Jan. 5, 1943. L. L. LADD 2,307,322

KILN

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Fig. 1

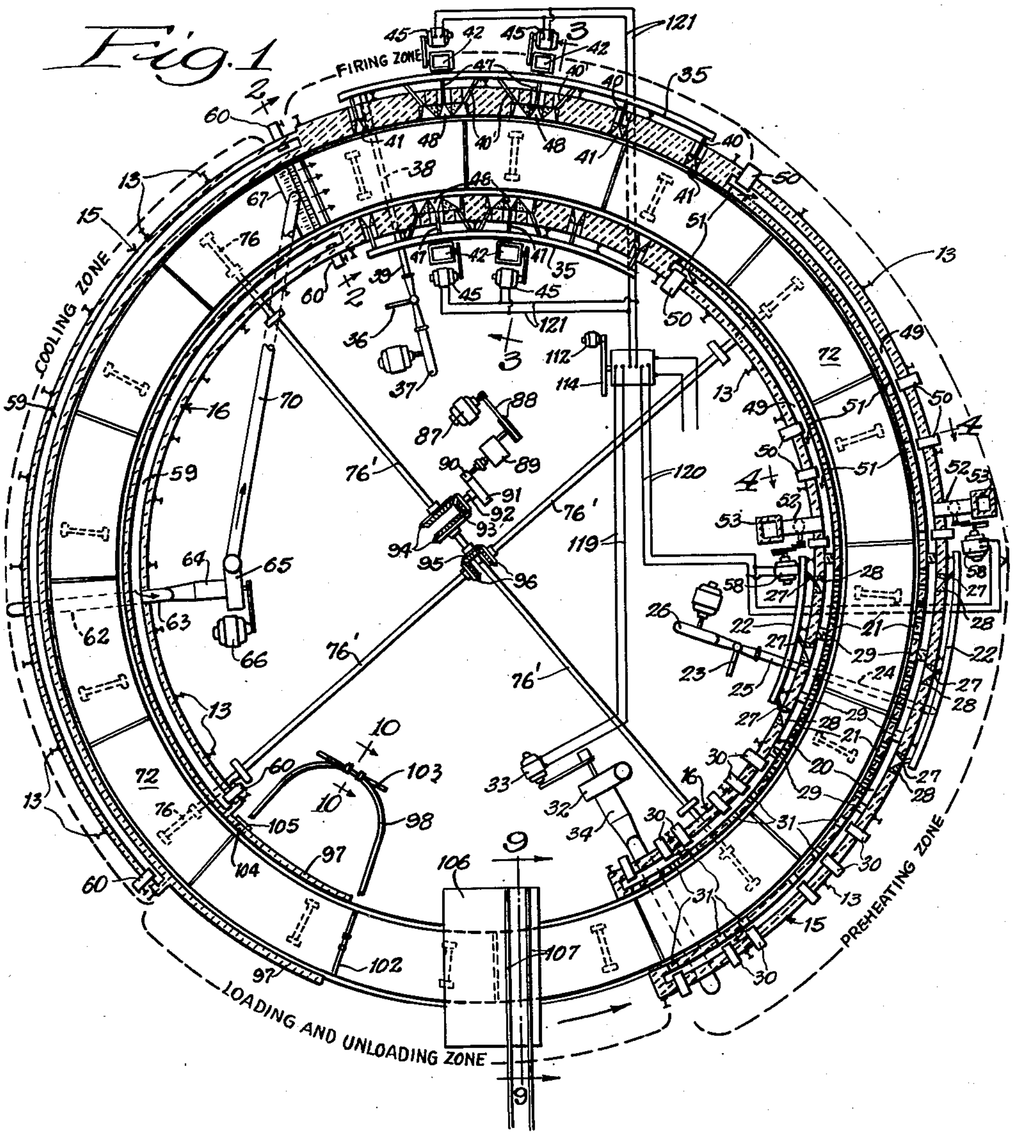

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Fig. 2

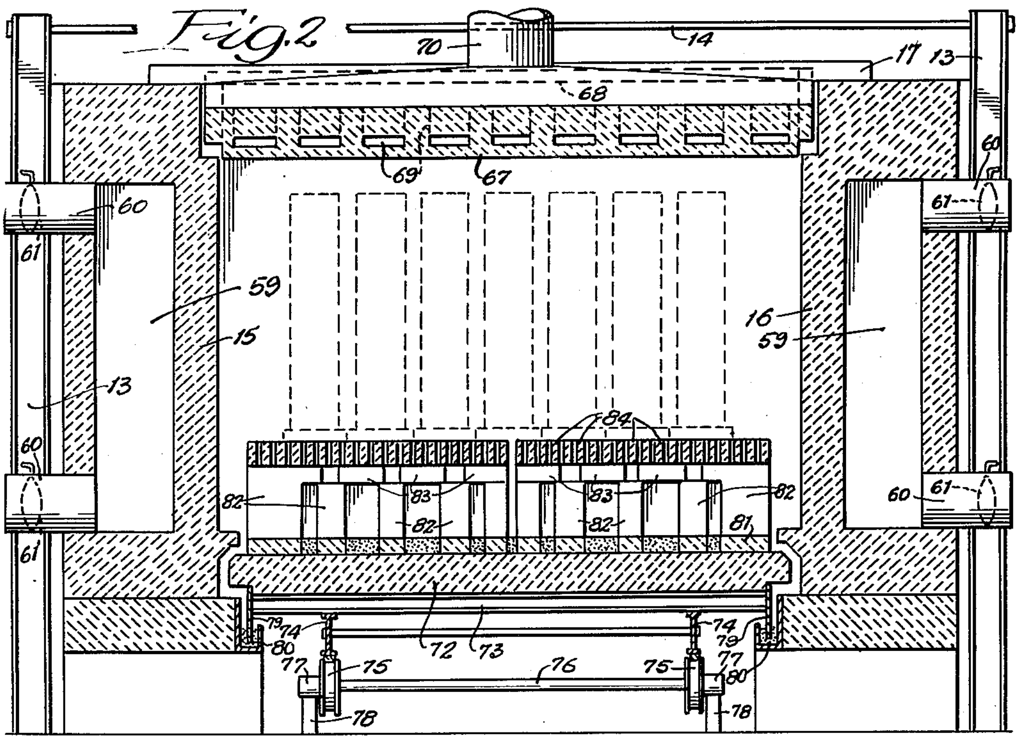
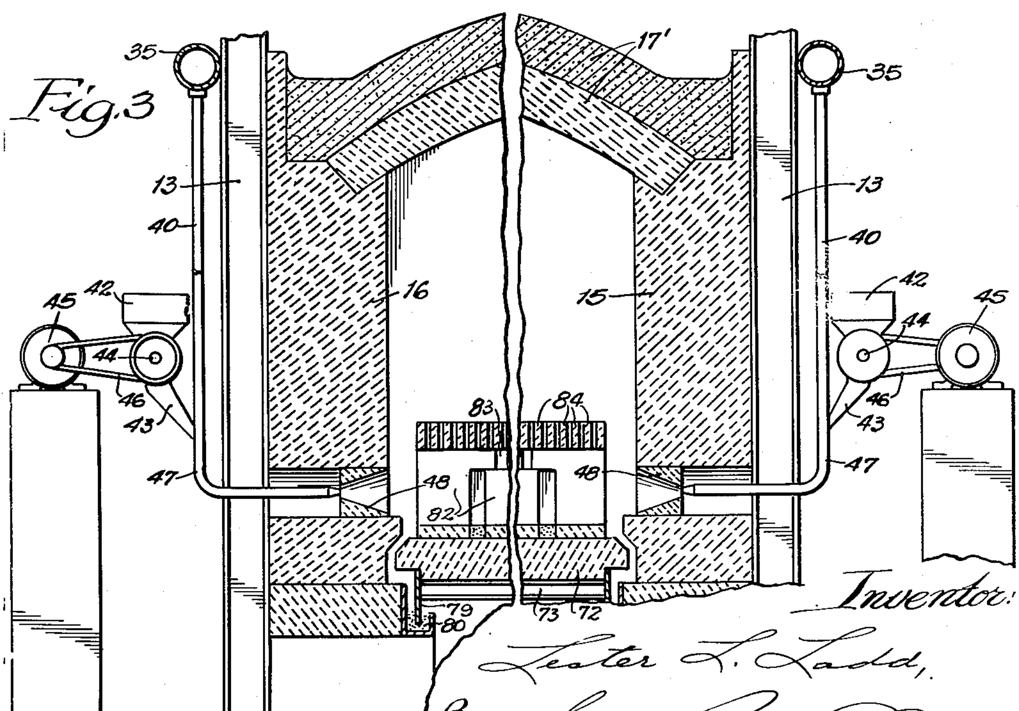


Fig. 3



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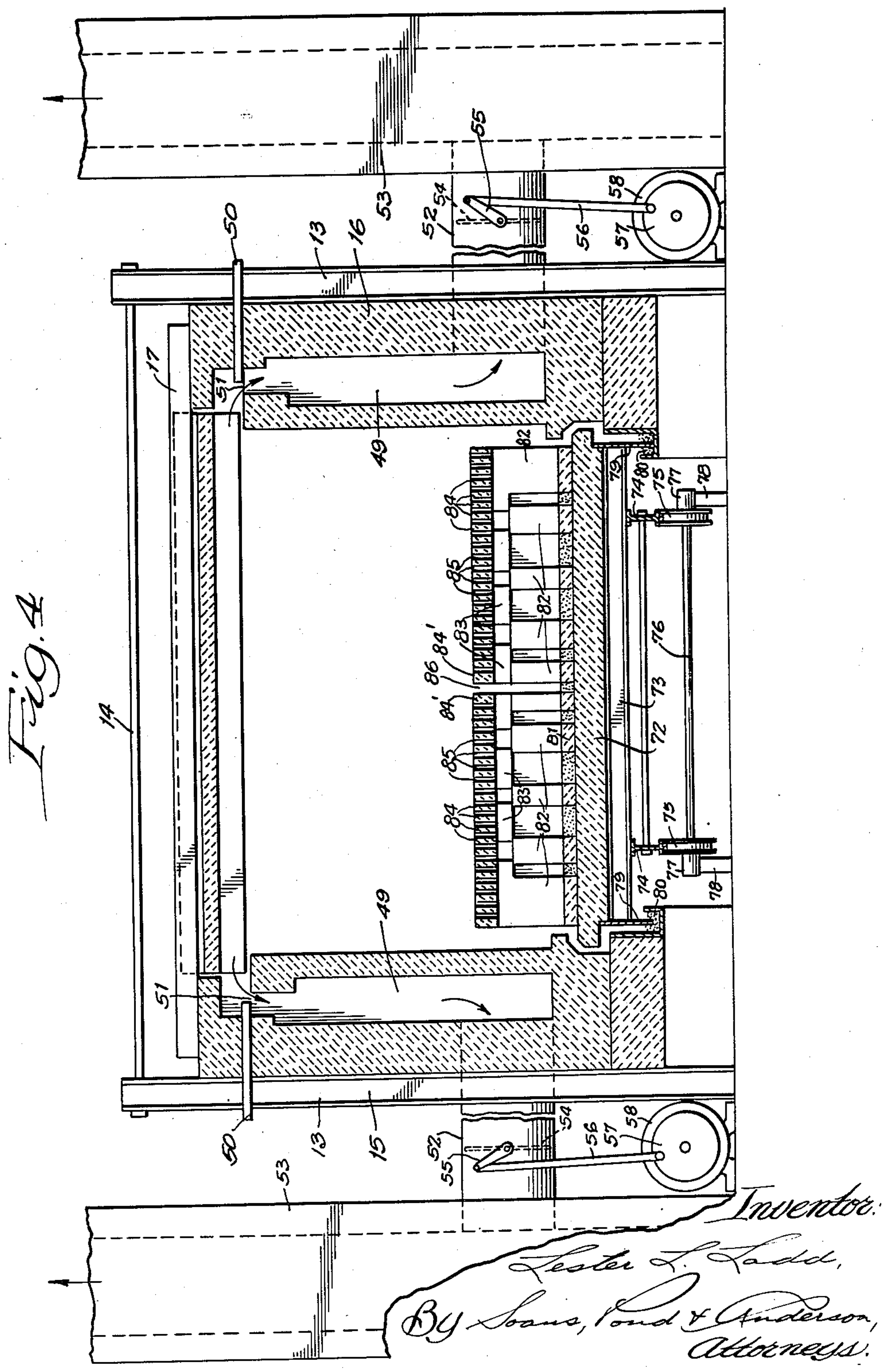

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Fig. 5

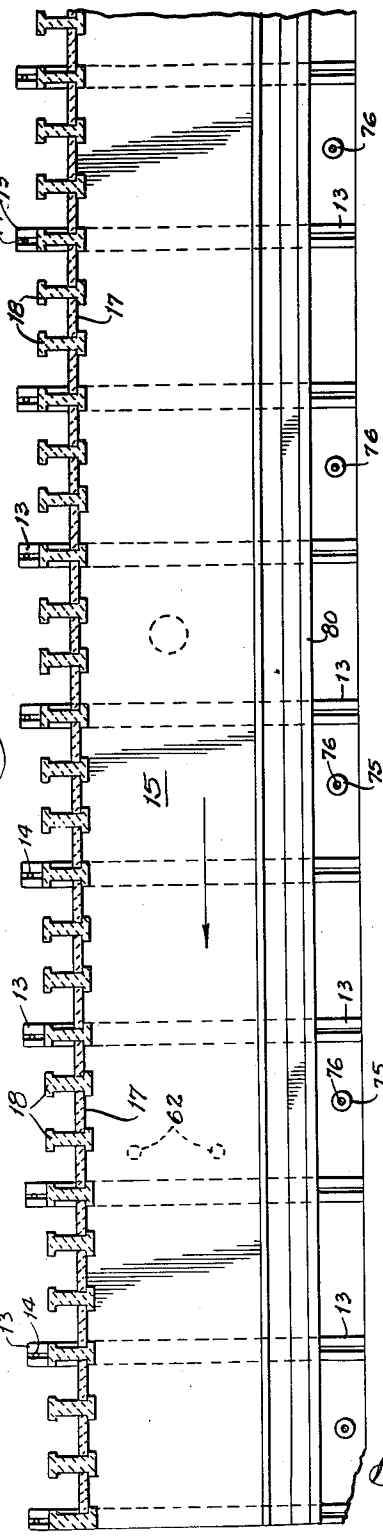
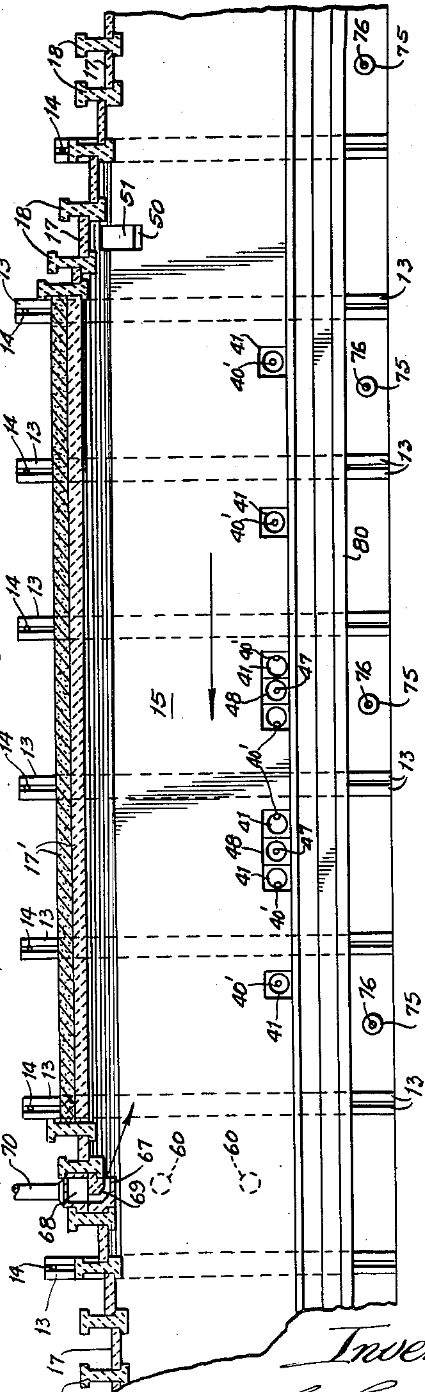


Fig. 6



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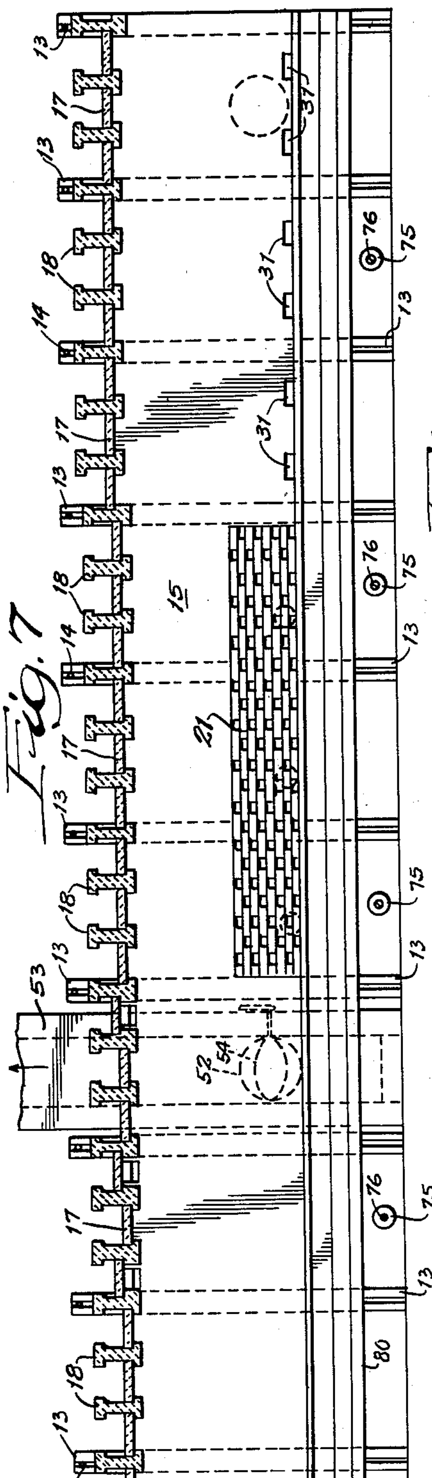

Fig. 7

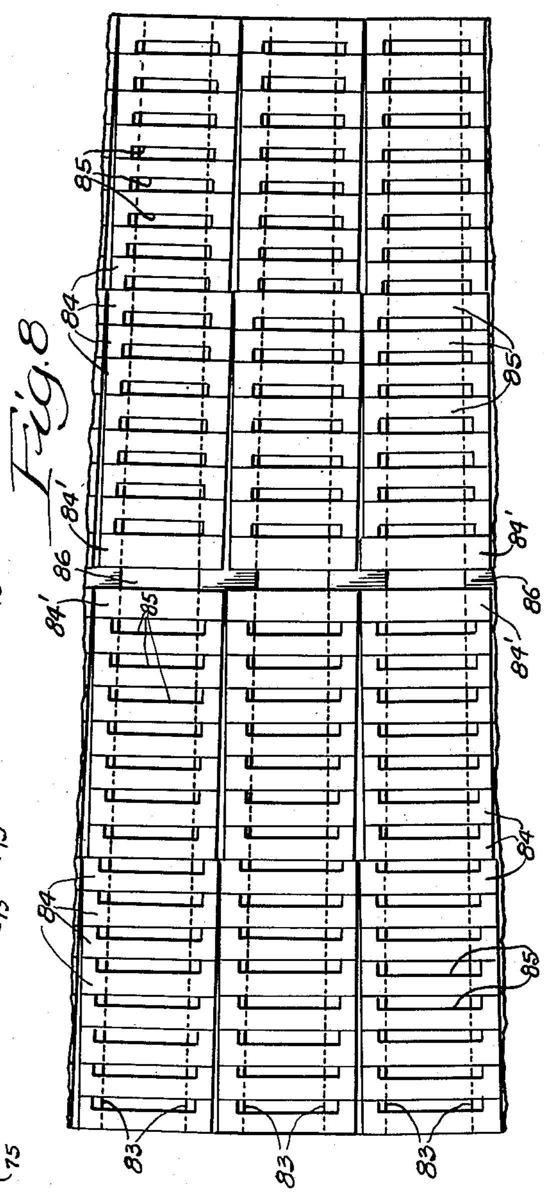

Fig. 8

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Fig. 9

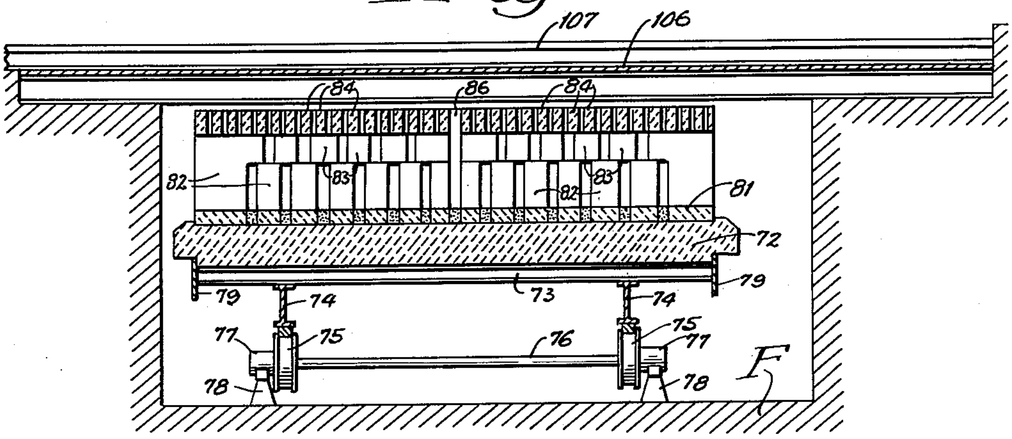


Fig. 10

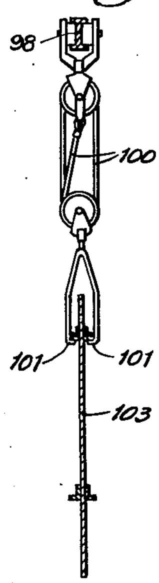


Fig. 12

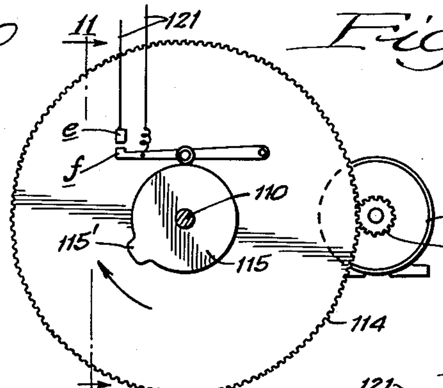
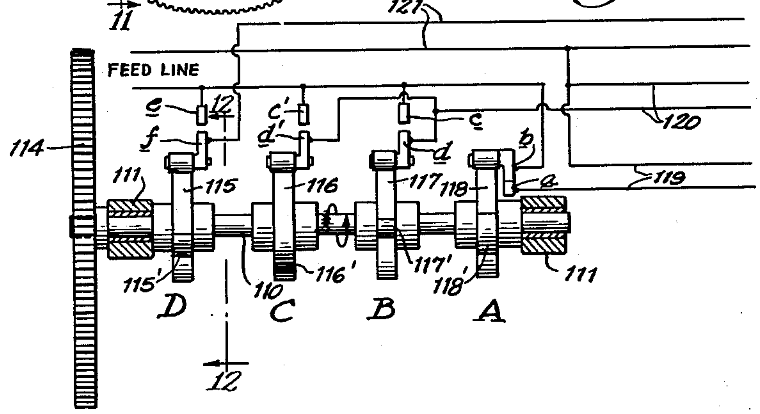


Fig. 11



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Patented Jan. 5, 1943

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UNITED STATES PATENT OFFICE

2,307,322

KILN

Lester L. Ladd, Lockport, Ill.

Application May 1, 1941, Serial No. 391,256

14 Claims. (Cl. 25—142)

This invention relates to kilns, particularly adapted for use in firing ceramic products. Some tunnel kilns are of the straight type, in which the ware travels on trucks or cars; and others are of the circular type in which the ware travels through the kiln on a circular conveyor. Typical circular kilns are illustrated in my former Patents No. 1,842,411, Jan. 26, 1932, No. 1,903,117, Mar. 28, 1933, and No. 2,127,742, Aug. 23, 1938. The present invention is primarily intended for use in a circular tunnel kiln, although many features thereof may be applied to kilns of the straight type, or to "bee-hive" kilns.

The kiln of my present invention has been designed more particularly for use in firing and glazing hollow ceramic sewer and other pipes. Since pipes of this character require to be glazed both exteriorly and interiorly, the firing and glazing of such pipes in a single operation has heretofore presented considerable difficulty. By my present invention, I have solved this difficulty, and produced a circular tunnel kiln in which the ware can be fired and glazed much more quickly, expeditiously, and economically than by modes of treatment heretofore used.

All types of tunnel kilns have what are known as a pre-heating zone, a firing zone, and a cooling zone, through which the ware travels successively in the order named. In circular kilns, between the discharge end of the cooling zone and the entrance end of the pre-heating zone is a loading and unloading zone; these four zones making up the entire circular kiln.

The glazing of the ware is usually effected by applying to the ware, when in a highly heated condition, common salt of a specified fineness, treated with sodium carbonate. In my present invention this salt glazing material is applied to the ware commingled with the hot flames of combustion of the fuel employed to raise the ware to the high firing temperature obtaining in the firing zone. Thus, the firing and glazing are performed simultaneously, which secures a large saving in the time required, and likewise, a large saving of fuel.

The present invention also includes a novel means and method of applying the commingled hot products of combustion to the pipes, by which the latter are fired and glazed on both their outer and inner surfaces. To effect this, the platform of the annular conveyor, instead of being made solid or imperforate, as heretofore, is of the open or checker-work type; and the firing and glazing gases are introduced at points below the checker-work platform so that they mainly rise into and around the pipes on the platform, thus firing and glazing the pipes simultaneously on both their outer and inner sides.

As above indicated, the main object of the present invention has been to provide a new and improved kiln for the treatment of clay pipes, tile and similar articles, by which the ware may not only be glazed simultaneously with the firing, but large savings in both time and fuel may be effected. Another important object ancillary to said main object has been to provide a means and method of supplying the salt directly to the burner fuel in the firing zone of the kiln. Still another important object has been to provide an improved system of control of the hot gases, salt fumes, and air in the kiln, under which the salt fumes, which are of a very acrid nature, are mostly confined to the firing and glazing zone of the kiln and are vented to high points in the atmosphere where they become sufficiently diluted to be non-irritating to workmen or others on the ground. Other objects of the invention have been to provide an improved means for loading and unloading the ware onto and from the conveyor, to provide a means for sealing the discharge end of the cooling zone when a batch of pipes is to be unloaded to prevent admission of cold air through the discharge end of the cooling zone during the unloading; to provide improved means for controlling the temperature in the pre-heating zone; and to provide an improved means for checking the flow of heat from the discharge end of the firing and glazing zone into the cooling zone as the ware passes from the former into the latter.

Still other objects and attendant advantages of the invention will be apparent to persons skilled in the art from the following detailed description, taken in connection with the accompanying drawings, in which—

Fig. 1 is a plan section of the circular kiln, with parts taken at different levels.

Figs. 2, 3 and 4 are enlarged transverse sections taken on the lines 2—2, 3—3 and 4—4, respectively, of Fig. 1; Fig. 2 showing in dotted lines a transverse row of sewer pipes on the conveyor and Fig. 3 being broken out midwidth to enable illustration of the burner manifolds and the salt feed features.

Figs. 5, 6 and 7 are continuous developments in longitudinal vertical section of the cooling, firing and glazing, and pre-heating zones, respectively.

Fig. 8 is a fragmentary enlarged plan view of the conveyor platform, on which the ware rests as it travels through the tunnel, showing the gradual increase in the length of the units between the inner and outer edges of the conveyor, necessitated by its annular form.

Fig. 9 is a vertical transverse section through the conveyor loading and unloading bridge, taken on the line 9—9 of Fig. 1.

Fig. 10 is a vertical section through a gate and gate-lifting and lowering mechanism at the discharge end of the tunnel, taken on the line 10—10 of Fig. 1.

Fig. 11 is a diagram of circuit control lines of the motors of the salt feeders, the fume exhaust dampers, and the exhaust fan at the entrance end of the pre-heating zone, viewed on the line 11—11 of Fig. 12.

Fig. 12 is a vertical section taken on the line 12—12 of Fig. 11.

In the structure illustrated, the kiln is of the circular type, and comprises a fabricated metal frame structure supported on a concrete foundation indicated at F in Fig. 9, and including outer and inner rows of spaced vertical I-beams 13 connected at their upper ends by tie-rod 14, outer and inner side walls 15 and 16, and roof slabs 17 spanning the tops of the side walls, the roof slabs of the glazing portion of the firing zone being preferably arched, as shown in Fig. 3. As shown in the vertical longitudinal sections, Figs. 5 and 7, the roofs of the cooling and pre-heating zones are for the most part made up of I-beam rafters 18 with the flat slabs 17 supported on and between the lower heads of adjacent I-beams, both beams and slabs being made up of the same refractory material as the side walls. The main portion of the roof of the firing zone may consist of a pair of long arched slabs 17'. These side walls and roof surround the tunnel passage and are made of various heat-resisting materials, such as brick, fire brick, tile, refractory infusorial earth and similar materials. By reference to Fig. 1 it will be observed that the side walls of the tunnel are of uniform thickness and are uniformly spaced throughout its entire length, and that the walls in the glazing portion of the firing zone are solid.

In the construction shown, the tunnel forms and defines a pre-heating zone, a firing and glazing zone, and a cooling zone, in the order named; the approximate longitudinal extents of these three zones, being identified by dotted lines and names applied thereto in Fig. 1.

Describing now the structural features of the pre-heating zone of the tunnel, which is shown in horizontal longitudinal section in Fig. 1, in vertical longitudinal section in Fig. 7, and in entrance end elevation in Fig. 9, the side walls of this zone are formed with longitudinally extending chambers 20, and the inner walls of these chambers throughout approximately one-half of their extent, and the lower half of their height are formed as checker-work 21, this appearing in side elevation in Fig. 7; and along the outer sides of the outer and inner walls are located fuel manifolds 22 that are supplied with gas or liquid fuel from a supply pipe 23 through branch pipes 24 and 25, commingled with air supplied by a motor-driven blower 26. The ignited fuel is directed by rearwardly inclined jet-nozzles 27 through openings 28 into the chambers 20 against the checker-work 21; these checker-work portions of the walls constituting muffles to protect the pipes on the conveyor against direct contact with the flames. The spaces of the longitudinal chambers 20 served by the several fuel jets are divided by partitions 29, so as to uniformly distribute the heating medium.

The solid portions of the outer walls of the chambers 20 between the checker-works and the entrance end are supplied with a number of sliding dampers 30 that co-operate with ports 31 in the inner walls of the chambers 20 to regulate the outflow of the heated gases that are drawn off by an exhaust fan 32 driven by an electric motor 33 and equipped with a branched suction pipe 34 that communicates with the ends of the chambers 20 at the entrance end of the pre-heating zone.

The firing and glazing zone of the tunnel, the entrance end of which is continuous with the discharge end of the pre-heating zone, is shown in horizontal longitudinal section in Fig. 1, in vertical longitudinal section in Fig. 6, and in vertical transverse section in Figs. 3 and 4. The glazing section of this zone occupies approximately its rear longitudinal half. Extending along the outer sides of the outer and inner walls 15 and 16 are fuel manifolds 35 that are supplied with gas or liquid fuel from a supply pipe 36, commingled with air furnished by a motor-driven blower 37; the commingled air and fuel entering the manifolds through the branches 38 and 39 of a supply pipe communicating respectively with the manifolds 35. Fuel is supplied to this portion of the tunnel through distributor pipes 40 ending in horizontal jet nozzles 40' discharging into Venturi blocks 41 (see Figs. 3 and 6) fitted into the inner surfaces of the outer and inner side walls of the tunnel. Common salt, of a specified fineness and treated with sodium carbonate, is fed into the firing zone in close association with the fuel flames at two of the five fuel supply points on each side. Referring to Figs. 3 and 6, 42 designates each of two pairs of salt hoppers, one pair located opposite the outer wall and the other opposite the inner wall. The discharge nozzles 43 of these hoppers 42 communicate with nozzle pipes 47, as best shown in Fig. 3. A uniform feed is effected by a fluted feed shaft 44 extending across the throat of the nozzle 43 that is driven from a motor 45 equipped with pulley and belt connection 46 to the shaft 44. In the two instances on each side where the commingled salt and fuel are supplied, three Venturi blocks are located side by side. The two end blocks of the trio admit the fuel through the nozzles 40' as above described. As shown in Fig. 1, the two fuel jet nozzles 40' are directed toward each other. The salt supplied through the central discharge nozzle 47 delivers to a central Venturi block 48. In this way, the fuel and the salt are intimately commingled. The addition of salt materially reduces the flame temperature at the burner nozzle through which the salt-fuel mixture is admitted to the kiln. However, I have found that by placing each burner nozzle of salted fuel in close association with two or more supporting or auxiliary burners of unsalted fuel, as shown in Figs. 1, 3 and 6, the temperature of the ware passage in the firing zone is not materially reduced during the salting operation. Moreover, with this arrangement, all of the glazing salt is completely vaporized in the flame and there is no free salt to be deposited on the ware.

As shown in Fig. 1, longitudinal chambers 49 are formed in the outer and inner side walls of the entrance portion of the firing and glazing zone, these chambers 49 being continuations of the chambers 20 of the pre-heating zone, and equipped with sliding dampers 50 that control ports 51 (Fig. 4) admitting more or less of the hot products from the tunnel passage of the firing and glazing zone to the chambers 49. Communicating with the chambers 49 at the entrance end of the firing and glazing zone are laterally extending pipes 52 (Fig. 4) that lead into tall vertical flue stacks 53, the main function of these stacks being to discharge to high points in the atmosphere the salt fumes created in the firing and glazing zone of the tunnel. It is important that the salt fume stacks be located at the entrance end of the firing and glazing zone rather than at the exit end thereof or adjacent the entrance to the cooling zone because in the latter case free salt would be deposited on the ware. Each of the pipes 52 is equipped with a damper 54, the pintle of which carries a crank arm 55 that is connected, by a link 56, with a crank disc 57 on the shaft of an electric motor 58. The relation of the operating connections 57, 56 and 55 from the motor shaft to the damper pintle is such that a half rotation of the motor shaft will turn the damper 90 degrees from closed to open position, and a further half rotation of the motor shaft in the same direction will turn the damper back to closed position. The purpose of these motors and dampers is to control the time and extent of exhaust through the stacks 53. As shown in Fig. 4, the ports 51 which place the chambers 49 in communication with the interior of the tunnel are located at the tops of the chambers 49 and are closed or opened more or less by manual manipulation of the dampers 50.

The cooling zone is continuous at its entrance end with the discharge end of the firing and glazing zone, and at its discharge end communicates with the loading and unloading zone, occupying slightly more than 90 degrees of the circular tunnel structure. The outer and inner walls of this cooling zone are formed with longitudinal chambers 59, closed at both ends, as shown in Fig. 1. The cooling medium of this zone consists of atmospheric air sucked into both ends of the chambers by a motor-driven cooling fan later described. As shown in Fig. 2 the chambers 59 communicate with the outside air through upper and lower lateral pipes 60 in which are manually operated dampers 61. This cool air inlet equipment is provided at both ends of the chambers 59. Communicating with the cooling chambers 59 about midlength thereof are the branches 62 and 63 of a suction pipe 64 that communicates with the suction side of an air fan 65 that is driven by an electric motor 66. This fan 65 not only effects the cooling of the cooling zone of the tunnel through its cooling effect on the side walls of the latter, but it also constitutes part of an important device for preventing the hot gases in the firing zone from flooding the cooling zone. This device is principally shown in Figs. 1 and 2. Fig. 2 being an enlarged cross-section on the line 2—2 of Fig. 1.

Set in the roof of the cooling zone at its entrance end and spanning and resting upon ledges in the side walls, is a slab 67 containing in its top portion an air chamber 68 and, communicating with the bottom of said chamber, a transverse row of L-shaped discharge ducts 69 that point toward the discharge end of the firing zone. Communicating with the discharge end of the cold air fan 65 is a pipe 70, by which cool air is delivered by the fan 65 into the chamber 68, and thence through the ducts 69 into and against the body of highly heated gas in the firing zone. Obviously, this checks the tendency of the heated products in the firing zone to drift into the cooling zone. By a proper setting of the dampers 61, the volume of such cooling air delivered by the fan 65 may be nicely regulated. No serious cooling effect on the heated gases in the firing zone is caused by this device, since the air delivered through pipe 70 is partially heated by contact with the walls of the chambers 59, which walls are necessarily somewhat heated by radiant heat from the ware passing through the cooling zone.

Referring next to the conveyor mechanism, the supporting and driving means of the latter quite closely follow the corresponding means disclosed in my Patent No. 2,127,742, but the conveyor itself on which the pipes, tile or other hollow articles rest, is quite different, being so designed as to conduct the commingled hot gases and salt fumes in the firing and glazing zone upwardly through the interiors, as well as around the exteriors, of the ware. The structural features of the conveyor supports are perhaps best shown in Figs. 1 and 2, wherein, 72 designates each of a circular series of heavy slabs of refractory material mounted and supported on cross beam 73 which, in turn, rest on I-beam rails 74, that travel on grooved wheels 75 fast on the end portions of shafts 76. The shafts 76 are journaled in bearings 77 on the upper ends if pillow blocks 78 that are mounted on the floor of the tunnel. Secured to the ends of the cross beams 73 are skirts 79 that travel in the usual sand troughs 80, which prevent the high heat from the tunnel chamber reaching down into the underlying space containing the conveyor supporting and driving mechanism.

On the top of each slab 72 is a layer 81 of mortar or cement, in which are set the lower ends of transverse rows of bricks 82; the bricks of each row being set upright and laterally spaced, and the bricks of adjacent rows being staggered. Spanning the spaces between, and supported at their ends on, adjacent bricks 82 are horizontal bricks 83, the adjacent ends of which bricks 83 are also spaced from each other, the bricks 83 in adjacent rows being likewise staggered. On these bricks 83 are supported adjacent transverse rows of blocks 84, that unitedly constitute the direct ware-supporting floor of the conveyor. A section of this floor, made up of the blocks 84, is shown in enlarged top plan in Fig. 8. By reference to Fig. 8 it will be seen that one side of each block 84 is formed with a recess or counter-sink 85 extending from top to bottom of the block; this recessed side being located adjacent to the solid side of the next block. Preferably, and as shown in Fig. 8, the blocks making up one-half the width of the floor face one way, and the blocks making up the other half of the width face the opposite way, there being two rows of unrecessed bricks 84' separated by a continuous narrow space 86 between the proximate ends of the two groups. This particular division of the blocks into two oppositely facing groups is not essential, but is preferably employed in order to secure a uniform upward flow of the hot gases through the floor of the conveyor and through the goods themselves, and reduce lateral dispersion of the gases.

Now, referring to Fig. 3, it will be seen that the hot products commingled with the glazing salt enter the firing and glazing zone horizontally directly against the sides of the checker-work represented by the bricks 82 and 83 and below the open-work conveyor floor that rests on the bricks 83. A small portion of these heated gases may hug the side walls of the tunnel, but the greater portion of them are directed into and upwardly through the conveyor floor itself, so that the pipes, tile, or other hollow articles, are very thoroughly and uniformly bathed in and by the firing and glazing gases.

A simple provision for driving certain of the shafts 76 and their wheels 75 is shown in Fig. 1, wherein it will be seen that certain of the shafts 76, located ninety degrees apart, are formed with extensions 76' that meet at the radial center of the tunnel structure. An electric motor 87, through a belt and pulley connection 88, and a speed reducer 89, drives a pinion 90, which, in turn, drives a gear 91 on the shaft 92 of a bevel pinion 93 that drives a pair of bevel gears 94 fast on two alined shaft extensions 76'. Also fast on one of the shafts 76' is a bevel gear 95 that drives in opposite directions two bevel gears 96 that are keyed on the proximate ends of the other two alined shaft extensions 76'.

It remains to describe the structural features of the loading and unloading zone, which is shown in top plan in Fig. 1, and in vertical section in Figs. 9 and 10. As before indicated, the main objects of the structural features of this loading and unloading zone are, to seal the exit end of the cooling zone when one slab load of ware is being removed from the kiln, and to facilitate the loading of the empty slab with dried pipe, tile or the like for transit through the kiln. The jets of air directed through the discharge ducts 69 of the slab 67 create a suction at the delivery end of the cooling zone which it is desirable to block. As shown in Fig. 1, the outer and inner chambered walls at the exit end of the cooling zone are extended as single solid walls 97 for about the length of one conveyor slab 72. Mounted above and crosswise of the ends of the extension 97 are the side limbs of a U-shaped trolley rail 98, from which are hung, by block and tackle suspensions 100 (Fig. 10) terminating in hooks 101, two independent flat solid gates 102 and 103; the hooks 101 being engageable with holes in transverse gate-stiffening angles on opposite sides of the gate. Similar transverse stiffening angles are applied to the sides of the gate lower down. The gates 102 and 103 are of a size to loosely fit the internal walls of the tunnel and enter between adjacent rows of pipes on the conveyor and so travel with the pipes on the conveyor. In the inner wall of the extension 97 is a vertical slot 104 of a size to admit a gate edgewise. A removable cap 105 closes this slot when not in use. As soon as the foremost loaded slab has entered the extension 97, the idle gate 103 is lowered and pushed along the trolley and through the slot 104 behind the row of pipes at the rear of the loaded slab. This seals the rear end of the cooling zone. The gate 102 at the front end of the loaded slab is then hooked onto the trolley, raised, and slid along the trolley to the idle position formerly occupied by the gate 103. The finished pipes on the loaded slab are then drawn forwardly onto the empty slab ahead of the loaded slab and removed. As soon as the next loaded slab has entered the extension 97, the same operation is repeated, the gate 102 being then inserted edgewise, and the gate 103 raised and shifted to idle position. By this means, the exit end of the cooling zone is constantly sealed against the inflow of outside air.

Spanning the conveyor about midway between the exit end of the extension 97 and the entrance end of the pre-heating zone is a loading platform 106 (Fig. 9) carrying a trackway 107 on which cars loaded with pipe to be fired and glazed are brought to a favorable position for transferring the pipes onto the underlying empty conveyor slab.

It may here be mentioned that the travel of the conveyor through the kiln is very slow, the conveyor making one complete cycle in 48 hours, which, with a kiln having a circumference of 220 feet and a diameter of 70 feet, is equivalent to a travel of four-fifths of an inch per minute. This slow rate of travel makes it entirely practicable to both unload the finished pipes and supply a new load of fresh pipes without stopping the conveyor at the loading and unloading zone.

A loading and unloading platform extending over the ware conveyor has a decided advantage over a platform located below the conveyor. With the former, a conveyor of any desired width may be employed, because the workman may stand on the platform while transferring ware from platform to conveyor and vice versa. With a platform extending below the conveyor, the workman must mount the conveyor and walk on the conveyor to transfer the ware. This is a laborious and time wasting procedure.

In a kiln of this type, it is quite essential to operate the salt feeders 42, the dampers 54 of the salt fume exhaust stacks 53, and the exhaust fan 32 in fixed timed relation to each other. The salt feeders are operated for a period of about six minutes once every hour. The dampers of the exhaust stacks are opened slightly in advance of the salt feed to create a draft before the salt is admitted to the burner flames, and said dampers are left open for a short period after the salt feed is stopped. This prevents the salt fumes from creeping into the pre-heating zone. Also, the exhaust fan 32 is started in operation slightly before the salt exhaust dampers are closed, and stops when said dampers are opened. This also contributes to preventing the salt fumes from flooding the pre-heating zone. In Figs. 1, 11 and 12 I have illustrated diagrammatically a wiring system to the motors of the salt feeders, the motors of the salt fume exhaust dampers, and the motor of the exhaust fan, for effecting the aforesaid timed operation of said parts.

In Figs. 11 and 12, 110 designates a shaft journaled in bearings 111 and given one complete rotation in one hour by a motor 112, a speed reducer (not shown), a pinion 113, and a large gear 114 fast on one end of shaft 110. Fast on shaft 110 are four cam discs 115, 116, 117 and 118. Disc 115 mounts a peripheral cam 115'; disc 116 mounts a peripheral cam 116'; disc 117 mounts a peripheral cam 117'; and disc 118 mounts a peripheral cam 118'. Cam 118' opens and closes a switch comprising fixed and movable contacts *a* and *b* in a circuit 119 leading to the motor 33 of the exhaust fan 32. Cams 117' and 116' both close and open (at different times), through fixed contacts *c* and *c'* and movable contacts *d* and *d'*, a circuit 120 leading to the motors 58 of the exhaust flue dampers 54. Cam 115', through a switch consisting of a fixed contact *e* and movable contact *f*, closes and opens a circuit 121 leading to the motors 45 of the salt feeders 42. As shaft 110 slowly rotates in the direction indicated by arrows in Figs. 11 and 12, the switch which I have designated as a whole by A in Fig. 11 first opens the circuit 119 to stop the operation of the exhaust fan 32. Shortly after this, the switch designated as an entirety by B closes the circuit 120 to open the exhaust flue dampers. Next, the switch designated as an entirety by D closes the circuit 121 to operate the salt feeders. As aforesaid, the salt feeders are kept in operation for about 6 minutes. Shortly after the close of the salt feeding operation, the switch A closes the circuit 119 to start up the exhaust fan 32; and finally, the switch designated by C closes the circuit 120 to close the dampers of the exhaust flues. All of the foregoing operations take place in the order recited during about one-eighth of the hourly revolution of the cam shaft 110. During the remaining seven-eighths of the revolution, the circuit 119 of the exhaust fan 32 is maintained closed.

The following recapitulation shows at a glance the sequence of the above described operations, starting with the shaft, cam discs and cams in the positions shown in Fig. 11:

1. Switch A opened to stop exhaust fan 32.
2. Switch B closed to open exhaust dampers 54.
3. Switch D closed to feed salt.
4. Switch D opened to stop salt feed.
5. Switch A closed to start exhaust fan 32.
6. Switch C closed to close exhaust dampers 54.

In some kilns which I have constructed, I have found that the draft of the exhaust stacks was sufficient to overcome the draft produced by the exhaust fan 32. In such case, the control switch A may be omitted thereby permitting continuous operation of the exhaust fan 32, even during the salting operation.

The operation has been described to a considerable extent, in connection with the descriptions of the structural features of the kiln, but may be briefly summarized as follows.

At the unloading and loading zone the finished ware is withdrawn from one of the conveyor slabs after sealing the exit end of the cooling zone by one of the gates 102 and 103, and the empty conveyor slab is then reloaded from the platform 106 with fresh dried ware to be fired and glazed. As stated, this is accomplished without halting the slow travel of the conveyor. In the pre-heating zone, the temperature of the ware is gradually raised to the fusion point by the heat furnished by the burner nozzles 27, it being noted that this heat is indirectly applied to the ware by virtue of the muffle walls 21, so as to prevent overheating in this zone. The products of combustion are drawn off by the exhaust fan 32 which is continuously operating during approximately seven-eighths of each conveyor cycle, and the temperature of the products of combustion can be nicely regulated by manipulation of the dampers 30, which permit the gases to flow more or less freely from the central tunnel space into the wall chambers 20 with which the exhaust fan 32 is connected. During the travel of the ware through the preheating zone, it is desirable to burn out all of the impurities in the ware by oxidation which usually occurs in the temperature range from 900° F. to 1600° F. If all of the impurities are not burned out in this temperature range, an undesirable black core is produced in the ware. This is known in the trade as "black coring" or "tightening up."

To operate a kiln satisfactorily, the temperature of the ware may rise fairly rapidly up to 900° F. but it is highly desirable to prolong the period of time during which the ware temperature rises from 900° F. to 1600° F. Obviously, the longer the period of oxidation, the greater will be the amount of impurities removed. With my improved kiln, the curve of preheating zone temperatures may be so accurately controlled that ware of high purity is definitely assured. From the pre-heating zone, the ware moves into the firing zone, wherein a maximum or peak temperature of approximately 2030° F. is maintained. As the ware travels through approximately the last half of the firing zone, it is subjected to the hot products of combustion of the fuel mingled with the fumes of the salt glazing material, by which a high polish is imparted to the surfaces of the ware. In practice I have found that about 100 pounds of salt is used in each 48-hour cycle of conveyor travel for glazing 36 tons of pipe, tile or other like hollow ware, each of the four salt hoppers delivering about one-half pound of salt per hour of conveyor travel. As previously explained, the commingled combustion gases and glazing gases are directed upwardly to and around and through the hollow ware by reason of the checker-work conveyor platform and the introduction of said gases at points below and beneath the platform. This mode of applying the gases to the ware is very important, especially in securing a good glazing effect. Just prior to the feeding of the glazing material, the dampers 54 of the glazing exhaust stacks are opened, so that during the 6-minute period of feeding the glazing material the acrid fumes are discharged through the stacks to the atmosphere; and, little or no fumes of the glazing material enter the preheating zone. From the firing and glazing zone the ware moves into the cooling zone, where there is a decided drop in temperature and the ware is rapidly cooled; the blower 65 operating continuously to both cool the walls of the cooling zone by drawing atmospheric air through the chambers 59 of the latter, and at the same time prevent the highly heated gases in the firing zone from entering the cooling zone by pushing the air exhausted from the walls of the cooling zone into the exit end of the firing zone.

From the peak temperature, the ware may be dropped rapidly to a temperature of 1350° F. to 1200° F. without danger of checking. The range from 1200° F. down to 500° F. is known in the trade as the tender range. In this range, dropping of the temperature must take place slowly to prevent checking. From 500° F. the temperature of the ware may be dropped rapidly without checking.

It will thus be seen that the temperature curve of the cooling zone flattens out through the "tender" range.

With my improved kiln, it is possible to obtain very accurate control of the temperatures throughout the ware passage so that I am able to employ a smaller or shorter conveyor than is necessary in kilns not having the features herein described and claimed.

Practical tests made with the tunnel kiln of the present invention operating on a 48-hour cycle, have shown a net saving of 40% in fuel, compared to periodic kiln firing which requires a 144-hour time cycle; and, although the power consumed in operating the rotating conveyor of the tunnel kiln and its auxiliary equipment cuts down some of the savings gained in fuel reduction, a greater percentage of first quality glazed pipe is obtained as compared with the output of periodic round, down-draft kilns.

I claim:

1. In a tunnel kiln for firing and glazing ceramic ware, the combination with a continuously traveling conveyor for moving the ware through the kiln, of means for introducing a gaseous fuel through the side walls of the kiln including burner nozzles, means for periodically

feeding a salt glazing powder directly into the flames issuing from said burner nozzles, vent stacks communicating with the conveyor chamber of the kiln, dampers in said stacks, and means for opening said dampers just prior to, and closing them just after, each periodic feeding of said glazing powder.

2. In a tunnel kiln for firing and glazing ceramic pipes, tile, and like hollow ware, the combination with a continuously traveling conveyor having a checker-work platform on which the ware is set endwise in upright position, of fuel inlet pipes extending through the side wall of the tunnel and terminating in horizontal nozzles located below said platform, means for periodically feeding a glazing material directly into the flames issuing from said burner nozzles, vent stacks communicating with the conveyor chamber of the kiln, dampers in said stacks, and means for opening said dampers just prior to, and closing them just after, each periodic feeding of said glazing material.

3. In a circular tunnel kiln having a preheating zone, a firing zone, and a cooling zone, a burner for supplying heat to said firing zone, said preheating zone being formed with longitudinal chambers in its side walls communicating with the ware passage between said walls, the combination of heating means for said preheating zone comprising an auxiliary burner adapted to project hot gases into the portions of said chambers adjacent the exit end of said preheating zone, and an exhaust fan communicating on its intake side with said chambers at points adjacent the entrance end of said preheating zone.

4. In a circular tunnel kiln having a preheating zone, a firing zone, and a cooling zone, a burner for supplying heat to said firing zone, said preheating zone being formed with longitudinal chambers in its side walls communicating with the ware passage between said walls, the combination of heating means for said preheating zone comprising an auxiliary burner adapted to project hot gases into the portions of said chambers adjacent the exit end of said preheating zone, a checker-work muffle wall opposite said auxiliary burner, and an exhaust fan communicating on its intake side with said chambers at points adjacent the entrance end of said preheating zone.

5. In a circular tunnel kiln having a preheating zone, a firing zone, and a cooling zone, a burner for supplying heat to said firing zone, said preheating zone formed with longitudinal chambers in its side walls communicating with the ware passage between said walls, the combination of heating means for said preheating zone comprising an auxiliary burner adapted to project hot gases into the portions of said chambers adjacent the exit end of said preheating zone, a checker-work muffle wall opposite said auxiliary burner, an exhaust fan communicating on its intake side with said chambers at points adjacent the entrance end of said zone, and damper-controlled ports in the inner walls of said chambers for regulating the outflow of heated gases drawn off by said exhaust fan.

6. In a tunnel kiln having a preheating zone, a firing zone continuous with said preheating zone, a cooling zone continuous with said firing zone, a loading and unloading zone between said cooling and pre-heating zones, and a conveyor movable through said zones, of a gate for sealing said cooling zone, and means for supporting said gate in a manner enabling it to be shifted edgewise onto said conveyor, said gate fitting loosely within the ware passage of the kiln and being carried by said conveyor from the point of entrance of the gate to said loading and unloading zone.

7. In a circular tunnel kiln having a preheating zone, a firing zone continuous with said preheating zone, a cooling zone continuous with said firing zone and formed with a vertical slot in a wall of the exit end portion thereof, a loading and unloading zone between said cooling and pre-heating zones, and a circular conveyor movable through said zones, of a U-shaped trolley rail the limbs of which transversely overhang the exit end portion of said cooling zone, and a solid gate of a size to loosely fit the internal walls of the tunnel suspended from said trolley rail and movable edgewise through said vertical slot to a sealing position.

8. In a circular tunnel kiln having a preheating zone, a firing zone continuous with said preheating zone, a cooling zone continuous with said firing zone and formed with a vertical slot in a wall of the exit end portion thereof, a loading and unloading zone between said cooling and pre-heating zones, and a circular conveyor movable through said zones, of a U-shaped trolley rail the limbs of which transversely overhang the exit end portion of said cooling zone, and a pair of solid gates of a size to loosely fit the internal walls of the tunnel detachably suspended from said trolley rail and alternately movable edgewise along said rail and through said vertical slot to a sealing position.

9. In a circular tunnel kiln for firing and glazing ceramic ware having a pre-heating zone, and a firing and glazing zone continuous with said pre-heating zone, the combination with glazing feeders and electric motors for operating the same, stacks for venting the glazing fumes communicating with said glazing zone, dampers in said stacks, and electric motors for opening and closing said dampers, an exhaust fan connected on its suction side to said pre-heating zone, and a motor for driving said exhaust fan, of an electric control system for operating all of said motors in timed relation, comprising a feed line and circuits therefrom to the motors of said glazing feeders, the motors of said dampers, and the motor of said exhaust fan, switches in said circuits, movable cams for opening and closing said switches, and means for actuating said cams; said cams and their actuating means being timed to first open the circuit of the motor of the exhaust fan, next close the circuit of the motors of the dampers to open the latter, next close the circuit of the salt feeder motors, next open the circuit of the salt feeder motors, next close the circuit of the motor of the exhaust fan, and finally close the circuit of the damper motors to close the dampers.

10. The herein described method of operating a portion of a conveyor travel cycle in a circular tunnel kiln having a pre-heating zone, a firing and glazing zone continuous with said pre-heating zone, a cooling zone continuous with said firing and glazing zone, an annular ware conveyor traveling continuously through said zones, glazing feeders at said firing and glazing zone, stacks for venting glazing fumes communicating with said firing and glazing zone and dampers in said stacks, and an exhaust fan communicating on its suction side with said pre-heating zone, which consists in first arresting the opera-

tion of said exhaust fan, then opening said dampers, then operating said glazing feeders for a fraction of the cycle, then stopping said salt feeders, then re-starting said exhaust fan in operation, and finally closing said dampers.

11. In a tunnel kiln for firing and glazing ceramic ware, the combination with a ware passage, a conveyor for moving the ware through said passage, of means for introducing a fuel through the side walls of the kiln including a burner nozzle, means for periodically feeding a salt glazing powder through said nozzle, a vent adapted to provide communication between the ware passage and the atmosphere, a damper controlling said vent, and means for opening said damper just prior to and closing it just after each periodic feeding of said glazing powder.

12. In a tunnel kiln for firing and glazing ceramic ware having a preheating zone, and a firing and glazing zone continuous with said preheating zone, the combination with a glazing feeder, an electric motor for operating said glazing feeder, a vent adapted to provide communication between said glazing zone and the atmosphere, a damper controlling said vent and an electric motor for operating said damper, of an electric control system for operating said motors in timed relation comprising a feed line and circuits therefrom to the motor of said glazing feeder and the motor of said damper, switches in said circuits, means for actuating said switches, said means being timed to close the circuit of the damper motor to open the damper, next close the circuit to the salt feeder motor, next open the circuit of the salt feeder motor, and finally close the circuit of the damper motor to close said damper.

13. In a tunnel kiln having a ware passage, a ware conveyor movable through said passage, and a gate for sealing the exit end of said passage, said kiln having an opening in a wall thereof to permit edgewise insertion of said gate into said ware passage and onto said conveyor, said gate fitting loosely within said passage and being adapted to be carried by said conveyor from said opening to said exit end.

14. In a tunnel kiln having a ware passage, a ware conveyor movable through said passage, a gate for sealing the exit end of said passage, said kiln having an opening in a wall thereof to permit edgewise insertion of said gate into said ware passage and onto said conveyor, said gate fitting loosely within said passage and being adapted to be carried by said conveyor from said opening to the exit end of said passage, a track located outside of said passage for supporting said gate in returning said gate to said opening, and a second gate adapted to be similarly inserted, conveyed and supported for sealing said ware passage when said first mentioned gate is removed.

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