primes added. The connecting conduits receive the supply of hot air from the discharge 116 of the hot air blower from the supply line and deliver them to the distribution lines by way of ducts formed in the kiln. Suitable manually adjustable throttle valves are provided for regulating the air flow to the burner assemblies.

Control means are provided for maintaining automatically a desired temperature in the soak zone. This control means involves two controlled zones, one in each of the firing sections 7 and 8, and comprises a pair of pyrometers 166 and 168 arranged to sense the temperature in firing sections 7 and 8, respectively, and to actuate a controller 170. The controller 170 may comprise suitable differential pressure transmitters and ratio relays for controlling the operation of motor operated valves 172 and 174 in the fuel supply lines 144 and 164, respectively, and motor operated valves 176 and 178 in the hot air supply lines 154 and 154', respectively. The lower burner asemblies of firing sections 7 and 8 also have their fuel supply lines controlled by motor operated valves responsive to the controller 170. The controller 170 regulates the air supply manifold pessure as a function of the air-gas manifold pressure to insure the proper ratio for full combustion at the various burner positions. Again, there will be maintained a minimum air supply to insure sufficient mass velocity. The controller 170 is responsive to the temperatures sensed by the pyrometers to control the burner temperatures to achieve the desired temperature within the firing section. In order to permit the use of a single controller with two separate control loops, there may be employed a timer-operated switching relay which transfers input and output circuits to the controller at regular intervals. The details of the temperature control will be apparent to those skilled in the art.

The hot air recirculating blower 118 draws air from the pre-cool zone by way of vertical conduits 180 connected at their lower ends with the firing sections 9 and 10, respectively, and at their upper ends with a horizontally extending blower intake duct 182. Manually adjustable throttle valves 184 are provided in the vertical conduits 180 for regulating flow therethrough.

The gas introducing means in the firing sections 9 and 10 of the pre-cool zone deliver only hot air into the kiln chamber. The upper nozzle assemblies receive hot air by way of the distribution conduits 186 providing communication between the inlet to the nozzle assembly and a manifold duct 188 receiving air from the discharge line 190 of a recirculating blower 192. The lower nozzle assemblies receive hot air from the discharge line 190 of the blower 192 by way of a manifold duct 194 and distribution lines 196. The distribution lines 186 and 196 have connected therein manually adjustable throttle valves for regulating flow therethrough.

In the cooling zone, the gas introducing means of each of the firing sections 11 to 15 comprises nozzle assemblies which receive cooling air through a longitudinal inlet and warm air through a side inlet. The cool and warm air mix in the diffusion chamber and the mixture is forced into the kiln chamber by way of the inlet nozzle passageway 21. This mode of operation is best illustrated in FIGURES 1C and 4.

The cooling air is delivered to a pair of horizontally extending manifold ducts 200 and 202 by way of the discharge duct 204 of a cooling air blower 206. The cool air in the manifold duct 200 is delivered to the longitudinal inlet of the upper nozzle assemblies by distribution connections 208. Each of the distribution connections 208 has a manually adjustable throttle valve therein for regulating flow therethrough. The cooling air in the manifold duct 202 is delivered to the longitudinal inlet of the lower nozzle assemblies by the distribution connections 210 each of which has a manually adjustable throttle valve therein for regulating flow therethrough.

The warm air is delivered to the horizontally extending manifold ducts 188 and 194 on opposite sides of the

kiln by way of a duct 212 connected to the discharge duct 190 of the warm air recirculating blower 192. The warm air in the front manifold duct 188 is distributed to the side inlet of the upper nozzle assemblies by suitable distribution conduits 214 each of which has a manually adjustable throttle valve therein for regulating flow therethrough and distribution passage 216 in the kiln wall. The warm air in the rear manifold duct 194 is delivered to the side inlet of the lower nozzle assemblies by suitable distribution conduits 218 each of which has a manually adjustable throttle valve therein for regulating flow therethrough and by distribution passages 220 in the kiln wall.

The recirculating blower 192 draws warm air from the crown of the cooling zone by means of a vertical conduit 222 communicating at its lower end with the crown of section 13 and at its upper end with the intake duct 224 for the blower 192. As is best shown in FIGURE 1C the blower 192 recirculates warm air through the kiln chamber. The discharge duct 190 of the blower has an outlet portion 226 which may be connected to driers or the like (not shown). The flow through this outlet portion 226 is regulated by a throttle valve 228 connected therein.

Means are provided to control the movement of gases through the kiln chamber so that there is a minimum of longitudinal movement of the gases, particularly between the soak and pre-cool zones. In this respect, the kiln in accordance with this invention differs radically from conventional kilns employing the counterflow principle. The control means comprises a pair of pressure controller units for maintaining the same pressure on either side of a baffle 230 between the soak and pre-cool zones. The baffle 230 is constructed to block flow between the sections 8 and 9 and has a central opening sized to permit movement of the kiln cars through the kiln. One controller unit comprises a pressure controller 232 responsive to the pressure sensed by a pressure sensing means 234 and arranged to operate a control motor 236 for a damper valve 238 in the outlet duct 126 of the exhaust blower 124. The pressure sensing means 234 is mounted on a kiln to be responsive to the pressure in the soak zone side of the baffle 230. The other controller unit comprises a pressure controller 240 arranged to be responsive to a pressure sensing means 242 and to operate a control motor 244 for the damper valve 228 in the outlet duct 226 of the recirculating blower 192. The pressure sensitive means 242 is mounted on the kiln to be responsive to the pressure in the kiln chamber in the pre-cool zone immediately adjacent the baffle 230.

The controller unit responsive to the soak zone pressure operates to adjust the amount of air drawn from the heat-up zone to maintain a predetermined kiln pressure at the pressure sensing location. At the same time, the pressure controller unit responsive to the pressure in the pre-cool zone adjusts the amount of air drawn from the cooling zone to maintain the same predetermined pressure in the pre-cool zone sensing location as that pressure maintained by the other controller unit. Accordingly, the pressure on each side of the baffle 230 is equalized to thereby minimize any flow of gases across what may be termed a static flow plane. This static flow plane is indicated by the lines A—A in alignment with the baffle 230.

To illustrate the operation of the pressure control, let it be assumed that the temperature control for the heat-up zone calls for more fuel and more preheated air in which case this additional preheated air is drawn from the pre-cool zone by the recirculating blower 118. This would create a reduction in pressure in the pre-cool zone which would be sensed by the pressure responsive means 242 in this zone. The pressure responsive means 242 then actuates the controller 240 to operate the damper valve 228 in a direction so that less air is exhausted from the cooling zone to the pre-cool zone. This movement restores the pressure balance to minimize any flow across the static flow plane. In a like manner, the pressure control on the heat zone side operates, by adjusting the damper valve 238 in accordance with the pressure sensed by pressure responsive means 234, to maintain the set pressure on the heat zone side of the static flow plane to restore the pressure balance thereat.

It will be apparent that the firing system in accordance with this invention is settable to achieve predictable temperatures in various zones along the length of the kiln. Moreover, the zone temperatures may be varied in accordance with a desired heating cycle for a particular ware. Each zone can be adjusted to any temperature level providing for slow or fast heating at any zone with a constant car speed. Since the temperature profile along the length of the kiln will be the same for the top and bottom, there being no stratification of the gases, this profile can be adjusted to meet with accuracy the requirements of ware quality and low kiln furniture costs. In regions midway between the locations of the burners of each firing section there is some mixing between the gases from adjacent firing sections whereby there is a gradual transition in temperature between adjacent firing sections. In adjusting the firing sections of the kiln, the throttle valves controlling the gas inputs are adjusted manually to produce the desired temperature as measured by temperature measuring means. The temperature measurement may be by thermocouples permanently installed in the kilns in locations so that they measure the temperature of one of the burner assemblies or by a portable pyrometer having a thermocuple which could be inserted through suitable holes in the kiln. The thermocouple access holes are indicated at 17 and extend horizontally through the vertical walls of the kiln at a central location. The temperature sensed at the opposite side of the kiln chamber from each burner is used as the basis for adjustment of such burner. This adjustment is made for each of the burner assemblies of each firing section. If desired, pyrometric controls could be installed to control all fifteen firing sections or merely certain critical groups of sections. It is apparent that most of the firing sections of the kiln disclosed may be set to various temperatures within a range of temperatures. Of course, all of the firing sections may be provided with such control if desired.

Stratification of the hot gases is avoided by setting the air and fuel flow rates into the burner assemblies so that the mixture of gases entering the kiln chamber have a sufficient mass velocity to overcome the buoyancy tendency of the hot gases. The gas streams enter the kiln chamber with sufficient velocity to maintain rapid circulation which results in uniform temperatures from top to bottom in each firing section.

During operation of the kiln, the various blowers direct gases into appropriate firing sections through nozzle or burner assemblies. The cooling air supplied by the blower 206 is circulated around the ware in the cooling zone and moves gradually toward the soak zone. A portion of the air supplied by blower 206 is withdrawn by blower 192 and is delivered to driers by way of outlet conduit 226 and the remaining portion of this air enters the intake 182 of blower 118. The baffle 230 between the soak zone and the pre-cooling zone in conjunction with the pressure controller units discussed above minimize movement of the air in the pre-cool and cooling zones into the soak zone which is the high temperature zone of the kiln. This results in increased thermal efficiency since any cooling gases moving into the soak zone would exert a cooling effect.

The blower 118 delivers hot air to the burner assemblies in the heat-up and soak zones. The amount of air discharged through each burner assembly is regulated by the throttle valves associated therewith. A partial mixture of gas and air is burned in each burner to raise the temperature of the mixture of burner combustion products and hot air to the desired level. The mixing takes place in the diffusion chamber of each burner assembly and the

discharging gas streams from the burner nozzles 21 sweep tangentially around the kiln chamber walls and circulate through the ware.

The gases introduced into the heat-up and soak zones sweep around the cars at right angles to the car movement and move gradually toward the entrance end of the kiln where these gases are exhausted by the blower 124. The blower 124 draws the gases through the conduits 120 and operates to withdraw gases at a temperature to prevent condensation of the alkalies and the like in the kiln chamber. If desired, the dampers 128 in the conduits 120 may be positioned to cause movement of the gases all the way to the entrance end of the kiln chamber, this arrangement achieving maximum thermal efficiency.

Automatic temperature control of the heat-up and soak zones is accomplished by operation of the control means discussed above. Briefly stated, this control is obtained by automatic adjustment of the amount of fuel and, through suitable interconnecting proportioning relays, the amount of hot air input.

It will be apparent that changes may be made in the construction and arrangement of parts without departing from the scope of the invention. For example, a kiln which is to operate at lower temperatures would not require the particular heat-up zone disclosed and the firing sections of this zone could be replaced by a blower supplying room temperature air to the burners. In this case the exhaust from the pre-cooling zone would be connected to the intake of the recirculating blower 192 for the cooling zone whereby the cooling zone encompasses the pre-cooling zone. Accordingly, it is not desired to be limited except as required by the following claims.

What is claimed is:

1. A continuous kiln comprising wall means defining a horizontally extending kiln chamber, a heat-up zone extending longitudinally of the kiln chamber, said heat-up zone comprising a plurality of adjacent firing sections extending longitudinally of the kiln chamber, a soak zone defined by a second longitudinal portion of said wall means and comprising at least one firing section extending longitudinally of the kiln chamber, each of said firing sections having means for introducing gases into said kiln chamber in a transverse direction to cause circulation of said gases in a transverse region along the wall means around the periphery of said kiln chamber, means for conveying ware to be heated longitudinally through said kiln chamber and through said zones, and means associated with each gas introducing means for adjusting the same to introduce gases into the kiln chamber at a selected temperature within a range of temperatures whereby each of said firing sections along the length of said kiln chamber may be set to provide a desired temperature condition within said kiln chamber at the firing section location.

2. A continuous kiln comprising wall means defining a horizontally extending kiln chamber, a heat-up zone defined by a first portion of said wall means extending longitudinally of the kiln chamber, said heat-up zone comprising a plurality of adjacent firing sections extending longitudinally of the kiln chamber, a soak zone defined by a second longitudinal portion of said wall means and comprising at least one firing section extending longitudinally of the kiln chamber, a cooling zone between said soak zone and the discharge end of the kiln chamber, said cooling zone being defined by a third longitudinal portion of said wall means comprising a plurality of adjacent firing sections extending longitudinally of the kiln chamber, each of said firing sections having means for introducing gases into said kiln chamber in a transverse direction substantially tangentially to said wall means and at a velocity to cause circulation of said gases in a transverse region along the wall means and around the periphery of said kiln chamber, means for conveying ware to be heated longitudinally through said kiln chamber and through said zones, and means associated with each gas introducing means for adjusting the same to introduce gases into the kiln chamber at a selected temperature within a range of temperatures whereby each of said firing sections along the length of said kiln chamber may be set to provide a desired temperature condition within said kiln chamber at the firing section location.

3. A continuous kiln comprising refractory wall means defining a horizontally extending kiln chamber, a heat-up zone defined by a first portion of said wall means extending longitudinally of the kiln chamber, said heat-up zone comprising a plurality of adjacent firing sections extending longitudinally of the kiln chamber, a soak zone defined by a second longitudinal portion of said wall means and comprising at least one firing section extending longitudinally of the kiln chamber, each of said firing sections having means for introducing gases into said kiln chamber in a transverse direction to cause circulation of said gases in a transverse region along the wall means around the periphery of said kiln chamber, means for conveying ware to be heated longitudinally through said kiln chamber and through said zones, and means associated with each gas introducing means for adjusting the same to introduce gases into the kiln chamber at a selected temperature within a range of temperatures whereby each of said firing sections along the length of said kiln chamber may be set to provide a desired temperature condition within said kiln chamber at the firing section location, said gas introducing means in said heat-up and soak zones comprising a pair of burner assemblies, one of said burner assemblies being located to direct a gas stream tangentially into the upper portion of said kiln chamber, the other of said burner assemblies being located to direct a gas stream tangentially into the lower portion of said kiln chamber in the same circumferential direction as said one burner assembly so that said burners provide supplementing gas streams.

4. A continuous kiln comprising refractory wall means defining a horizontally extending kiln chamber, a heat-up zone defined by a first portion of said wall means extending longitudinally of the kiln chamber, said heat-up zone comprising a plurality of adjacent firing sections extending longitudinally of the kiln chamber, a soak zone defined by a second longitudinal portion of said wall means and comprising at least one firing section extending longitudinallly of the kiln chamber, each of said firing sections having means for introducing gases into said kiln chamber in a transverse direction to cause circulation of said gases in a transverse region along the wall means around the periphery of said kiln chamber, means for conveying ware to be heated longitudinally through said kiln chamber and through said zones, and means associated with each gas introducing means for adjusting the same to introduce gases into the kiln chamber at a selected temperature within a range of temperatures whereby each of said firing sections along the length of said kiln chamber may be set to provide a desired temperature condition within said kiln chamber at the firing section location, each of said gas introducing means in said heat-up and soak zones comprising a pair of burner assemblies, one of said burner assemblies being located to direct a gas stream tangentially into the upper portion of said kiln chamber, the other of said burner assemblies being located to direct a gas stream tangentially into the lower portion of said kiln chamber in the same circumferential direction as said one burner assembly, each of said burner assemblies comprising a diffusion chamber, a burner directing its products of combustion through said diffusion chamber and into said kiln chamber, and means for supplying air to said diffusion chamber in an amount to increase the mass velocity of the gas stream entering said kiln chamber to a rate to effect circulation thereof around the circumference of the kiln chamber whereby the temperature in each firing section is substantially the same from the top to the bottom thereof.

5. A continuous kiln comprising wall means defining a horizontally extending kiln chamber, a heat-up zone defined by a first portion of said wall means extending lon-

gitudinally of the kiln chamber, said heat-up zone comprising a plurality of adjacent firing sections extending longitudinally of the kiln chamber, a soak zone defined by a second longitudinal portion of said wall means and comprising at least one firing section extending longitudinally of the kiln chamber, each of said firing sections having means for introducing gases into said kiln chamber in a transverse direction to cause circulation of said gases in a transverse region along the wall means around the periphery of said kiln chamber, means for conveying ware to be heated longitudinally through said kiln chamber and through said zones, and means associated with each gas introducing means for adjusting the same to introduce gases into the kiln chamber at a selected temperature within a range of temperatures whereby each of said firing sections along the length of said kiln chamber may be set to provide a desired temperature condition within said kiln chamber, said gas introducing means of each firing section comprising a pair of burner assemblies, each of said burner assemblies comprising a diffusion chamber, a burner directing its products of combustion through said diffusion chamber and into said kiln chamber, means for supplying fuel to said burner, means for supplying air to said diffusion chamber for mixture with the burner combustion products to increase the mass velocity of the gas stream entering said kiln chamber, a throttle valve adjustable to regulate the amount of fuel supplied to said burner, and a throttle valve adjustable to regulate the amount of air supplied to said diffusion chamber.

6. A continuous kiln comprising wall means defining a horzontally extending kiln chamber, a heat-up zone defined by a first portion of said wall means extending longitudinally of the kiln chamber, said heat-up zone comprising a plurality of adjacent firing sections extending longitudinalty of the kiln chamber, a soak zone defined by a second longitudinal portion of said wall means and comprising at least one firing section extending longitudinally of the kiln chamber, a cooling zone between said soak zone and the discharge end of the kiln chamber, said cooling zone being defined by a third longitudinal portion of said wall means and comprising a plurality of adjacent firing sections extending longitudinally of the kiln chamber, each of said firing sections having means for introducing gases into said kiln chamber in a transverse direction to cause circulation of said gases in a transverse region along the wall means around the periphery of said kiln chamber, means for conveying ware to be heated longitudinally through said kiln chamber and through said zones, means associated with each gas introducing means for adjusting the same to introduce gases into the kiln chamber at a selected temperature within a range of temperatures whereby each of said firing sections along the length of said kiln chamber may be set to provide a desired temperature condition within said kiln chamber, each of said gas introducing means including at least one burner assembly, each of said burner assemblies comprising a diffusion chamber, a burner directing its products of combustion through said diffusion chamber and into said kiln chamber, and means for supplying preheated air to said diffusion chamber to increase the mass velocity of the gas stream entering said kiln chamber, said air supply means being connected between a portion of said cooling zone in the vicinity of said soak zone for supplying preheated air from said cooling zone to said diffusion chamber.

7. A continuous kiln comprising wall means defining a horizontally extending kiln chamber, a heat-up zone defined by a first portion of said wall means extending longitudinally of the kiln chamber, said heat-up zone comprising a plurality of adjacent firing sections extending longitudinally of the kiln chamber, a soak zone defined by a second longitudinal portion of said wall means and comprising at least one firing section extending longitudinally of the kiln chamber, a cooling zone between said soak zone and the discharge end of the kiln chamber, said cooling zone being defined by a third longitudinal portion of said wall means and comprising a plurality of adjacent firing sections extending longitudinally of the kiln chamber, each of said firing sections having means for introducing gases into said kiln chamber in a transverse direction substantially tangentially to said wall means and at a velocity to cause circulation of said gases in a transverse region along the wall means and around the periphery of said kiln chamber, means for conveying ware to be heated longitudinally through said kiln chamber and through said zones, means associated with each gas introducing means for adjusting the same to introduce gases into the kiln chamber at a selected temperature within a range of temperatures whereby each of said firing sections may be set to provide a desired temperature condition within said kiln chamber at the firing section location, and means for restricting gas flow between said soak zone and said cooling zone.

8. A kiln as claimed in claim 7 wherein said flow restricting means comprises a vertically extending baffle blocking flow between said soak and cooling zones, said baffle being mounted on said wall means between said soak and cooling zones and having a pair of side portions extending vertically along the sides of said wall means and a horizontal portion extending between said pair of side portions across the top of the kiln chamber.

9. A kiln as claimed in claim 7 wherein said flow restricting means comprises means maintaining a constant pressure in a plane between said soak zone and said cooling zone.

10. A continuous kiln comprising wall means defining a horizontally extending kiln chamber, a heat-up zone defined by a first portion of said wall means extending longitudinally of the kiln chamber, said heat-up zone comprising a plurality of adjacent firing sections extending longitudinally of the kiln chamber, a soak zone defined by a second longitudinal portion of said wall means and comprising at least one firing section extending longitudinally of the kiln chamber, a cooling zone between said soak zone and the discharge end of the kiln chamber, said cooling zone being defined by a third longitudinal portion of said wall means and comprising a plurality of adjacent firing sections extending longitudinally of the kiln chamber, each of said firing sections having means for introducing gases into said kiln chamber in a transverse direction to cause circulation of said gases in a transverse region along the wall means around the periphery of said kiln chamber, means for conveying ware to be heated longitudinally through said kiln chamber and through said zones, means associated with each gas introducing means for adjusting the same to introduce gases into the kiln chamber at a selected temperature within a range of temperatures whereby each of said firing sections may be set to provide a desired temperature condition within said kiln chamber at the firing section location, and means maintaining a constant pressure along a static flow plane extending vertically between said soak zone and said cooling zone whereby the flow of gases between said soak and cooling zones is minimized, said last-mentioned means including means for exhausting gases from said heat-up zone at a rate to maintain said constant pressure at the soak zone side of said static flow plane and means for exhausting gases from said cooling zone at a rate to maintain said constant pressure at the cooling zone side of said static flow plane.

11. A continuous kiln comprising wall means defining a horizontally extending kiln chamber, a heat-up zone defined by a first portion of said wall means extending longitudinally of the kiln chamber, said heat-up zone comprising a plurality of adjacent firing sections extending longitudinally of the kiln chamber, a soak zone defined by a second longitudinal portion of said wall means and comprising at least one firing section extending longitudinally of the kiln chamber, a cooling zone between said soak zone and the discharge end of the kiln chamber, said

cooling zone being defined by a third longitudinal portion of said wall means and comprising a plurality of adjacent firing sections extending longitudinally of the kiln chamber, each of said firing sections having means for introducing gases into said kiln chamber in a transverse direction to cause circulation of said gases in a transverse region along the wall means around the periphery of said kiln chamber, means for conveying ware to be heated longitudinally through said kiln chamber and through said zones, means associated with each gas introducing means for adjusting the same to introduce gases into the kiln chamber at a selected temperature within a range of temperatures whereby each of said firing sections may be set to provide a desired temperature condition within said kiln chamber at the firing section location, and means maintaining a constant pressure along a static flow plane extending vertically between said soak zone and said cooling zone whereby the flow of gases between said soak and cooling zones is minimized, said last-mentioned means including a first blower for exhausting gases from said heat-up zone, means regulating the rate of said exhaust of said first blower, first pressure sensing means arranged to sense the pressure in said kiln chamber immediately adjacent the soak zone side of said static flow plane, first control means operatively connected to said regulating means for said exhaust of said first blower and responsive to the pressure sensed by said first sensing means to adjust said first blower exhaust regulating means to exhaust gases at a rate to maintain said constant pressure at said first pressure sensing location, a second blower for exhausting gases from said cooling zone, means regulating the rate of said exhaust of said second blower, second pressure sensing means arranged to sense the pressure in said kiln immediately adjacent the cooling zone side of said static flow plane, and second control means operatively connected to said regulating means for the exhaust of said second blower and responsive to the pressure sensed by said second sensing means to adjust said second blower exhaust regulating means to exhaust gases at a rate to maintain said constant pressure at said second pressure sensing location.

12. A continuous kiln comprising wall means defining a horizontally extending kiln chamber, a heat-up zone defined by a first portion of said wall means extending longitudinally of the kiln chamber, said heat-up zone adjacent the charging end of the kiln chamber comprising a plurality of adjacent firing sections extending longitudinally of the kiln chamber, a soak zone defined by a second longitudinal portion of said wall means and adjacent the heat-up zone comprising at least one firing section extending longitudinally of the kiln chamber, a cooling zone between said soak zone and the discharge end of the kiln chamber, said cooling zone being defined by a third longitudinal portion of said wall means and comprising a plurality of adjacent firing sections extending longitudinally of the kiln chamber, each of said firing sections having means for introducing gases into said kiln chamber in a transverse direction to cause circulation of said gases in a transverse region along the wall means around the periphery of said kiln chamber, means for conveying ware to be heated longitudinally through said kiln chamber and through said zones, means associated with each gas introducing means for adjusting the same to introduce gases into the kiln chamber at a selected temperature within a range of temperatures whereby each of said firing sections along the length of said kiln chamber may be set to provide a desired temperature condition within said kiln chamber at the firing section location, means drawing gases from said cooling zone and supplying them directly to the gas introducing means of said heat-up and soak zones for introduction into said kiln chamber, means for exhausting gases from the charging end of said heat-up zone, and means drawing gases from said cooling zone and returning a portion of said withdrawn gases directly to said cooling zone and directly exhausting the remaining portion of said withdrawn gases.

13. A continuous kiln comprising wall means defining a horizontally extending kiln chamber, a zone extending longitudinally of the kiln chamber, said zone comprising a plurality of adjacent firing sections extending longitudinally of the kiln chamber, each of said firing sections having means for introducing gases into said kiln chamber in a transverse direction substantially tangentially to said wall means and at a velocity to cause circulation of said gases in a transverse region along the wall means and around the periphery of said kiln chamber, means for conveying ware to be heated longitudinally through said kiln chamber and through said zones and means associated with each gas introducing means for adjusting the same to introduce gases into the kiln chamber at a selected temperature within a range of temperatures whereby each of said firing sections along the length of said kiln chamber may be set to provide a desired temperature condition within said kiln chamber at the firing section location.

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