PERIODIC OXIDATION AND REDUCTION KILN

Fig. 5.

Fig. 6.

Fig. 7.

Fig. 8.

MICHAEL KALAN
INVENTOR.

R. E. Deauggue
ATTORNEY
This invention relates to a periodic oxidation and reduction kiln and more particularly to a kiln in which there are no muffle, bag-walls or sagger utilized and the wares are heated by radiant heat from the insulating refractories and by the flame temperature directly.

In prior kilns which utilize muffles, bag-walls or sagger, the refractories are formed of fire clay having a high specific heat and consequently a considerable time is required to heat the kiln to the desired temperature and considerable time is required to cool off the kiln. Because of this time lag, it has been found expedient to idle the prior kilns when they are not in use rather than to let the kilns completely cool off and, of course, idling requires the use of unnecessary fuel. For instance, in prior kilns utilizing muffles, the muffles can only supply heat to the ware by conductivity through the muffles and a considerable time is required to heat up the muffles. Also, with the muffle type kiln, the volatiles cannot escape and are trapped inside the kiln to cause contamination of the ware. The muffles, bag-walls or sagger in these prior kilns are necessary to prevent contamination of the ware by the products of combustion since the wares are always composed of oxides of minerals, such as silica, alumina, and calcium oxide which will react with the usual combustion products. Also, when such prior kilns were attempted to be used as reduction kilns, it was necessary to place within the kiln some material to take out the oxygen, such as champhor balls, or silicon carbide (SiC) so that the products of combustion would be carbon monoxide rather than carbon dioxide. By the present invention, an open fire kiln is provided which eliminates the use of muffles, bag-alls and sagger. An oxidizing condition is deliberately created within the kiln atmosphere by the introduction of excess air and the kiln is equipped with combustion chambers and flues large enough to insure complete combustion with an excess of oxygen. Thus, the wares cannot be contaminated by the products of combustion. The use of upshot, open fire burners and insulating refractories of low specific heat and high thermal conductivity makes it possible in the present invention to have radiant heat available immediately for the wares and also to utilize the flame temperature. Since insulating refractories are utilized for the kilns walls, there is relatively little heat storage or heat loss through the walls so that most of the sensible heat from the products of combustion is directed directly to the ware by way of radiation and convection.

In the kiln of this invention, the wares can be set openly on clay tile shelves or setters without danger of contamination. Because of the low specific heat of the insulating refractories, immediate radiant heat is obtained from the refractories and also from the flame temperature and the refractories will cool off quickly so that the operator can take advantage of rapid heating and cooling cycles in producing his wares and it is unnecessary to idle the kiln in order to have it available for quick utilization. By these rapid cycles, it is possible to freeze the glazes and obtain beautiful highlights and lusters.

When the kiln is used as an oxidation kiln, two sets of burners are utilized to obtain a uniform temperature throughout the kiln. One set of burners is located around the sides of the kiln so that the tile shelves do not interfere with the flame of this set of burners and these burners will heat the upper side walls and the top of the kiln.

A second set of burners is directed through passages in the floor of the kiln below the tile shelves and the flame passes from under the tile shelves to heat the lower side walls and the bottom of the kiln. Both sets of burners have combustion chambers and flues large enough to insure complete combustion with an excess of oxygen and by adjusting each of the burners, either by hand or automatic control, uniform temperature can be maintained throughout the kiln.

In addition to the oxidizing burners, the kiln is equipped with a set of reduction burners which are sealed so that the burners introduce pure gas into the kiln at a point underneath the tile shelves. In utilizing the kiln as a reducing kiln, the kiln can first be brought to a desired temperature by the two sets of oxidizing burners, and the oxidation burners can then be shut off and reducing burners turned on. Even though the reduction process is an endothermic reaction in that the ware absorbs heat, the temperature can continue to rise in the kiln with only the reduction burners turned on. Also, both the reduction and oxidizing sets of burners can be used at the same time and the oxidizing burners will be used to counterbalance the increase in temperature of the reduction cycle if necessary. All of the burners have pressure gauges or manometers in the gas supply line so that the operator can introduce a controlled reducing medium into the kiln at will and at any time and at any pressure. By keeping a record of draw trials, the operator can consistently duplicate the results of prior runs by keeping a chart of the pressure versus time for the various oxidizing and reduction sets of burners. In this way, beautiful copper reds and iron soledons can be reproduced at a later time.

During the time the kiln is used as an oxidizing kiln, it is possible to automatically control the temperature within the kiln to cycle the temperature and maintain the temperature uniform between the top and bottom of the kiln throughout the cycle. In order to accomplish this result a thermocouple can be placed in the upper side wall and the lower side wall of the kiln to continually measure the temperatures at these two positions and a motor driven cam can be utilized to select the various temperatures over a given period of time. By comparing the actual temperature in the kiln with the selected temperature, it is possible to control the gas supply to the two sets of oxidizing burners in order to have the actual temperature follow the selected temperature. Also, it is desirable to have the temperature control switch from the top thermocouple to the lower thermocouple during short intervals so that the burners will be controlled alternately in accordance with the selected cycle. It is understood that the kiln of the present invention can be made either in the form of a stationary periodic kiln or in the form of a periodic car shutter or pusher type kiln. Thus, the present invention provides a novel kiln which can be utilized for both oxidation and reduction and the temperature and atmosphere in the kiln can be accurately and selectively controlled by the oxidizing and reducing burners.

It is therefore an object of the present invention to provide periodic oxidation and reduction kiln having large enough combustion chambers and flues to insure complete combustion of the fuel in the oxidizing burners with an excess of oxygen and having reducing burners to
introduce pure fuel into the kiln independently of the oxidizing burners.

Another object of the present invention is to utilize up-shot, open fire oxidizing burners and insulating refractories of low specific heat and thermoconductivity so that the radiant heat is immediately available from the refractories to higher temperatures in order to quickly bring the kiln to a desired temperature prior to operation of the reducing burners.

Another object of the invention is to provide a kiln in which the oxidizing burners are supplied with an excess of oxygen so that it is unnecessary to utilize muffle walls or snuggers in order to protect the ware from contamination by the products of combustion and in which the reducing burners introduce pure fuel directly into the kiln.

Another object of the invention is to provide two sets of oxidizing burners, one directed up the sides of the kiln in order to heat the upper side walls and top of the kiln and a second directed toward the tile shelves holding the wares in order to heat the lower side walls and bottom of the kiln and to provide a set of reducing burners directed toward the tile shelves.

Another object of the invention is to utilize oxidizing and reducing burners in which the fuel flow to each of the burners can be measured by a pressure gauge so that reproducible atmospheres can be obtained to give any desired type of glaze.

Another object of the invention is to provide a kiln which is flexible in its control of atmosphere both for oxidation and reduction and in which reduction atmospheres can be reproduced accurately.

These and other objects of the invention not specifically set forth above will become readily apparent from the accompanying drawings and description in which:

Figure 1 is a perspective view of a stationary kiln incorporating the present invention showing the gas manifold for the various burners and the automatic temperature control box.

Figure 2 is a transverse vertical section along line 2-2 of Figure 1 illustrating the sets of oxidizing and reducing burners and the tile setting for the wares.

Figure 3 is a horizontal section along line 3-3 of Figure 2 illustrating the placement of the piers for the tile setting and the position of the various burner ports in the floor of the kiln.

Figure 4 is a horizontal section along line 4-4 of Figure 2 showing the manifolds for the oxidizing and reduction burners and the pressure gauges and solenoid valves for the manifolds.

Figure 5 is a vertical section along line 5-5 of Figure 2 illustrating the construction of one of the oxidizing burners and its position with respect to the floor of the kiln.

Figure 6 is a vertical sectional view along line 6-6 of Figure 2 illustrating one of the reduction burners and the manner in which it passes through the floor of the kiln.

Figure 7 is a prospective view of the automatic temperature control for controlling the solenoid valves in the inlets to the oxidizing burner.

Figure 8 is a schematic wiring diagram illustrating the circuit for the automatic temperature control unit.

Referencing to Figure 1, a kiln 10 of rectangular shape is illustrated having sides 11 and 12, rear wall 13, arched roof 14, and front door 15. All of these structures are constructed of layers 16 and 17 of insulating refractory fire brick of low specific heat so that it can be heated up and cooled off quickly by the kiln burners. Of course, the layer 16 must be resistant to higher temperature than layer 17. The floor 18 of the kiln is constructed of a firebrick of single composition and has openings for the various oxidizing and reduction burners utilized for the kiln. The floor and sides of the kiln can be supported by posts 19 at each corner which are set on transverse beams 20 at each end of the kiln. The top of the kiln is supported by hinges 21 and is closed by a latch 21'.

The arrangement of the oxidizing and reduction burners underneath floor 18 are illustrated in Figure 4 and the burners have a main manifold 22 connected to a gas supply through passage 23. A first set of oxidizing burners 24-33 are all connected to a rectangular manifold 34 which is supported by cross member 20 and is connected to the main manifold 22 through a passage 35. A second set of oxidizing burners 36-38 is connected to a straight manifold 40 which extends between the sides of manifolds 34 and the manifold 40 is connected to the main manifold 22 through a passage 41. A pair of reduction burners 42 and 43 are positioned above the manifold 40 and are connected to the main manifold 22 by a passage 44. A pilot light for each of the oxidizing burners is provided by a rectangular passage 45 which has a cross passage 46 so that all of the oxidizing burners are adjacent to either passage 45 or 46. The passage 45 is connected with the main manifold 22 by passage 47 and the passages 45 and 46 have burner openings 48 which provide a constantly available flame for lighting the oxidizing burners. Passage 47 contains a valve 49 for regulating the amount of pilot light needed to light the burners. The passages 35, 41 and 44 have manual control valves 50, 51 and 52, respectively, to control the amount of gas supplied to the various burners and these passages and manifolds contain pressure gauges 53, 54 and 55, respectively, to indicate the amount of gas which is flowing to the various burners. In addition, solenoid valves 56 and 57 are positioned in passages 35 and 41, respectively, and are connected to the automatic temperature control through conduits 58 and 59, respectively. The oxidizing burners 24-33 are all of the upshot, open fire, insulating type.

Referencing to Figure 3, the floor 18 of the kiln has openings 69-69 positioned directly over the burners 24-33, respectively, and also has openings 70-70 for the burners 36-38, respectively, and in addition, openings 74 and 75 are provided so that reduction burners 42 and 43 can pass snugly through the floor 18. The tile setting for the ware is composed of three tile sections 76, 77 and 78 which are supported on blocks 79 which are positioned on the floor of the kiln as illustrated in Figure 3. These blocks are spaced along each side of the kiln and two rows of two blocks each are positioned intermediate the side rows with the blocks staggered with respect to the blocks of the side rows. It will be seen that a space 79 exists between the tile setting and the sides, back and front of the kiln, which space is sufficient for the openings 69-69 to discharge the fire from the burners 24-33 downwardly along the sides, back and front of the kiln.

Since the tile setting covers the openings 71-73 for burners 36-38, respectively, the fuel discharged from these openings will be dispersed along the bottom of the tile setting and will be discharged in a direction towards the sides, back and front of the kiln.

The construction of oxidizing burner 36 is illustrated in Figure 5 and it is understood that all of the oxidizing burners 24-33 and 36-38 are of similar construction.

The burner has a nozzle 37 which connects with an opening 81 in the manifold 40 and this nozzle supports a tubular member 82 to which is secured a conical member 83. Air is drawn through member 83 and is mixed with fuel from the nozzle in member 82. The nozzle 80 is threaded to support a plate 84 which can be moved relative to the bottom opening in the conical member 83 in order to vary the primary air supplied to the burner. Also, a space 85 exists between the lower surface of floor 18 and the upper end of member 82 so that secondary air can be added to the fuel mixture leaving the burner and entering the kiln. By supplying the burners with primary air through member 83 and with secondary air through space 85, sufficient air is mixed with the fuel in order to assure an excess of oxygen within the kiln. With such an excess of air, the flame temperature from the oxidizing burners 24-33 occurs at the upper half and top of the kiln and serves to heat the
sulting refractory fire brick which is positioned in this upper part of the kiln. Also, the flame temperature of burners 36–38 will serve to heat the setting and floor of the kiln and the flame will be directed towards the lower sides, front and back of the kiln to heat this region. By regulating the plate 84 of each oxidizing burner, an oxidizing condition in the kiln is maintained by the introduction of externally and complete combustion of the fuel will take place with an excess of oxygen so that the ware will not be contaminated with combustion products. By utilizing the upshot, open fire burners and volatilizing refractories of low specific heat and low thermal conductivity, it is apparent that radiant heat will be immediately available from the volatilizing refractories and from the flame temperature without the ware being contami-
ated. By adjusting the fuel supply and air supply for the two sets of oxidizing burners, the temperature in the upper half of the kiln controlled by burners 24–33 can be made equal to the temperature in the lower half which is controlled by the burners 36–38 so that uniform temperature can be maintained throughout the kiln. Because of the excess of oxygen, it is unnecessary to use muffles, bag-walls or saggers in the kiln and because of the low heat storage in the kiln, the kiln can operate in a rapid cycle to obtain a quick freezing of glazes and colors of ware to give high lustre. A large area is provided in the roof 14 of the kiln so that the volatiles resulting from the oxidation of the wares can pass to the surrounding atmosphere and not contaminate the ware.

Since the two sets of oxidizing burners can be adjusted to give uniform temperature throughout the kiln and a uniform change in temperature, it is possible to automatically control these two sets of burners to heat the kiln through any desired time-temperature oxidation cycle. A control box 87 is positioned at the side 12 of the kiln and contains the automatic control apparatus which is connected to a thermometer 86 through line 39 and to thermocouple 90 through line 91. The thermocouple 86 is located in the upper part of side 12 and measures the temperature in the upper portion of the kiln resulting from burners 24–33 while the thermocouple 90 is located in the lower part of side 12 and measures the temperature in the lower portion of the kiln resulting from burners 36–38. As illustrated in Figure 7, the automatic temperature control has a millivolt meter 92 of standard construction which moves a pointer 93 along temperature scale 94 of dial 95 to indicate the actual temperature to thermocouple 88 or 90 in a manner presently to be described. The pointer 93 carries an opaque shield 96 which is positioned to pass between a light source 97 and a photocell 98 both of which are mounted on a pivoted arm 99. The arm 99 also carries a pointer 100 for indicating the selected temperature on the scale 101 of the dial 95. The arm 99 is connected to an arm 100' having a roller 102 which continually bears upon the surface of cam 102, and the cam 102 is driven by a constant speed motor 103 so that it rotates at a uni-
form rate. The photocell 98 is connected to solenoid valve 56 through line 58 and to solenoid valve 57 through line 59 in order to energize these valves. As the cam 102 is rotated, the arm 99 and the pointer 100 will be moved to indicate the desired temperature at any given time and the light source 97 and photocell 98 will move with the arm 99. In the event that the actual temperature being measured by the millivolt meter 92 does not correspond with the selected temperature indicated by pointer 100, the solenoids 56 will not interrupt the light path from light source 97 to photocell 98 and the photocell will be energized to open one or the other of the valves 56 or 57 and supply fuel to the associated burners. However, should the temperature indicated by the pointers correspond, then the shield 94 will inter-
rupt the light path and the valves would remain closed. It is understood that the cam 102 can be of any desired shape to obtain the desired time-temperature cycle.

Since it is desired to maintain a uniform temperature between the upper and lower parts of the kiln, it is necessary to have the automatic control responsive to both the thermocouples 88 and 90. For this purpose, a relay switch is provided having arms 104 and 105 for alternately opening and closing lines 58 and 59 to the valves 56 and 57, respectively, and for alternately opening and closing lines 89 and 91 to thermocouples 88 and 90, respectively. The switch arms are carried by armature 106 and winding 107 is connected to battery source 108 through a movable switch arm 109, which is alternately moved into and out of contact with terminal 110. Switch arm 109 carries roller 111 which bears against arm 112 which is rotated by a constant speed motor 113, and cam 112 is designed so that the switch arm 109 will contact terminal 110 during half the rotation of the cam when the roller 111 is on the high portion of the cam. When the cam roller follows the lower surface of the cam, the switch arm 109 will be moved away from terminal 110 in order to break the circuit to the solenoid winding 107. With the solenoid winding 107 de-energized, the switch arms 104 and 105 will assume the dotted line position of Figure 8 in order to complete the circuit from thermocouple 90 through line 91 to the millivolt meter 92 and to complete the circuit from photocell 98 through line 58 to the solenoid valve 57. When the solenoid winding is en-
ergized by arm 109, the switch arms 104 and 105 assume the full line position of Figure 8 and arm 104 will connect thermocouple 88 through line 89 to the millivolt meter 92 and will connect the photocell 98 through line 58 to the solenoid valve 56. If the temperature measured by thermocouple 88 does not correspond to the selected temperature, the photocell will be energized to open valve 56 and increase the temperature in the upper part of the kiln and if the temperature measured by thermocouple 90 does not correspond to the selected temperature, the valve 57 will be opened to increase the temperature in the lower part of the kiln. The cam 112 is rotated at a speed such that the switch arms 104 and 105 will switch the automatic temperature control from thermocouple 88 and valve to thermocouple 90 and valve 57 every few seconds so that it is impossible for any substantial temperature difference to exist between thermocouples 88 and 90. It has been found that if the control is switched every thirty seconds or so that the kiln can be raised in temperature and a uniform temperature maintained between the lower and upper parts of the kiln. As previously described, the thermocouple 90 and burners 36–38 control the temperature in the upper part and roof of the kiln while the thermocouple 90 and burners 36–38 control the temperature at the floor and lower section of the kiln. It is only when the indicator 98 selects a different temperature from that existing in the kiln that the valves 56 and 57 are opened to supply more fuel. The automatic control will only be used to increase the temperature of the kiln and the shield 96 can have an extension 96' to prevent the control system from operating upon a decrease in kiln temperature. Also, an automatic cut-off switch (not shown) can be used to disconnect light source 97 when the end of the heating cycle is reached. In either case, the millivoltmeter 92 will continue to register temperature but the photocell 98 will not be operative during cooling of the kiln. The arrangement of two sets of oxidizing burners and the arrangement of the two ther-
mcouples makes it possible to use the kiln as an oxidiz-
ing kiln and raise its temperature in accordance with any time schedule by selecting the shape of cam 103. The cooling cycle of the kiln can be regulated by the hand valves 50 and 51 for the two sets of oxidizing burners and this control can be in accordance with the actual temperature indicated by pointer 93. Of course, the cooling could be controlled automatically by utilizing
cooling means such as air jet under control of a proper cam. Referring now to the operation of the kiln as a reduction kiln, the reducing burners and 42 and 43 both project snugly through openings 74 and 75, respectively, in the floor 18 in the manner illustrated in Figure 6 and these openings are small enough that no air is drawn from beneath the kiln. The tip of each burner extends slightly above the upper surface of the floor so that the burners will supply pure gas to the interior of the kiln at positions underneath the tile settings. In utilizing the kiln as a reduction kiln, it is more convenient to conduct draw trials with the various wares in order to obtain the beautiful violet colors and iron calxons which can be produced by the kiln. In these draw trials, the oxidizing burners and the reduction burners are regulated by the hand valves 59-52 and a record of the pressures, as indicated by pressure gauges 53-55, against time is kept so that the desired reducing atmospheres in the kiln can be duplicated. By regulating the valve 52, pure gas as the reducing medium can be introduced into the kiln at any time and at any pressure. The kiln can be first brought up to a desired temperature by the oxidizing burners and the reduction burners 42 and 43 can then be turned off to obtain a desired reduction atmosphere since the combustion of this pure gas depletes the oxygen supply within the kiln and also reduces the oxides of the ceramic ware. By regulating both the reduction burners and the oxidizing burners, both burners can be used at the same time and the temperature of the kiln can be increased by the oxidizing burners if necessary. While the reduction process is endothermic in nature, it has been found that sufficient oxygen is available in the kiln after the oxidizing burners have been turned off and the reduction burners turned on, to produce some rise in temperature. Also, the temperature in the kiln can be maintained uniform by utilizing both the reduction and oxidizing burners at the same time. The supply of pure fuel through the reducing burners produces carbon monoxide rather than carbon dioxide within the kiln since insufficient air is available to produce carbon dioxide. It is understood that pressure on the individual manifolds is an indication of the amount of fuel being supplied to each set of burners and that the temperature of the kiln will vary with regulation of pressure.

After the draw trials have been run and the desired time-pressure relationship has been determined, it is contemplated that the process could be automatically controlled by an automatic control system, such as previously described, to regulate the oxidizing and reduction burners. In the usual reduction process, the kiln would be brought up to a desired temperature with the oxidizing burners before turning on the reduction burners. By the present invention, a periodic oxidation and reduction kiln is provided which utilizes upshot, open fire oxidizing burners to heat the kiln and an excess of oxygen is deliberately supplied to the kiln in order to maintain an oxidizing condition. The upshot, open fire burners are positioned within the kiln so that one set of burners will heat the upper portion and the top of the kiln while another set of burners will control the temperature in the lower portion and at the floor of the kiln. By utilizing insulating refractories of low specific heat, fast temperature cycles can be obtained. The reduction burners for the kiln will supply pure fuel to the interior of the small area to create a reduction atmosphere within the kiln and the reduction cycle can be varied in any manner by using the reduction and oxidizing burners simultaneously or separately. The automatic control for the oxidizing burners makes it possible to increase the temperature of the kiln on any desired time-temperature cycle.

It is apparent that the kiln of the present invention provides a highly flexible control of the kiln atmosphere for reduction, and there is no contamination of the ware from the products of combustion nor from the impingement of flames. By the combination of oxidizing and reducing burners, a controlled atmosphere is available at any temperature within the operating temperature range of the kiln, and the kiln can be operated at will for either reduction or oxidation. Another important feature of the kiln is that reflux of heat by flame temperature and radiation rather than by conduction through refractories, such as muffle, bag-walls and saggars, and, thus, refractory maintenance is low. Because of the quick heating available within the kiln, the kiln is very economical in the fuel consumption since it need not be held at idle temperature for long periods of time. In the present kiln, volatiles are permitted to escape from the kiln so that the wares will not become contaminated as in prior kilns where the volatiles are trapped inside the kiln. The kiln can be constructed in various sizes and shapes and the arrangement of the oxidizing and reducing burners can be varied to produce the desired heating of the kiln and the desired distribution of the reducing gas. Various types of insulating refractories can be utilized so long as they have a low specific heat. Various other modifications are contemplated by those skilled in the art without departing from the spirit and scope of the invention as hereinafter defined by the appended claims.

What is claimed is:

1. A periodic kiln for ceramic ware comprising a tile support for the ware spaced from the floor of said kiln, a first set of upshot inspirating burners positioned below the floor of said kiln, a first set of burner openings in said floor above said first set of burners and spaced around the sides of said kiln, a second set of upshot, inspirating burners positioned below the floor of said kiln and a second set of openings in said floor above said second set of burners and located toward the center of said kiln from said first set of burner openings, said first set of burners serving to heat the upper walls and roof of the kiln and said second set of burners being directed toward said support to heat the lower walls and floor of the kiln, and a set of reduction burners extending into said kiln and passing snugly through openings in said floor located between said second set of openings to obtain maximum turbulence of the pure fuel introduced to the kiln and maximum mixture of the fuel with the ware.

2. A periodic kiln as defined in claim 1 wherein said first set of burner openings are located nearer the sides of the kiln than the edges of said support to cause the fuel discharge from said first openings to be directed upwardly in the kiln, and said second set of burner openings are positioned below said support to cause the fuel discharge from said second openings to pass horizontally between said support and said floor, said set of reduction burners also being positioned below said support.

3. A periodic kiln as defined in claim 2 wherein an air passage exists between the top of each burner of said first and second sets and the lower surface of the floor to permit secondary air to enter the burner opening for each burner, means for adjusting the primary air supply to each of said first and second sets, said primary and secondary air supplies being sufficient to cause an excess of oxygen within the kiln when said set of reduction burners is inoperative.

4. A periodic kiln as defined in claim 1 wherein the walls, roof and floor of said kiln are constructed of insulating refractory material of low specific heat so that the wares positioned on said support are heated directly by flame temperature and by radiation from said walls, roof and floor, the low heat storage of said refractory material permitting rapid heating and cooling of the wares.

5. A periodic kiln as defined in claim 1 having means
for regulating the pressure of the fuel supply to each set of burners, and means for continually measuring said pressure, said regulating means being adjustable to select a desired reduction cycle and said measuring means providing a record of fuel supply pressure during the cycle period so that said cycle can be reproduced.

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